ASIAN JOURNAL OF FORESTRY
Volume 7, Number 2, December 2023 E-ISSN: 2580-2844
Pages: 115-125 DOI: 10.13057/asianjfor/r070206

Woody plant diversity and aboveground carbon stock of *Dipterocarpus chartaceus* dominant forests in Binh Chau-Phuoc Buu Nature Reserve, South Vietnam

NGUYEN VAN HOP♥, NGUYEN VAN QUY, NGUYEN VAN LAM, PHAN THANH TRONG, PHAM CHI THINH
Faculty of Natural Resources and Environment, Vietnam National University of Forestry - Dong Nai Campus, No. 98 Tran Phu, Trang Bom Town, Trang Bom District, Dong Nai Province 76000, Vietnam. Tel./Fax.: +84-977-672338, ♥email: nvhop@vnuf2.edu.vn

Manuscript received: 23 March 2023. Revision accepted: 3 June 2023

Abstract. *Hop NV, Quy NV, Lam NV, Trong PT, Thinh PC. 2023. Woody plant diversity and aboveground carbon stock of* Dipterocarpus chartaceus *dominant forests in Binh Chau-Phuoc Buu Nature Reserve, South Vietnam. Asian J For: 115-125.* The dominant forest of *Dipterocarpus chartaceus* Symington in Binh Chau-Phuoc Buu Nature Reserve, South Vietnam, has an important ecological role and high conservation value relevant to climate change by storing large amounts of CO_2 from the atmosphere. This study assesses the diversity of woody plants and estimates biomass and carbon stocks in different forest states. The study used a typical sample plot setting method was used. Trees with a Diameter at Breast Height (DBH) > 6 cm were measured, and species were identified in 9 sample plots of 50m x 20m in the very poor, poor, and medium forests. A total of 640 tree individuals belonging to 45 species, 34 genera, and 25 families were recorded. The most species-rich family was represented by Dipterocarpaceae (7 species). A total of 15 threatened species (33.33%) belonging to 11 genera from 8 families were listed in the Vietnam Red Data Book (2007) and IUCN Red List (2022). The Margalef (d), Shannon-Wiener (H'), Simpson (Cd), and Sorensen Index (SI) were analyzed for tree species. The study illustrated that medium forests had the highest diversity, followed by poor forests, and the lowest belonged to very poor forests. The ability to accumulate biomass and aboveground carbon stocks varied widely from 48.15 t/ha-196.15 t/ha and 24.07 Ct/ha-98.42 Ct/ha. The medium forest had the highest total carbon stock, followed by the very poor forest and the lowest poor forest. The study provides an essential database for strategies and plans for conserving plant biodiversity and improving the power of CO_2 accumulation to adapt to climate change.

Keywords: AGB, biomass, carbon assimilation, DBH, Dipterocarp forest, plant diversity, Vietnam

INTRODUCTION

Plant diversity, in general, and woody plant diversity, in particular, have significant roles and values for the existence and development of humanity because they are considered important resources and carbon sinks. It reduces greenhouse gas concentrations by absorbing vast amounts of carbon from the atmosphere. Meanwhile, human activities such as land-use conversion, illegal farming, and logging have reduced the area of forests worldwide; there have been increased emissions of CO_2 and greenhouse gases and which are directly affecting the global climate (Hop et al. 2021a).

Biodiversity has socio-economic and cultural value and provides many other important benefits such as climate regulation, waste decomposition, reduction of negative impacts of natural disasters, and especially the potential for carbon storage. Previous studies have shown that the key biodiversity areas and biodiversity corridors with developed forest vegetation, such as the Northeast, Northwest, Central Coast, and Central Highlands, are where total biomass carbon storage is highest (Ministry of Natural Resources and Environment 2013; Hop et al. 2021b). Plant diversity and carbon stocks have been hot topics of interest since the last century. This is a big issue that has been and is being given focus by many countries worldwide. However, this topic has not yet received due attention, commensurate with the potential of plant biodiversity in Vietnam (Hop et al. 2021b), one of the global biodiversity centers.

Biodiversity and carbon stocks play an important role in the context of increasingly complex climate change (Hop et al. 2020). In Asia, some typical studies on this topic have been carried out. This issue was only implemented in Vietnam on evergreen broad-leaved objects, deciduous forests from the North to South Central (Hop et al. 2021b), and Highlands (Hop et al. 2021b). At the same time, most other studies on plant diversity and carbon stocks have been conducted independently. Simultaneous biodiversity and carbon stock studies have been conducted on some vegetation types. However, these are still very limited and inadequate to the potential of forest ecosystem diversity, vegetation types, and land use types in Vietnam (Hop et al. 2021b).

Moreover, studying biodiversity and carbon stocks has practical and important implications for the REDD+ program. However, reality has shown that improving carbon stock capacity and promoting biodiversity can hardly be done simultaneously due to limitations in human resources, finances, management capacities, etc. (Mandal et al. 2013; Hop et al. 2021b). Therefore, studies about quantifying forest carbon stock and plant diversity have been conducted worldwide. However, many forest ecosystems and vegetation types have remained unexplored (Japitana et al. 2020), especially the *Dipterocarpus chartaceus* Symington dominant forest in Binh Chau-Phuoc Buu Nature Reserve, South Vietnam.

Binh Chau-Phuoc Buu Nature Reserve (NR) was established in 1996 in southern Vietnam's Dipterocarp forest ecological region, one of the biodiversity conservation areas highly prioritized by WWF (Baltzerm et al. 2001; Bang et al. 2013). The primary vegetation type is a tropical moist, semi-evergreen closed forest (Baltzerm et al. 2001; Bang et al. 2013). including sub-types: Semi-evergreen closed forest on sandy soil, Semi-evergreen closed forest on basalt, Dipterocarp forest on sandy soil, and grassland (Baltzerm et al. 2001; Bang et al. 2013). A new species for science and a new record for Vietnam flora were found, such as *Stereospermum binhchauensis* (Son 2015), *Kaempferia champasakensis* (Van et al. 2018), etc. A total of 732 plant species were recorded (Minh 2019), of which 121 species, 113 genera 63 families were identified as having medicinal value (Hop and Huong 2017), and many endangered, precious, and rare species, such as *Dalbergia bariensis*, *Afzelia xylocarpa*, *D. chartaceus*, etc. (Minh 2019). The *D. chartaceus* and other plants form the dominant forest of *D. chartaceus*. It is considered an endemic plant species of the Nature Reserve. Moreover, up till now, no quantitative studies of plant diversity and carbon have been conducted in the *D. chartaceus* forest of Binh Chau-Phuoc Buu Nature Reserve. This study aims to (i) quantitatively evaluate some plant diversity indexes and (ii) identify the potential of the *D. chartaceus* forest in Binh Chau - Phuoc Buu as a valuable carbon pool.

MATERIALS AND METHODS

Study area

The study was carried out from July to December 2021 in Binh Chau - Phuoc Buu Nature Reserve, Ba Ria - Vung Tau Province, Vietnam (10°28’65" to 10°38’04" North Latitude and 107°24’77" to 107°33’52" East Longitude) (Figure 1). The total natural area was 10,400.9 ha of flat terrain and low slope. The flat area occupies the most significant area, about 9,000 ha. The hilly area had an area of about 600ha; the coastal sandy area covers about 500 hectares, and the lake area has about 200 hectares. The Nature Reserve was located in the tropical rainy season. The average annual rainfall was 1,396 mm; from May to October, the rainy season was concentrated in July, August, and September. The dry season was from November to April next year. The average annual temperature was 25.3°C, and the average annual air humidity was 85.2%. The dominant forest of *D. chartaceus* was distributed on typical coastal sandy soil near the wetlands and swamps. Besides, the slope was less than 5°, an altitude of 20 m-35 m above sea level, often affected by a forest fire. This type of forest forms patches of land surrounding wetlands or forms small patches (Hop and Huong 2017).

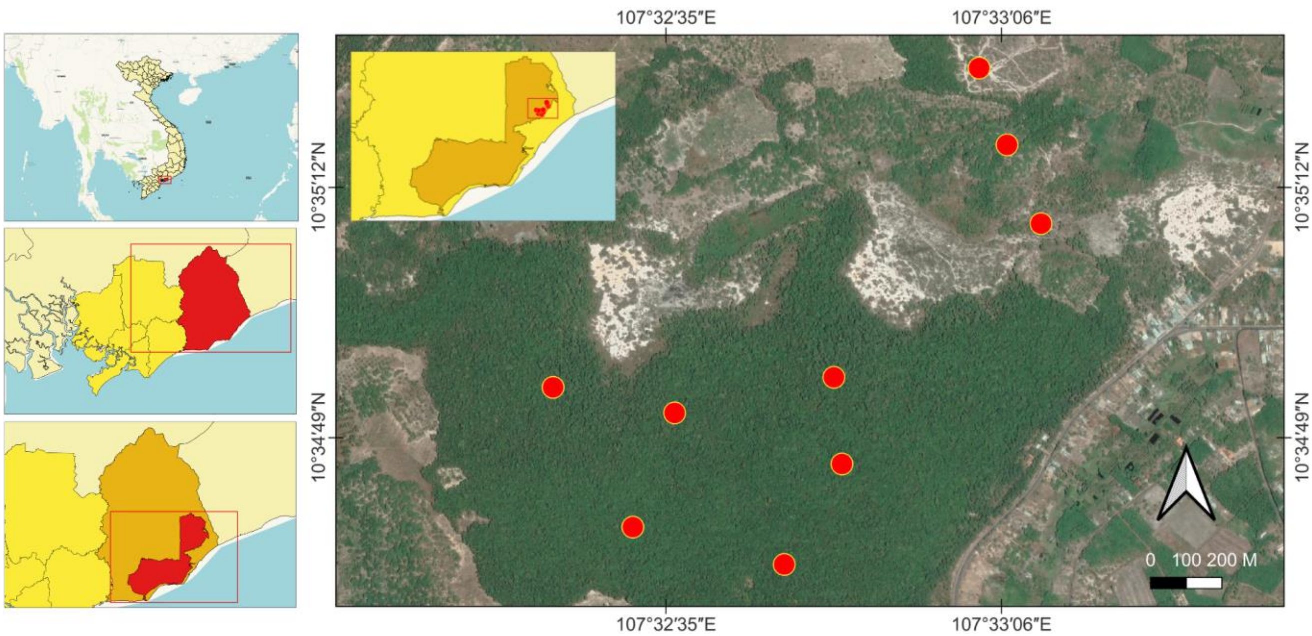

Figure 1. Map of the study area and sample plots of investigation in Binh Chau - Phuoc Buu Nature Reserve, Xuyen Moc District, Ba Ria - Vung Tau Province, Vietnam

Field survey

Based on the preliminary survey results and the current forest status map in 2020, the location of the samples was set up using typical samples representing three forest states (very poor, poor, and medium forests). Then based on the terrain, sample plots were arranged in the field and adapted to the investigation site. Nine sample plots of 50m x 20m were divided equally among very poor, poor, and medium forests. The location of the sampling plots was recorded using the Global Positioning System (GPS 64s) device. The tree individuals with more than 6 centimeters DBH were considered for measuring the total height (Hvn) and DBH (Figure 1).

Data analysis

Determination of the forest status

The forest status name (forest type) was identified and described according to Circular 33/2018/TT of the Ministry of Agriculture and Rural Development, Vietnam (Ministry of Agriculture and Rural Development. 2018), which includes (i) Very poor forest: from 10 to 50 m^3/ha, (ii) Poor Forest: from 50 to 100 m^3/ha, (iii) Medium forest: from 100 to 200 m^3/ha.

Plant species identification

The collecting and processing of plant samples were carried out, according to Thin (1997). Comparative morphological and expert methods were used to treat and identify plant specimens, and voucher specimens were deposited in the Vietnam National University of Forestry - Dong Nai Campus. We used the technical documents of (Ho 1999-2003) and (Hop 2002) were consulted to determine species names that did not have specimens for comparison. The accepted scientific name of the plants was checked with Plants of the World Online (2022) and World flora online (2022). The plant species list was arranged according to Brummitt (1992).

Determination of threatened species

Threatened species were identified according to the Vietnam Red Data Book (Ministry of Science and Technology 2007) and the IUCN Red List (2021) (updated September 2022).

Some plant diversity indices

Margalef Index (d): The Margalef Index was calculated using the formula:

$$d = \frac{s-1}{\log N}$$

Where:

d: Margalef diversity index

S: A total of species in the sample

N: A total of the individual in the sample.

Shannon – Wiener Diversity Index (H’): Shannon – Wiener Index (H’) assessed species diversity in each sample plot. The species diversity outcomes were interpreted using the description by Fernando (1998): Low (H’ = 1-2.49), Moderate (H’ = 2.50-2.90), and High (H’ = 2.91-4.0).

$$H' = -\sum_{i=1}^{s} Pi * \ln(Pi)$$

Where:
H’: Shannon – Wiener Index
Pi: Ni/N
Pi: A proportion of individuals in the population
S: The number of species
Ni: The number of individuals of species i
N: A total number of individuals of all species
Ln: Log base

The concentration of dominance (Cd): The concentration of Dominance (Cd) was determined by the formula of Simpson (1949).

$$Cd = \sum_{i=1}^{s} (Pi)^2$$

Where:
Cd: Concentration of Dominance Index or the Simpson Index.
Pi: Ni/N
Ni: Number of individuals of species i
N: Total number of individuals of all species.

Sorensen’s index: The Index of similarity (SI) was determined by the formula: SI = 2C/(A + B), where: C = the number of species in sample A and sample B; A = the number of species in sample A; B = several species in sample B.

Estimation of biomass and carbon stock

The Aboveground Biomass (AGB) of each tree was calculated for each plot using Eq. (1) for the dry forest, where rainfall was below 1500 mm/year (Brown et al. 1989). This equation was selected as it was appropriate to estimate a wide range of parameters ranging from DBH to AGB with the lowest prediction error value. Moreover, this equation was developed for semi-deciduous or deciduous forest types and DBH from 5 cm-40 cm. Besides, this equation was developed in areas having similar environmental conditions (climate and soils) in the study area.

AGB (kg/tree) = exp (- 1.996 + 2.320 * ln (DBH (cm)), DBH = 5cm - 40cm, $R^2 = 0.89$ (1)

For the biomass density, the total biomass per plot was multiplied by 10,000 m^2 divided by the plot size in square meters, which was 50 m x 20 m (0.1 ha). On the other hand, tree carbon stock was computed by multiplying the tree biomass with the IPCC default carbon fraction value of 50% (0.50) (Houghton et al. 1997).

C(AGB) (kg/tree) = AGB (kg/tree) * 0.50 (2)

Where:
AGB: Estimation of the Aboveground Biomass
C(AGB): Aboveground carbon stocks
DBH: Diameter (cm) at Breast Height (1.3 m).

Tree data were converted into tree biomass per unit area (ha^{-1}).

RESULTS AND DISCUSSION

Species diversity and conservation status

Species component

A total of 640 tree individuals belonging to 45 species and 34 genera, and 25 families were identified (Table 3). The most species-rich family was characterized by Dipterocarpaceae, with seven species (15.56%), followed by Anacardiaceae, with four species (8.89%); Ebenaceae and Clusiaceae, three species each (6.67%); Sapotaceae, Myristicaceae, Hypericaceae, and Annonaceae two species each (4.44%); while single species represented by 16 families each were *Syzygium* represented the most species-rich genus with four species (6.67%), followed by *Diospyros* and *Shorea* with three species each (5.50%); *Madhuca, Knema, Cratoxylum,* and *Garcinia* with two species each (3.33%); while rest 27 genera had single species. Among 45 species, *D. chartaceus* had the highest number of trees, with 244 trees (38.13%), followed by *S. roxburghii* with 75 trees (11.72%), *A. costata* with 48 trees (7.50%), while the remaining species represented 0.16%-4.06%.

Regarding species richness, there were 149 tree individuals, 17 species, and 17 genera belonging to 12 families in the very poor forest; while the poor forest had 215 trees, 25 species, and 21 genera belonging to 18 families; and the medium forest had 276 trees, 31 species, 27 genera belonging to 19 families respectively.

In terms of tree abundance, the very poor forest: *D. chartaceus* had the highest number of trees (86 trees), followed by *G. usitata* (15 trees), *A. costata* (12 trees), and the remaining species had 1-7 trees; in a poor forest: *D. chartaceus* had the highest number of trees (83 trees), followed by *S. roxburghii* (42 trees), *A. costata* (19 trees), *X. vielana* (13 trees), and the remaining species had 1-8 trees; while in the medium forest, *D. chartaceus* had the highest number of trees (75 trees), followed by *S. roxburghii* (33 trees), *A. costata* (17 trees), *X. noronhianum* (14 trees), *H. odorata* (13 trees), and the remaining species (101 trees) (Table 3).

The analysis showed that medium forest was rich in species composition and abundance in trees, followed by poor forest, and the lowest is very poor forest. In addition, the number of species and individual trees belonging to Dipterocarpaceae is the highest and plays an essential ecological role in the three forest states.

Species diversity

The Shannon – Wiener Index (H') ranges from low to moderate. The medium forest was the highest (H': 2.79), with 276 trees of 31 species. The poor forest (H': 2.19) had 215 trees belonging to 25 species. At the same time, the very poor forest had the value of lowest (H': 1.66), with 149 trees belonging to 17 species (Table 1).

For the Margalef Index (d), the value was highest for the medium forest (d: 12.29), followed by the poor forest (d: 10.29), while the value was lowest for the very poor forest (d: 7.36) (Table 1).

For the Simpson Index (Cd), the value was highest for the medium forest (Cd: 0.11), followed by the poor forest (Cd: 0.20) and the very poor forest (Cd: 0.36).

For the Index of Similarity (SI), the species composition in the poor and medium forests had the highest similarity (SI: 0.50), followed by the very poor and poor forests (SI: 0.48), the lowest was the very poor and medium forests (SI: 0.46) (Table 2).

Conservation status

There were 15 threatened species (33.33%) belonging to 11 genera of 8 families. Nine species were least concern (LC), four species were Vulnerable (VU), and two species were Endangered (EN) as per IUCN (2022) (Table 2). The *A. costata* was listed in Vietnam Red Data Book (2007) as Endangered. For the very poor forest, six species were listed in IUCN (2022) (three species at the LC level, two species at the EN level, and one species at the VU level), and one species was listed at the EN level in Vietnam Red Data Book (2007). For the poor forest, eight species were listed in IUCN (2022) (five species at LC, two species at EN, and one species at the VU), and one species was listed as EN in Vietnam Red Data Book (2007); While in the medium forest, 11 species were listed in IUCN (2022) (five species at LC, two species at EN, four species at the VU) and one species was listed as EN in Vietnam Red Data Book (2007).

In addition to the conservation value, species of high ecological and economic importance were confirmed as *A. costata, H. odorata, S. roxburghii, S. siamensis, S. guiso, T. calamansanai, V. pinnata, D. chartaceus*, etc. (Table 4). These species have experienced a decrease in both population and range due to a significant reduction in forest area and quality in recent years. Deforestation, forest fires, and illegal encroachment have become complex, posing a threat to the natural habitat of wild plants (Minh 2019).

Table 1. Species richness, abundance, and some diversity indices

Forest status	Species richness	Abund.	Margalef (d)	Shannon-Wiener (H')	Simpson (Cd)
Very poor	17	149	7.36	1.66	0.36
Poor	25	215	10.29	2.19	0.2
Medium	31	276	12.29	2.79	0.11

Table 2. Index of Similarity (SI) between forest states

Forest status	Very poor	Poor	Medium
Very poor	1.00	0.48	0.46
Poor		1.00	0.50
Medium			1.00

Table 3. The species composition of woody plants in Binh Chau-Phuoc Buu Nature Reserve, South Vietnam

Scientific name	Vietnamese name	Family name	No. of trees	No. of species	No. of genera	Forest status		
						Very poor	Poor	Medium
Bouea oppositifolia (Roxb.) Meisn.	Thanh trà	Anacardiaceae	1	4	1			x
Gluta usitata (Wall.) Ding Hou	Sơn đào	Anacardiaceae	26		1	x	x	x
Semecarpus cochinchinensis Engl.	Sưng nam bộ	Anacardiaceae	8		1	x		x
Spondias pinnata (L. f.) Kurz	Cóc rừng	Anacardiaceae	5		1	x		
Sphaerocoryne affinis (Teijsm. and Binn.) Ridl.	Cơm nguội	Annonaceae	6	2	1			x
Xylopia vielana Pierre	Dền đỏ	Annonaceae	17		1		x	x
Peltophorum dasyrrhachis (Miq.) Kurz	Lim vàng	Caesalpiniaceae	3	1	1		x	
Capparis micrantha A.Rich.	Cáp gai	Capparaceae	1	1	1		x	
Parinari ananmensis Hance	Cám	Chrysebalanceae	5	1	1		x	x
Calophyllum calaba L.	Còng tía	Clusiaceae	2	3	1		x	
Garcinia celebica L.	Rỏi mật	Clusiaceae	10		2			x
Garcinia vilersiana Pierre	Vàng nhựa	Clusiaceae	6			x		x
Terminalia calamansanai (Blanco) Rolfe	Chiêu liêu nước	Combretaceae	1	1	1		x	
Dillenia ovata Wall.	Sổ trai	Dilleniaceae	8	1	1	x	x	x
Anisoptera costata Korth.	Vên vên	Dipterocarpaceae	48	7	1	x	x	x
Dipterocarpus chartaceus Symington	Dầu cát	Dipterocarpaceae	244		1	x	x	x
Hopea odorata Roxb.	Sao đen	Dipterocarpaceae	16			x		x
Shorea guiso (Blanco) Blume	Chò chai	Dipterocarpaceae	8		3			x
Shorea roxburghii G.Don	Sến mủ	Dipterocarpaceae	75				x	x
Shorea siamensis Miq.	Cẩm liên	Dipterocarpaceae	7			x	x	
Vatica odorata (Griff.) Symington	Làu táu	Dipterocarpaceae	11		1		x	x
Diospyros malabarica (Desr.) Kostel.	Cườm thị	Ebenaceae	22	3	3	x	x	x
Diospyros maritima Blume	Cẩm thị	Ebenaceae	8				x	
Diospyros venosa Wall. ex A.DC.	Săng đen	Ebenaceae	1					x
Aporosa tetrapleura Hance	Thầu tầu	Euphorbiaceae	9	1	1		x	x
Millettia diptera Gagnep.	Mát hai cánh	Fabaceae	1	1	1			x
Lithocarpus dinhensis (Hickel and A.Camus) A.Camus	Dẻ núi dinh	Fagaceae	2	1	1		x	
Cratoxylum cochinchinense (Lour.) Blume	Thành ngạnh nam	Hypericaceae	2	2	2		x	
Cratoxylum formosum (Jacq.) Benth. and Hook.f. ex Dyer	Thành ngạnh đẹp	Hypericaceae	7			x	x	x
Irvingia malayana Oliv. ex A.W.Benn.	Kơ nia	Irvingiaceae	4	1	1	x		x
Barringtonia pauciflora King	Chiếc tam lang	Lecythidaceae	2	1	1		x	
Memecylon ligustrinum Blume	Sầm lá lớn	Melastomataceae	8	1	1	x	x	x
Knema globularia (Lam.) Warb.	Máu chó lá nhỏ	Myristicaceae	11	2	2			x
Knema pierrei Warb.	Máu chó Pierrei	Myristicaceae	1					x
Syzygium borneense (Miq.) Miq.	Trâm sẻ	Myrtaceae	4	4	4			x
Syzygium cumini (L.) Skeels	Trâm mốc	Myrtaceae	8				x	x
Syzygium pachysarcum (Gagnep.) Merr. and L.M.Perry	Trâm nhuộm	Myrtaceae	4				x	
Syzygium lanceolatum Wight and Arn.	Trâm trắng	Myrtaceae	1			x		
Ochna integerrima (Lour.) Merr.	Mai	Ochnaceae	1	1	1			x
Carallia brachiata Merr.	Săng mã nguyên	Rhizophoraceae	5	1	1			x
Gardenia philastrei Pierre ex Pit.	Dành dành láng	Rubiaceae	4	1	1	x	x	
Xerospermum noronhianum (Blume) Blume	Trường	Sapindaceae	17	1	1	x	x	x
Madhuca elliptica (Pierre ex Dubard) H.J.Lam	Viết	Sapotaceae	4	2	2			x
Madhuca floribunda (Pierre ex Dubard) H.J.Lam	Sến nhiều hoa	Sapotaceae	2			x		
Vitex pinnata L.	Bình linh lông	Verbenaceae	4	1	1			x

Table 4. Conservation status of woody plants

Scientific name	Vietnamese name	The entire study area		Forest status					
				Very poor		Poor		Medium	
		IUCN (2021)	Vietnam Red Data Book (2007)	IUCN (2021)	Vietnam Red Data Book (2007)	IUCN (2021)	Vietnam Red Data Book (2007)	IUCN 2020	Vietnam Red Data Book (2007)
Anisoptera costata Korth.	Vên vên	EN	EN	EN	EN	EN	EN	EN	EN
Cratoxylum cochinchinense (Lour.) Blume	Thành ngạnh nam	LC				LC			
Cratoxylum formosum (Jacq.) Benth. et Hook.f. ex Dyer	Thành ngạnh đẹp	LC		LC		LC		LC	
Diospyros maritima Blume	Cẩm thị	LC				LC			
Dipterocarpus chartaceus Symington	Dầu cát	EN		EN		EN		EN	
Hopea odorata Roxb.	Sao đen	VU		VU				VU	
Irvingia malayana Oliv. ex A.W.Benn.	Kơ nia	LC		LC				LC	
Knema globularia (Lam.) Warb.	Máu chó lá nhỏ	LC						LC	
Knema pierrei Warb.	Máu chó Pierrei	VU						VU	
Shorea guiso (Blanco) Blume	Chai	VU						VU	
Shorea roxburghii G.Don	Sến mủ	VU				VU		VU	
Shorea siamensis Miq.	Cẩm liên	LC		LC		LC			
Syzygium cumini (L.) Skeels	Trâm mốc	LC				LC		LC	
Terminalia calamansanai (Blanco) Rolfe	Chiêu liêu nước	LC							
Vitex pinnata L.	Bình linh lông	LC						LC	

Note: EN: Endangered, VU: Vulnerable, LC: Least Concern

Mean DBH

Among the three forest states, the medium forest was the highest range of mean DBH with 510.83 cm, followed by the poor forest (365.99 cm) and the very poor forest (203.01 cm) (Table 5).

Generally, species with a large diameter, including woody trees with minor ecological roles and economic value, are found in low numbers (usually 1-3 trees) in extremely poor forests, with exceptions such as *D. chartaceus*. Examples of such species and their respective diameters are *M. confusum* (29.3 cm), *G. usitata* (15.31 cm), *X. noronhianum* (14.01 cm), and *D. malabarica* (15.15 cm). In the poor forest, species like *S. cumini* (21.18 cm), *C. micrantha* (3.89 cm), and *D. malabarica* (19.94 cm) can be found. In the medium forest, the prominent species include *S. cinereum* (39.17 cm), *M. elliptica* (24.47cm), and *G. usitata* (25.04 cm). Species with significant ecological, conservation, and economic value, often characterized by numerous trees and varying diameter sizes, are primarily found in poor and medium forests. These species are mainly from the Dipterocarpaceae family. Examples include *A. costata* (11.82-15.79 cm), *S. roxburghii* (18.53 cm), *H. odorata* (9.72 cm), and *D. chartaceus* (15.75 cm). However, in the very poor forest, larger specimens of *A. costata* (39.3 cm), *D. chartaceus* (20.38 cm), *H. odorata* (43.51 cm), and *S. roxburghii* (21.45 cm) can be found.

Total aboveground biomass and carbon stock

In the very poor forest, the estimated biomass and carbon stock range from 53.34 t/ha to 84.03 t/ha and 26.67 t/ha to 42.02 t/ha, respectively, representing 6.15% to 9.68% of the total. The highest values were recorded in Plot 2, with 84.03 t/ha for biomass and 42.02 t/ha for carbon stock, accounting for 9.68% of the total. For *D. chartaceus*, the biomass and carbon stock ranged from 14.41 t/ha to 35.23 t/ha and 7.21 t/ha to 17.62 t/ha, respectively. The highest values were observed in Plot 1, with 35.23 t/ha for biomass and 14.62 t/ha for carbon stock. The percentage of biomass and carbon stock attributed to *D. chartaceus* compared to the entire area exhibited significant variability, ranging from 1.66% to 4.06%, with the highest value recorded in plot 1 (4.06%). Other species, such as *A. costata, S. roxburghii, P. ananmensis, D. malabarica*, and *S. siamensis*, also displayed relatively high biomass and carbon stock values.

For the poor forest, the estimated biomass and carbon stocks vary from 48.15 t/ha-73.84 t/ha and 24.07 t/ha-36.92 t/ha, respectively, representing 5.55%-8.51% of the total. The highest values were observed in Plot 4, with 73.84 t/ha for biomass and 36.92 t/ha for carbon stock, accounting for 8.51% of the total. As for *D. chartaceus*, the biomass and carbon stocks ranged from 42.65 t/ha-55.62 t/ha and 21.33 t/ha-27.81 t/ha, respectively. The highest value was recorded in Plot 4, with 55.62 t/ha for biomass and 27.81 t/ha for carbon stock, representing 6.41% of the total. Comparatively, the contribution of *D. chartaceus* to the entire area in terms of biomass and carbon stock was relatively low, accounting for a substantial percentage (4.92%-6.41%), with the highest value observed in plot 4 (6.41%). The main species contributing to biomass and carbon stocks include *S. cochinchinensis, G. usitata, A. costata*, and *D. malabarica*.

In the medium forest, the estimated biomass and carbon stocks range from 44.04 t/ha to 196.83 t/ha and 72.02 t/ha to 98.42 t/ha, respectively, representing 16.60% to 22.68% of the total. The highest values were recorded in Plot 3, with 196.83 t/ha for biomass and 98.42 t/ha for carbon stock, accounting for 22.68% of the total. For *D. chartaceus*, the biomass and carbon stocks ranged from 23.60 t/ha to 46.45 t/ha and 11.80 t/ha to 23.22 t/ha, respectively. The highest values were observed in plot 9, with 46.45 t/ha for biomass and 23.22 t/ha for carbon stock. The biomass and carbon stocks of *D. chartaceus* compared to the entire area represent a relatively low percentage (2.72% to 5.35%), with the highest value found in plot 9 (5.35%). Other species such as *A. costata, S. roxburghii, H. odorata, G. usitata, D. malabarica, S. cinereum*, and *I. malayana* also contribute significantly to biomass and carbon stocks in this forest type.

The biomass and carbon stock was the highest in the medium forest (56.27%), followed by the poor forest (22.74%), and lowest in the very poor forest (21.00%) (Figure 2). Meanwhile, biomass and carbon stocks of *D. chartaceus* were highest in the poor forest (16.80%), followed by the medium forest (12.19%), and lowest in the very poor forest (8.12%) (Figure 3).

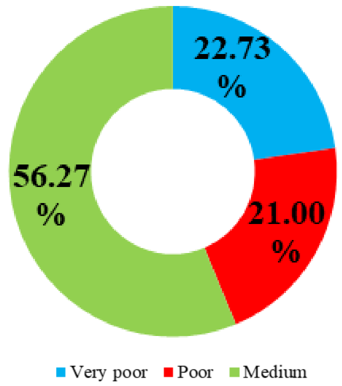

Figure 2. The percentage of biomass and carbon stocks by forest status

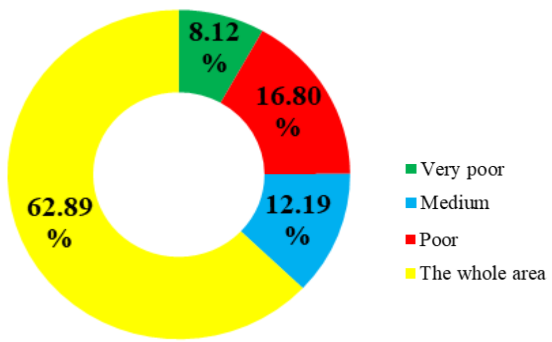

Figure 3. The percentage biomass and carbon stock of *D. chartaceus* and the whole area

Table 5. Abundance and mean diameter of trees by forest status

Status	Botanical name	Vietnamese name	No. of trees	Mean DBH (cm)
Very poor	*Gluta usitata* (Wall.) Ding Hou.	Sơn huyết	15	15.31
	Semecarpus cochinchinensis Engl.	Sưng nam bộ	7	12.18
	Spondias pinnata (L. f.) Kurz	Cóc rừng	5	8.81
	Garcinia vilersiana Pierre	Vàng nhựa	1	6.37
	Dillenia ovata Wall.	Sô trai	2	7.17
	Anisoptera costata Korth.	Vên vên	12	11.82
	Dipterocarpus chartaceus Symington	Dầu cát	86	21.74
	Hopea odorata Roxb.	Sao đen	3	9.72
	Shorea siamensis Miq.	Cẩm liên	1	7.64
	Diospyros malabarica (Desr.) Kostel.	Cườm thị	7	15.15
	Cratoxylum formosum (Jacq.) Benth. and Hook.f. ex Dyer	Thành ngạnh đẹp	1	12.42
	Irvingia malayana Oliv. ex A.W.Benn.	Kơ nia	1	7.32
	Memecylon confusum Blume	Sâm lá lớn	1	29.3
	Syzygium lanceolatum Wight and Arn.	Trâm trăng	1	7.64
	Gardenia philastrei Pierre ex Pit.	Dành dành láng	2	8.44
	Xerospermum noronhianum Blume	Trường	2	14.01
	Madhuca floribunda H.J.Lam	Sến nhiều hoa	2	7.96
	Total		17	203.01
Poor	*Anisoptera costata* Korth.	Vên vên	19	15.79
	Aporosa tetrapleura Hance	Thẩu tấu	1	14.97
	Barringtonia pauciflora King	Chiếc tam lang	2	11.62
	Calophyllum calaba L.	Cồng tía	2	7.48
	Capparis micrantha A.Rich.	Cáp gai	1	23.89
	Cratoxylum cochinchinense (Lour.) Blume	Thành ngạnh nam	1	9.55
	Cratoxylum formosum (Jacq.) Benth. and Hook.f. ex Dyer	Thành ngạnh đẹp	1	8.28
	Dillenia ovata Wall.	Sô trai	4	13.06
	Diospyros malabarica (Desr.) Kostel.	Cườm thị	5	19.94
	Diospyros maritima Blume	Cậm thị	8	12.02
	Dipterocarpus chartaceus Symington	Dầu cát	83	15.75
	Gardenia philastrei Pierre ex Pit.	Dành dành láng	2	11.62
	Gluta usitata (Wall.) Ding Hou.	Sơn đào	4	14.81
	Lithocarpus dinhensis (Hickel and A.Camus) A.Camus	Dẻ núi dinh	2	16.72
	Memecylon confusum Blume	Sâm lá lớn	2	11.15
	Parinari anamensis Hance	Cám	4	22.53
	Peltophorum dasyrhachis (Miq.) Kurz	Lim vàng	3	8.07
	Shorea roxburghii G.Don	Sến mủ	42	18.53
	Shorea siamensis Miq.	Cẩm liên	6	18.52
	Syzygium cumini (L.) Skeels	Trâm mốc	2	21.18
	Syzygium pachysarcum (Gagnep.) Merr. and L.M.Perry	Trâm nhuộm	4	12.42
	Terminalia calamansanai (Blanco) Rolfe	Chiêu liêu nước	1	21.34
	Vatica odorata (Griff.) Symington	Làu táu	2	17.68
	Xerospermum noronhianum Blume	Trường	1	9.24
	Xylopia vielana Pierre	Dền đỏ	13	9.84
	Total		25	365.99
Medium	*Anisoptera costata* Korth.	Vên vên	17	39.13
	Aporosa tetrapleura Hance	Thẩu tấu	8	13.83
	Bouea oppositifolia (Roxb.) Adelb.	Thanh trà	1	10.51
	Carallia brachiata Merr.	Săng mã nguyên	5	15.71
	Cratoxylum formosum (Jacq.) Benth. and Hook.f. ex Dyer	Thành ngạnh đẹp	6	8.23
	Dillenia ovata Wall.	Sô trai	2	11.78
	Diospyros malabarica (Desr.) Kostel.	Cườm thị	10	14
	Diospyros venosa Wall.	Săng đen	1	7.32
	Dipterocarpus chartaceus Symington	Dầu cát	75	20.38
	Garcinia celebica L.	Rỏi mật	10	13.38
	Garcinia vilersiana Pierre	Vàng nhựa	5	14.55
	Gluta usitata (Wall.) Ding Hou.	Sơn đào	7	25.04
	Hopea odorata Roxb.	Sao đen	13	43.51
	Irvingia malayana Oliv. ex A.W.Benn.	Kơ nia	3	18.16
	Knema globularia (Lam.) Warb.	Máu chó lá nhỏ	11	10.64
	Knema pierrei Warb.	Máu chó pierrei	1	8.92
	Madhuca elliptica H.J.Lam	Viết	4	24.47
	Memecylon confusum Blume	Sâm lá lớn	5	11.62
	Millettia diptera Gagnep.	Mát hai cánh	1	9.24
	Ochna integerrima (Lour.) Merr.	Mai rừng	1	11.15
	Parinari anamensis Hance	Cám	1	15.92
	Semecarpus cochinchinensis Engl.	Sưng nam bộ	1	13.69
	Shorea guiso Blume	Chò chai	8	10.15
	Shorea roxburghii G.Don	Sến mủ	33	21.45
	Sphaerocoryne affinis Ridl.	Cơm nguội	6	11.94
	Syzygium borneense Miq.	Trâm sẻ	4	39.17
	Syzygium cumini (L.) Skeels	Trâm mốc	6	15.54
	Vatica odorata (Griff.) Symington	Làu táu	9	9.48
	Vitex pinnata L.	Bình linh lông	4	10.77
	Xerospermum noronhianum Blume	Trường	14	19.21
	Xylopia vielana Pierre	Dền đỏ	4	11.94
	Total		31	510.83

Table 6. Total biomass, carbon stocks, and the whole area

Plot	Very poor forest Biomass density (t/ha)	Carbon Stock (t/ha)	%	Plot	Poor forest Biomass density (t/ha)	Carbon Stock (t/ha)	%	Plot	Medium forest Biomass density (t/ha)	Carbon Stock (t/ha)	%
1	53.34a	26.67a	6.15	4	73.84a	36.92a	8.51	8	147.38a	73.69a	16.98
	35.23b	17.62b	4.06		55.62b	27.81b	6.41		23.60b	11.80b	2.72
2	84.03a	42.02a	9.68	5	60.21a	30.11a	6.94	9	144.04a	72.02a	16.60
	14.41b	7.21b	1.66		47.53b	23.76b	5.48		46.45b	23.22b	5.35
7	59.92a	29.96a	6.90	6	48.15a	24.07a	5.55	3	196.83a	98.42a	22.68
	20.83b	10.42b	2.40		42.65b	21.33b	4.92		35.70b	17.85b	4.11
Total	197.29a	98.64a	22.74		182.20a	91.10a	21.00		488.25a	244.13a	56.27
	70.48b	35.24b	8.12		145.80b	72.90b	16.80		105.75b	52.87b	12.19
Average	65.76a	32.88a	7.58		60.73a	30.37a	7.00		162.75a	81.38a	18.76
	23.49b	11.75b	2.71		48.60b	24.30b	5.60		35.25b	17.62b	4.06

Note: a: Biomass and carbon stocks of plot/forest status, b: Biomass and carbon stock of *D. chartaceus*

Discussion

Diversity of woody plants

The results of the present study indicate a low to moderate diversity, as reflected by H' values ranging from 1.66 to 2.79. This can be attributed to the dominance of *D. chartaceus, A. costata,* and *S. roxburghii* in the forest. The species composition structure within the studied tree species communities is relatively simple, with species richness (S) ranging from 17 to 31 species. In a dominant forest of *S. roxburghii* in Dong Nai province, Vietnam, a higher species richness (S=61-64 species) and diversity ranging from medium to high (H'=2.87-3.05) were recorded in comparison to the present study (Hop et al. 2020). A report focusing on dominant communities of *D. dyeri, D. alatus, H. odorata, S. roxburghii, and A. costata* showed higher species richness and Shannon-Wiener index values than the present study. The recorded species richness for these communities was 53, 62, 60, 42, and 57 species, respectively, with corresponding H' values of = 2.95, 3.23, 2.78, 2.52, and 2.87, respectively (Hop et al. 2021b).

The species richness in the present study was lower than in some studies reported from Asia. A report in the deciduous forest of Odisha, India discovered 70 species belonging to 63 genera and 35 families (Pattnayak et al. 2021); in the Western Ghats, India also showed similar results with 76 recorded tree species (Kothandaraman and Sundarapandia 2017). Studies in Myanmar's mixed deciduous and dipterocarp forests have determined that the number of species varies from 25 to 57 (Myo et al. 2016). Reporting on tropical deciduous forests of the Eastern Ghats, Odisha also discovered 57 species of trees (Sahu et al. 2012); in Western India, where 93 plant species belonging to 85 genera of 24 families were recorded (Kumar et al. 2010); In the Northeastern Ghats, India recorded 135 species of 105 genera, belonging to 45 plant families (Naidu et al. 2018). The diversity and composition of tree species can change due to the variation in latitude, longitude, and altitudinal factors (Thakur and Khare 2006). Tree species diversity varies considerably from site to site due to changes in habitat and biogeographic disturbances (Majumdar et al. 2014).

Several studies in Asia showed that the diversity index (H') in Odisha, India was lower than in the present study (H' = 0-2.31) (Pattnayak et al. 2021); in the West, India (H') ranged from 0.67 to 0.79 (Kumar et al. 2010). The study carried out in the Eastern Ghats, India, also gave similar results to this study (H'= 1.85-2.05) (Panda et al. 2013). However, some other studies recorded a higher diversity, such as in the Northeastern Ghats, India, the index (H') ranged from 3.59 to 4.05 (Naidu et al. 2018); in the dipterocarp and mixed deciduous forest in Myanmar, diversity varied from low to high (H' = 2.39-3.68). The study in Chhatisgarh, India, showed that the index (H') varied widely from 0.19 to 3.35 (Lal et al. 2015). When studying mixed dipterocarp forests in Malaysia, recorded (H') from 3.1 to 4.3 (Ganivet et al. 2020). This comparison shows that the present study plots have been disturbed to varying degrees by anthropogenic and ecological factors. Differences in diversity in different ecological regions due to the influence of different disturbance levels, latitudes, environments, soils, and climates. Areas with high biodiversity often occur in stable environmental conditions with low disturbance.

Carbon stock of woody plants

This study is lower than the *S. roxburghii* dominant forest, which obtained average biomass and carbon stock from 106.20t/ha-282.63 t/ha and 53.07 tC/ha -141.32 tC/ha (Hop et al. 2020). The report was conducted by Hop et al. (2021a) in some communities dominant of Dipterocarpaceae, where it gained average carbon stock from 108.89 tC/ha-174.61 tC/ha in different forest statuses. However, the study of Hai and Trieu (2015) in the deciduous forest is similar to this study, which recorded average carbon stock ranging from 27.84 tC/ha-90.58 tC/ha in different forests. Some studies in Asia showed that carbon stocks ranged from 59.18t/ha to 60.62t/ha in Nepal's dominant forest *S. robusta*, lower than this study (Rawal and Subedi 2022). At the same time, the carbon stock of *S. robusta* ranged from 29.94 t/ha to 38.95 t/ha, which is higher than this study's (Rawal and Subedi 2022). A study in Central Nepal showed that carbon stocks ranged from 70 t/ha to 183 t/ha, lower than the present study (Magar and

Shrestha 2015). However, another study in western Nepal recorded a variable carbon stock of 148.5-202.3 t/ha, higher than the present study (Bhatta and Devkota 2020).

Plant communities can serve as a source and retain large amounts of carbon over a long period since trees assimilate carbon through photosynthesis, of which woody plants are vital and play a major role in carbon sequestration. Therefore, maintaining species richness and individual tree abundance plays a decisive role in the potential for carbon storage. In addition, enhancing the growth in DBH of individual trees is also a key factor contributing to promoting the forest's ability to assimilate carbon. Human activities at low, medium, and high levels affect species diversity and carbon stocks in forest areas, which are positively and significantly correlated (Kpontsu 2011). The degree of anthropogenic disturbance has a significant impact and is positively correlated with woody plant diversity and carbon stocks in the forests of southern Ethiopia (Yohannes et al. 2015). However, some other studies have found that the degree of disturbance by human activities complicates the correlation between carbon and plant diversity (Hop et al. 2021b). Some diversity indices showed a significant correlation, while others did not (Hop et al. 2021b). This study found a statistically significant but weakly negative correlation between the (J') index and the carbon stock (r = -0.388, p-value < 0.001). At the same time, there was no statistically significant correlation (p-value > 0.05) between species richness, abundance, (H'), (Cd), and (d) index with the carbon stock. The above statement is supported by Zhang et al. (2011). This finding reported a negative relationship between woody plant diversity and carbon stock and suggested that carbon stocks are determined not only by the number of species but are more likely to be determined by DBH and the density characteristics of the present species. The reciprocal relationship between woody plant species diversity and carbon stock reflects that carbon stock management and biodiversity conservation can be done simultaneously (Assaye and Asrat 2016). Therefore, minimizing disturbance can be a dual solution for maintaining woody plant diversity and carbon stocks (Hop et al. 2021b). The study highlights the significant role of the dominant forest, particularly the species *D. chartaceus*, in the accumulation of biomass and carbon stocks. This underscores its importance in environmental protection and climate regulation. The findings indicate that *D. chartaceus* serves as a potential carbon pool, suggesting its potential contribution to addressing climate change issues in the study area. The study emphasizes the ecological significance of this species and its capacity to mitigate the effects of climate change.

In conclusion, the dominant forest of *D. chartaceus* exhibits high species richness and abundant tree individuals, highlighting its conservation value and crucial ecological role. This study emphasizes the significant role of this forest type in mitigating climate change in the study area, primarily through its aboveground biomass and carbon stocks, with *D. chartaceus* playing a significant role in carbon accumulation. Additionally, this forest type harbours numerous species of ecological and conservation importance. As a result, it is crucial to prioritize and effectively manage this forest type, particularly in terms of preventing detrimental human activities. Further research should focus on developing policies and programs for conserving this area in the future. Furthermore, future studies should consider other carbon pools, such as soil, roots, stems, branches, and foliage, to understand this ecosystem's carbon dynamics comprehensively.

ACKNOWLEDGEMENTS

We thank the Binh Chau-Phuoc Buu Nature Reserve South Vietnam officials. Special thanks to the forest ranger Nguyen Van Len, who provided the forest status map and supported the field investigation. We want to thank our colleagues who commented on this paper's manuscript.

REFERENCES

Assaye H, Asrat Z. 2016. Carbon storage and climate change mitigation potential of the forests of the Simien Mountains National Park, Ethiopia. Agric For Fish 5 (2): 8-17. DOI: 10.11648/j.aff.20160502.11.

Baltzerm C, Dao NT, Shore RG. 2001. Towards a Vision for Biodiversity Conservation in the Forests of the Lower Mekong Ecoregion Complex. WWF Indochina/WWF US, Hanoi, and Washington D.C [Vietnamese]

Bang TV, Long V, Duc HM. 2013. The mammal fauna of Binh Chau-Phuoc Buu Nature Reserve, Xuyen Moc District, Ba Ria-Vung Tau Province. Natl Sci Conf Ecol Biol Resour 5th: 384-390. [Vietnamese]

Bhatta SP, Devkota A. 2020. Carbon stock in the community-managed Sal (*Shorea robusta*) forests of Dadeldhura District, Western Nepal. South For: J For Sci 82 (1): 47-55. DOI: 10.2989/20702620.2019.1686690.

Brown S, Gillespie AJR, Lugo AE. 1989. Biomass estimation methods for tropical forests with applications to forest inventory data. For Sci 35: 881-902.

Brummitt RK. 1992. Vascular Plant: Families and Genera. Royal Botanic Gardens, Kiew.

Fernando E. 1998. Forest Formations and Flora of the Philippines. College of Forestry and Natural Resources. University of the Philippines Los Banos (unpublished).

Ganivet E, Unggang J, Bodos V, Demies M, Ling CY, Sang J, Bloomberg M. 2020. Assessing tree species diversity and structure of mixed dipterocarp forest remnants in a fragmented landscape of north-western Borneo, Sarawak, Malaysia. Ecol Indic 112: 106117. DOI: 10.1016/j.ecolind.2020.106117.

Hai VD, Trieu DT. 2015. Study on Carbon Sequestration Capacity of Evergreen Broad-Leaved, Semi-Evergreen, and Deciduous Forests in the Central Highlands. The Report Summarizes the Results of the Research Topic at the Ministerial Level. [Vietnamese]

Ho PH. 1999-2003. An Illustrated Flora of Vietnam. Young Publishing House, Hanoi. [Vietnamese]

Hop NV, Huong KM. 2017. Medicinal plant diversity of Binh Chau – Phuoc Buu Nature Reserve, Ba Ria – Vung Tau Province. Natl Sci Conf Ecol Biol Resour 7th: 1180-1185. [Vietnamese]

Hop NV, Long LV, Quy NV, Luong NT. 2021a. Woody plants diversity and aboveground carbon stocks of some Dipterocarpaceae communities in Tan Phu, Dong Nai Province. J Agric Rural Dev 21: 94-103. [Vietnamese]

Hop NV, Quoc BH, Quy NV, Luong NT. 2021b. Relationship between plant biodiversity and carbon stocks in evergreen broad-leaved forests in the Central Highlands. J For Sci Technol 11: 59-69.

Hop NV, Viet LH, Bao TQ, Luong NT. 2020. Woody plant diversity and aboveground carbon stocks of *Shorea roxburghii* G. Don dominant forests in Tan Phu, Dong Nai Province. J For Sci Technol 10: 66-76.

Hop T. 2002. Timber Resources in Vietnam. Agricultural Publishing House, Hanoi. [Vietnamese]

Houghton J, Filho M, Lim B, Treanton K, Mamaty I, Ponduki Y, Griggs D, Callander B. 1997. Greenhouse Gas Inventory Workbook. Intergovernmental Panel on Climate Change (IPCC), Organization for Economic Cooperation and Development (OECD) and the International Energy Agency (IEA), Paris, France.

Japitana RA, Olor JF, Mante KMB. 2020. Tree diversity and aboveground carbon stock assessment in Sitio Bokbokon, Las Nieves, Agusan del Norte, Philippines. Intl J Biosci 17 (3): 58-66. DOI: 10.12692/ijb/17.3.58-66.

Kothandaraman S, Sundarapandian S. 2017. Structure of plant community in tropical deciduous forests of Kanyakumari Wildlife Sanctuary, India. Biodiversitas 18 (1): 391-400. DOI: 10.13057/biodiv/d180151.

Kpontsu EA. 2011. Patterns of Woody Plant Species Richness, Diversity, and Structure Along a Disturbance Gradient in the Atiwa Range Forest Reserve, Eastern Region, Ghana. [Thesis]. Kwame Nkrumah University, Kumasi. [Ghana]

Kumar JIN, Kumar RN, Bhoi RK, Sajish PR. 2010. Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. Trop Ecol 51 (2): 273-279.

Lal C, Singh L, Attri V, Sarvade S. 2015. Tree species diversity, distribution, and population structure in a tropical dry deciduous forest of Chhatisgarh, India. J Appl Nat Sci 7 (2): 681-685. DOI: 10.31018/jans.v7i2.666.

Magar KB, Shrestha BB. 2015. Carbon stock in community-managed Hill Sal (*Shorea robusta*) forests of Central Nepal. J Sustain For 34 (5): 483-501. DOI: 10.1080/10549811.2015.1031251.

Majumdar K, Shankar U, Datta BK. 2014. Trends in tree diversity and stand structure during restoration: A case study in fragmented moist deciduous forest ecosystems of Northeast India. J Ecosyst 2014: 845142. DOI: 10.1155/2014/845142.

Mandal RA, Dutta IC, Jha PK and Karmacharya S. 2013. Relationship between carbon stock and plant biodiversity in Collaborative Forests in Terai, Nepal. Intl Sch Res Not 2013: 625767. DOI: 10.1155/2013/625767.

Minh B. 2019. Binh Chau - Phuoc Buu Nature Reserve: Developing ecotourism associated with forest protection and biodiversity conservation. J Environ 3: 63-64. [Vietnamese]

Ministry of Agriculture and Rural Development. 2018. Circular 33/2018/TT, Dated November 16, 2018, of the Ministry of Agriculture and Rural Development, Stipulates Investigating, Inventory, and Monitoring Forest Resource Developments in Hanoi. [Vietnamese]

Ministry of Natural Resources and Environment. 2013. Decision 1250/2013 of the Prime Minister Dated 31/07/2013 Approving the National Strategy on Biodiversity to 2020, vision to 2030, Hanoi. [Vietnamese]

Ministry of Science and Technology. 2007. Vietnam Red Data Book, Part: Plants. Natural Science and Technology Publishing House, Hanoi. [Vietnamese]

Myo KK, Thwin S, Khaing N. 2016. Floristic composition, structure and soil properties of mixed deciduous forest and deciduous dipterocarp forest: Case Study in Madan Watershed, Myanmar. Am J Plant Sci 7: 279-287. DOI: 10.4236/ajps.2016.72027.

Naidu MT, Premavani D, Suthari S, Venkaiah M. 2018. Assessment of tree diversity in tropical deciduous forests of Northcentral Eastern Ghats, India. Geol Ecol Landsc 2 (3): 216-227. DOI: 10.1080/24749508.2018.1452479.

Panda PC, Mahapatra AK, Acharya PK, Debata AK. 2013. Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape-level assessment. Intl J Biodivers Conserv 5 (10): 625-639. DOI: 10.5897/IJBC2013.0581x.

Pattnayak S, Behera RK, Sahu SC, Dhal NK. 2021. Assessment of woody plant species composition in secondary deciduous forests of Odisha, India. Environ Conserv J 22 (3): 327-339. DOI: 10.36953/ECJ.2021.22338.

Plants of the World Online. 2022. www.powo.science.kew.org. Accessed September 2022.

Rawal K, Subedi PK. 2022. Vegetation structure and carbon stock potential in the community-managed forest of the Mid-Western Hilly Region, Nepal. Asian J For 6 (1): 15-21. DOI: 10.13057/asianjfor/r060103.

Sahu SC, Dhal NK, Mohanty RC. 2012. Tree species diversity, distribution, and population structure in a tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats, India. Trop Ecol 53 (2): 163-168. DOI: 10.31018/JANS.V7I2.666.

Simpson EH. 1949. Measurement of diversity. Nature 163: 688. DOI: 10.1038/163688a0.

Son DV. 2015. A new species of *Stereospermum* (Bignoniaceae) from Southern Viet Nam. Acta Phytotax Geobot 66 (2): 91-94.

Thakur AS, Khare PK. 2006. Species diversity and dominance in the tropical dry deciduous forest ecosystem. J Environ Res Dev 1 (1): 26-31.

The IUCN Red List of Threatened Species. 2022. www.iucnredlist.org. Accessed September 2022.

Thin NN. 1997. Biodiversity Research Manual, Agriculture Publishing House, Hanoi, [Vietnamese]

Van TTK, Nga NP, Son LV, Viet H. 2018. *Kaempferia champasakensis* Pichean and Koonterm–A new record species for Vietnam. Sci Technol Dev J - Nat Sci 2 (1): 13-18. DOI: 10.32508/stdjns.v2i1.668. [Vietnamese]

World flora online. 2022. www.worldfloraonline.org. Accessed September 2022.

Yohannes H, Soromessa T, Argaw M. 2015. Carbon stock analysis along the slope and slope aspect gradient in Gedo Forest: Implications for climate change Mitigation. J Earth Sci Clim Change 6: 305. DOI: 10.4172/2157-7617.1000305.

Zhang Y, Duan B, Xian J, Korpelainen H, Li C. 2011. Links between plant diversity, carbon stocks, and environmental factors along a successional gradient in a subalpine coniferous forest in Southwest China. For Ecol Manag 262: 361-369. DOI: 10.1016/j.foreco.2011.03.042.