EnvironmentAsia
The international journal published by the Thai Society of Higher Education Institutes on Environment

Available online at www.tshe.org/ea/index.html
EnvironmentAsia 10(1) (2017) 52-62
DOI

Plant Diversity in Dong Na Tard Provincial Protected Area, Lao People's Democratic Republic (Lao PDR): Species Structure and Forest Zonation

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Abstract

The spatial distribution of plant diversity in Dong Na Tard Provincial Protected Area (PPA) has not been accurately recorded in previously published literature. This study was conducted to assess and evaluate plant species and its correlation with environmental variables. Plot methods coupled with informal community folk interviews were done. Cluster analysis indicated six forest zones which were classified based on Relative Basal Area (RBA) of dominant species. The species composition in each forest zone was significantly influenced by slope, elevation, human disturbance, and distance from the main road to a dense forest. Dipterocarp forests were the most dominance and should be conserved in sustainable manner.

Keywords: species composition; forest zonation; Dong Na Tard

1. Introduction

Dong Na Tard PPA is a diverse landscape. However, this resource is currently deteriorating due to agricultural expansion and increasing urbanization as mentioned by Intralawan and Rueangkitwat (2016). Rapid resource exploitation has brought in natural resource and environmental degradation (Dilokwanich *et al*., 2015). A study on structure and forest zonation is, therefore, urgently needed as it will serve as baseline information and guideline for a sustainable forest management and conservation. Effective conservation efforts can be implemented if information on plant diversity is available (Müller and Bradl, 2009). Identifying forest zones can assist in understanding species composition, while the correlations between plants and environmental variables could provide information on influential factors affecting the species. For Dong Na Tard PPA, floral distributions varied spatially and temporally as most of the local people are heavily dependent on them to survive. However, the exact level of the effects is still not known. The absence of adequate information on plant species could lead to failure in conservation planning (Balangcod *et al*., 2011). This study aimed to assess species composition and its dominance in order to determine forest zonation; and to evaluate correlations between plant diversity and environmental variables for identifying negative factors affecting the plant species.

2. Materials and Methods

2.1 Study area

Dong Na Tard PPA is located in Savannakhet Province, Lao PDR covering a total area of 6,385 ha (Fig.1). It lies between 16º 35' 20" and 16º 40' 40" N latitude and between 104º 50' 00" and 104º 57' 10" E longitude. It is influenced by the North-East and South-West monsoons causing highly uneven rainfall. The annual average temperature is 27.2ºC, while the relative humidity is 74%, and rainfall is 1,445 mm (Chanthavong, 2004).

2.2 Sampling site establishment

A reconnaissance survey was conducted to gather preliminary data on the plant species, physical environments and land use types. The number and location of sampling plots (10 x10 m) were randomly determined with land-use types and distance from main road. There were fifty-four (54) spatially distributed plots from which samples from different vegetation patches were gathered (Fig. 2). Twenty (20) plots (1^{st}-20^{th}) were designed to get samples in the nearest locations to National Road No. 9 and Nong Kolm village (Kaisone Phomvihanh district), while eighteen (18) plots (21^{st}-35^{th}) were determined to get samples

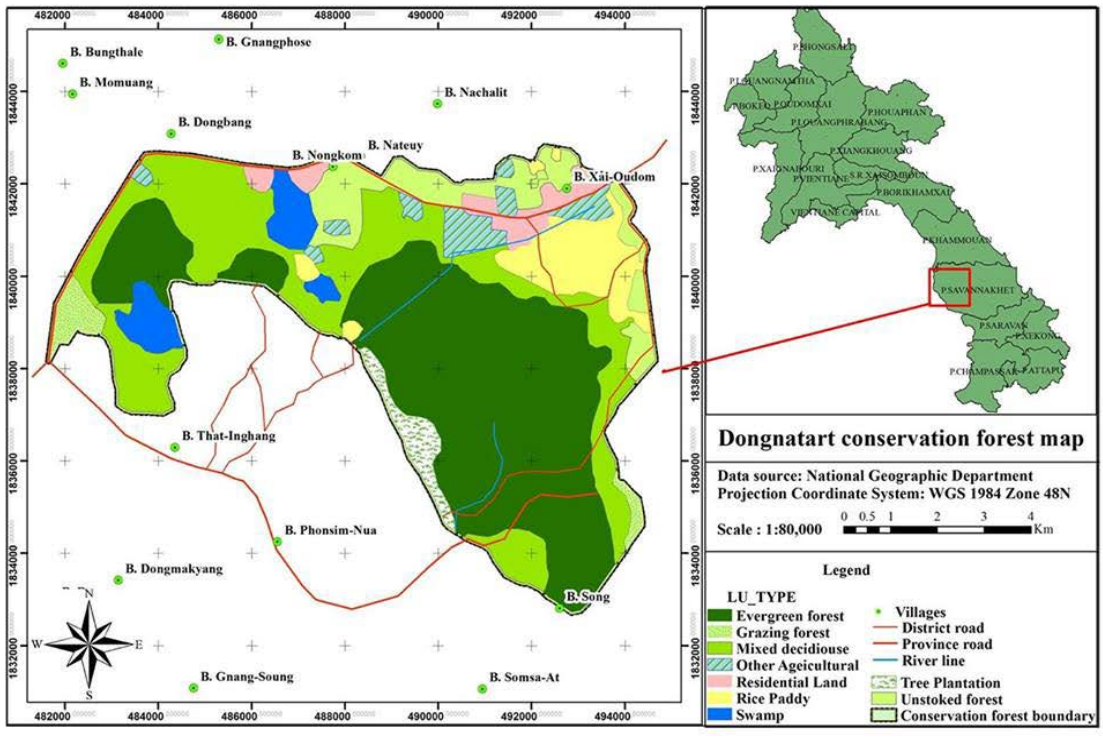

Figure 1. Map of Dong Na Tard Provincial protected area (Map source: aerial photograph, 2014)

in the nearest locations to National Road No. 9 and Na That village (Outhoumphone district). The remaining sixteen (16) plots (39^{th}-54^{th}) were considered to get samples in a dense forest (Fig. 2).

2.3 *Floral assessment*

All plants more than one meter in height were considered sample. The following data were gathered: (a) name of species; (b) diameter at breast height (DBH); (c) total height; (d) land-use type; and (e) presence and type of human disturbances. Environmental factors such as altitude, slope, location, and distance from the road were directly gathered from the plots using convenient survey instruments: GPS receiver, compass, clippers, tape meters, and SUUNTO clinometers.

2.4 *Nomenclature*

No specimen collection was done in this study. Local species names were mostly identified in the field by key informants. The unknown species were photographed and identified at the Department of Forestry, Savannakhet Province by forestry experts. Scientific names were confirmed from the books of Lao "Flora" published in 2008 (Inthakoun and Delang, 2008) and "A Rapid Participatory Biodiversity Assessment" published in 2008 (IUCN, 2008).

2.5 *Vegetation analysis*

Vegetation parameters, *i.e.* diameter at breast height (DBH), total height (H), density (D), basal area (BA), frequency (F), relative density (RD), relative basal area (RBA), and relative frequency (RF) were calculated using methods adopted from Mueller-Dombois and Ellenber (1974). Species diversity was calculated using Shannon-Wiener's index of diversity *H'* (Shannon and Wiener, 1963). The formulas were as follows:

(1) Relative Density (RD)

$$\mathrm{RD} = \frac{Individual\ of\ a\ species}{Total\ individual\ of\ all\ species} \times 100$$

(2) Relative Basal Area (RBA)

$$\mathrm{RBA} = \frac{Basal\ area\ of\ a\ species}{Total\ basal\ area\ for\ all\ species}$$

(3) Relative Frequency (RF)

$$\mathrm{RF} = \frac{Frequency\ of\ a\ species}{Total\ frequency\ for\ all\ species} \times 100$$

(4) Species diversity *H*

$$H' = \sum_{i=1}^{m} (p_i)\,(\log_{10} p_i)$$

Where p_i = proportion of all individuals per species, m = number of species.

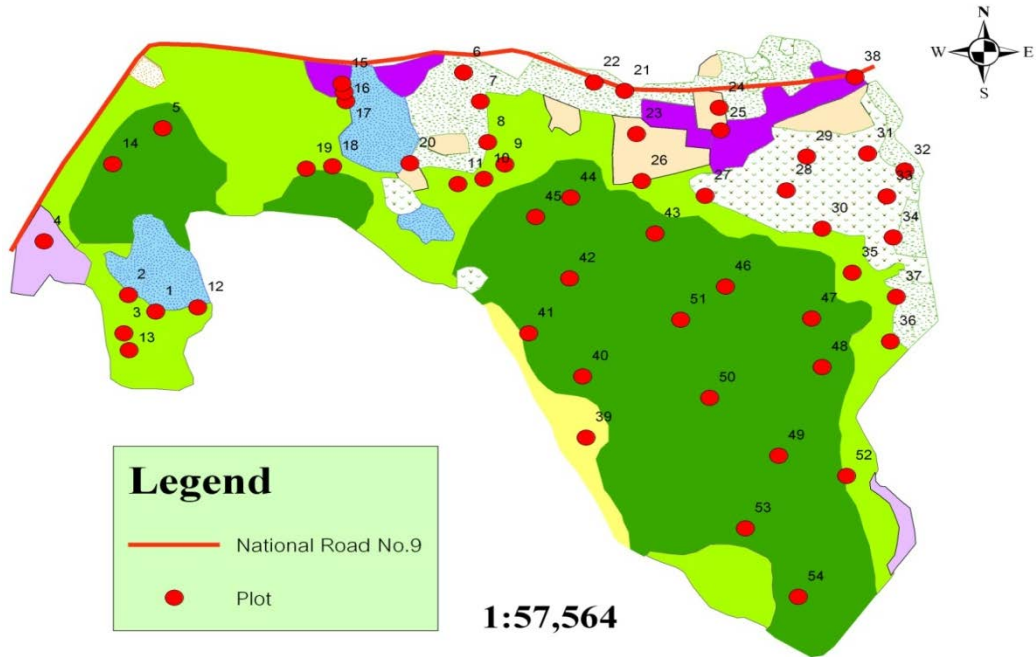

Figure 2. Sampling plots (10x10 m) distributed in Dong Na Tard Provincial protected area.

2.6 Cluster analysis

The dissimilarity matrix of the floristic composition in every sampling site was calculated based on the relative basal area (RBA) using Squared Euclidean distance (Tanaka and Tarumi, 1995; Buot and Okitsu, 1998) as follows:

$$d_{ij} = \sum_{k=1}^{m} (x_{ki} - x_{kj})\,2$$

Where: d_{ij} is squared Eucliden distance between plots *i* and *j*, m is the number of species, x_{ki} is the relative basal area of the k^{th} species in plot *j*.

2.7 Dominance and structural analyses

The relative basal area (RBA) values were used to determine the dominant species in each forest zone. For the zones, three to five species with the highest RBA value were considered as dominant species. Species parameters were employed to describe the structural variations for the zones.

2.8 Regression analysis

The relationships between species parameters (RD, RBA, and RF) and environmental variables were analyzed using the equation:

$$Y = b0 + b1X1 + b2X2\ldots + bqXq$$

where:

Y = dependent variables

X1, X2,…Xq = independent variables

b0, b1, b2,…bq = partial regression coefficients of the independent variables

Species parameters in each zone were used as dependent variables (Y) while the environmental factors were determined as independent variables.

3. Results and Discussion

3.1 Species composition and dominants

A total of 675 individuals, 70 species, and 33 families of plants were identified. *Dipterocarpus* sp. Roxburgh ex G had the highest number of individuals, relative frequency (RF), relative density (RD), and relative basal area (RBA) with 91; 9.49; 13.48; and 27.93, respectively. Based on the RBA, *Dipterocarpus* sp.; *Irvingia harmandiana* Oliv. ex A. Benn; *Dialium indum* L.; *Xylia xylocarpa* (Roxb.)Taub; and *Tectona grandis* Linn were the top five (5) dominant species in the park (Table 1).

Dipterocarpus sp. was the most dominant species. It was also included in the Red List of threatened species (EN) of IUCN (2008). The dominant species belongs to family of trees that dominate canopies of rainforests in Southeast Asia (Kaewgrajang *et al*., 2013). It is also considered an important pool of Tan Phu forest in Vietnam (Millet and Truong, 2011). In Lao PDR, this

species is important for its timber and its oleoresin used by indigenous people for making traditional light torch (Ankarfjard, 2000).

The second and third dominants were *Irvingia harmandiana* and *Dialium indum* respectively, (Table 1) which could be found in the local and national parks of Lao PDR. They are hardwood species used for timber, charcoal, firewood making, and wild fruit consumption (IUCN, 2008). In Thailand, the *D. indum* occurred in the southern parts and its fruit is used for desert mixed with sugar and chili peppers (Subhadrabandhu, 2001). In Malaysia, the fruits of *D. indum* were used as sources of sugar and energy (Shaffiq *et al*., 2013).

Xylia xylocarpa, the fourth dominant species, was found in all parts of the park (Table 1). In Vietnam, the *X. xylocarpa* was one of 12 threatened species found in the Tan Phu forest (Millet and Truong, 2011). In Myanmar, the species was the most abundant in the Dry Upper Mixed Deciduous and Moist Upper Mixed Deciduous Forests (Sein *et al*., 2015). It was also among the top ten dominant species in the Northern and Southeastern Ghats of Andhra Pradesh, India (Babar *et al*., 2011).

The last of the top five dominants, *Tectona grandis* (teak), was found only in plantation forest along the main road (Fig. 1). It is native to the tropical deciduous forests of India, Myanmar, Thailand and Laos estimated to cover 29.035 million ha (Fofana *et al*., 2009; Kollert and Cheruini, 2012). In India, the demand for teak had increased several folds during the last five decades (Fofana *et al*., 2009).

Past studies indicated that *Dipterocarpus* sp. could be found in many areas of the region. However, the dominant species may become extinct if they are continuously overused or disturbed. In the Philippines, dipterocarps were the former dominants of the forest landscape of Mount Makiling. The dipterocarps are still occupying the low DBH classes and maybe it will have to take several years before they can regain dominance (Buot and Osumi, 2011) when disturbances are lessened or removed.

3.2 Forest zonation

The RBA of each species was subjected to cluster analysis using Ward's hierarchical clustering method (Fig.3). There were six forest zones which were named according to the respective dominant species:

Zone I. *Dipterocarpus* sp-*Afzelia xylocarpa-Diospyros malabarica* zone. This zone is the second most abundant and most diverse among the six zones with 127 individuals represented by 35 species. *Dipterocarpus* sp. was the most dominant at 10.59% RBA. The DBHmax and height values of species in the zone were 145 cm and 50 m, respectively, found in Plot 45 at the elevation of 180 m (Table 2; Fig. 3).

Zone II. *Artocarpus* sp-*Ziziphus cambodiana-Dipterocarpus* sp. zone. This zone is the least abundant among the six zones with 78 individuals represented by 21 species. *Artocarpus* sp. was the most dominant with 19.35% RBA. The DBHmax and maximum height values were100 cm and 40 m found in Plot 30 at the altitude 170 m (Table 2; Fig. 3).

Zone III. *Dipterocarpus* sp.-*Irvingia harmandiana-Dialium indum* zone. This zone is the most abundant and most diverse among the six zones with 195 individuals represented by 42 species. *Dipterocarpus* sp. was the most dominant having 24.75% RBA. The DBHmax value was 150 cm found in Plot 48 at the altitude 180 m, while the maximum height value was 45 m found in Plot 53 at the altitude 180 m (Table 2; Fig. 3).

Zone IV. *Dipterocarpus* sp-*Anisoptera costata-Solanum torvum* zone. This zone is low in abundance with 86 individuals represented by 27 species. *Dipterocarpus* sp. was the most dominant having 56.74 % RBA. The DBHmax and maximum height values were 100 cm and 45 m, respectively, found in Plot 3 at the altitude 180 m (Table 2; Fig. 3).

Zone V. *Dipterocarpus* sp.-*Dipteroarpus macrocarpus-Syzygium tinctorium* zone. This zone is also low in abundance with 85 individuals represented by 25 species. *Dipterocarpus* sp. was the most dominant having 37.04% RBA. The DBHmax and maximum height values were 100 cm and 45 m found in Plot 1 at the altitude 160 m (Table 2; Fig. 3).

Zone VI. *Tectona grandis-Eucalyptus* sp. plantation zone. This zone is the third abundant with 104 individuals represented by 21 species. *Tectona grandis, Dipterocarpus* sp., and *Eucalyptus* spp. shared the dominance having 36.76, 22.08, and 7.692 % RBA, respectively (Table 2; Fig. 3).

In the study area, Zone I and Zone III were located far from the main road and the villages. Though the species was the most dominance, both zones were still rich in species diversity compared to the other zones (Tables 1 and 2). Zone II was located near the agricultural farms making plants prone to disturbance and extraction. This goes with the observation of Buot and Osumi (2011) that the distance from the agricultural farms are linearly correlated with species stem density in various land- use types.

Since Zone IV and Zone V were located closest to Nong Kolm village (Fig. 1), they had lower number of individuals than Zone I and Zone III (Table 2). Zone VI was a plantation forest, all dominant species here had high economic importance. *Tectona grandis* and *Eucalyptus* sp. were the famous species planted in the Lao PDR.

Table 1. Species composition in Dong Na Tard Provincial Protected Area

Family/Species	Local name	NO. OF INDIV.	O	F	D	DBH cm	BA cm^2	RF (%)	RD (%)	RBA (%)
Anacadiaceae										
Spondia spinnata (Koening& L.F.)	MakKok	9	6	0.11	0.0017	515.4	208394	1.63	1.33	1.40
Ancistrocladaceae										
Ancistrocladus tectorius (Lour.) Merr	Khu Hang kouy	14	6	0.11	0.0026	142.1	15841	1.63	2.07	0.11
Apocynaceae										
Alstonia rostrata Fisher	Mai Tin pet	3	2	0.04	0.0006	129.1	13072	0.54	0.44	0.09
Wrightia arborea (Dennstedt) Mabberley	Mai Mouk	6	6	0.11	0.0011	325.1	82909	1.63	0.89	0.56
Arecaceae										
Cocos nucifera L.	Ton Makpao	2	2	0.04	0.0004	31.1	758	0.54	0.30	0.01
Wallichia gracilis Beccari	Ton Tao	4	3	0.06	0.0007	113.3	10069	0.81	0.59	0.07
Bignoniaceae										
Fernandoa adenophylla Wall ex. G. Don	Ton Kaekhon	4	4	0.07	0.0007	101.3	8057	1.09	0.59	0.05
Oroxylum indicum (L.) Ventenat.	Kok Lin mai	1	1	0.02	0.0002	62.8	3096	0.27	0.15	0.02
Bombacaceae										
Bombax albidum Gagnepain	NgieuPaa	4	4	0.07	0.0007	257.2	51918	1.09	0.59	0.35
Combretaceae										
*Terminalia catappa*L.	Ton Houkouang	6	5	0.09	0.0011	72.6	4133	1.36	0.89	0.03
Terminalia corticosa Pirre ex Lanessan	Mai Peuy lard	5	5	0.09	0.0009	366.9	105602	1.36	0.74	0.71
Cucurbitaceae										
Lagenaria siceraria	Ton Maknamtao	9	4	0.07	0.0017	54.0	2291	1.09	1.33	0.02
Dipterocapaceae										
Anisoptera costata Korth	Mai Bak	21	7	0.13	0.0039	673.4	355811	1.90	3.11	2.40
*Dipterocarpus obtusifolius*Teijsm.ex Miq	Mai Sad	9	7	0.13	0.0017	720.6	407434	1.90	1.33	2.75
Dipterocarpus sp. Rox burgh ex G	Mai Nhang	91	35	0.65	0.0169	2298.8	4146149	9.49	13.48	27.93*
Hopea odorata Roxb	Mai Khaenhua	5	3	0.06	0.0009	338.5	89912	0.81	0.74	0.61
Hopea recopei Pierre	Mai La Aen	4	3	0.06	0.0007	204.9	32956	0.81	0.59	0.22
Shorea obtusa Wall. ex Blume	Mai Chik	8	3	0.06	0.0015	304.9	72924	0.81	1.19	0.49
Vatica odorata (Griff.) Symington	Mai Jik dong	5	4	0.07	0.0009	401.6	126546	1.08	0.74	0.85
Ebenaceae										
Diospyros filipendula Piere ex Lecomte	KokKanthong	16	19	0.35	0.0030	116.7	10689	5.15	2.37	0.07
Diospyros malabarica (Desr.) Kostel	Kok Lang dam	16	11	0.20	0.0030	474.4	176560	2.98	2.37	1.19
Diospyros mollis Griffith	Ton Makkuoi	9	5	0.09	0.0017	266.2	55607	1.36	1.33	0.37
Elaeocarpaceae										
Elaeocarpus stipularis Blume	Sommoun	2	2	0.04	0.0004	36.6	1053	0.54	0.30	0.01
Euphorbiaceae										
Aporosa villosa (Lindl.) Baillon	Mai Maed	8	5	0.09	0.0015	125.2	12291	1.36	1.19	0.08
Baccaurea ramiflora Gagnepain	Mai Makfai	11	10	0.19	0.0020	161.6	20487	2.71	1.63	0.14
Bridelia stipularis (L.) Blume	Mai Sa long khong	2	2	0.04	0.0004	36.6	1053	0.54	0.30	0.01
Croton joufra Roxburgh	KokPao	4	4	0.07	0.0007	115.8	10518	1.08	0.59	0.07
Fabaceae										
Afzelia xylocarpa (Kurz) Craib	Mai Tae kha	25	13	0.24	0.0046	462.3	167690	3.52	3.70	1.13
Bauhinia malabarica Roxburgh	Mai Somseio	2	2	0.04	0.0004	53.5	2245	0.54	0.30	0.02
Dalbergia cochinchinensis Pierre	Mai Pa dong	1	1	0.02	0.0002	15.7	193	0.27	0.15	0.00
Dialium cochinchinense Pierre	Mai Kheng	3	3	0.06	0.0006	192.1	28941	0.81	0.44	0.19
Dialium indum L.	Ton MakKheng	24	13	0.24	0.0044	1489.1	1739704	3.52	3.56	11.72*
Peltophorum dasyrachis Kurz	Mai Sa phang	25	14	0.26	0.0046	931.2	680405	3.80	3.70	4.58
Pterocarpus macrocarpus Kurz	Mai Dou	21	12	0.22	0.0039	648.1	329529	3.25	3.11	2.22
Sindora siamensis Teysm. ex Miquel	Mai Tae nam	1	1	0.02	0.0002	60.0	2826	0.27	0.15	0.02
Xylia xylocarpa (Roxb.) Taub	Mai Deng	35	8	0.15	0.0065	948.1	705288	2.17	5.19	4.75*
Flacourtiaceae										
Hydnocarpus anthelmintica Pierre	Ton Kabao	4	4	0.07	0.0007	77.5	4714	1.08	0.59	0.03
Hypericaceae										
Cratoxylum formosum (Jack) Dyer	Tieu som	14	8	0.15	0.0026	229.8	41416	2.17	2.07	0.28
Irvingiaceae										
Irvingia harmandiana Oliv. Ex A. Benn	Mai Bok	20	18	0.33	0.0037	1664.7	2174392	4.88	2.96	14.65*
Lythraceae										
Lagerstroemia balansae Koehne	Mai Peuy	3	3	0.06	0.0006	56.9	2539	0.81	0.44	0.02
Lagerstroemia sp.	Mai Peuyhin	30	16	0.30	0.0056	732.2	420612	4.34	4.44	2.83
Meliaceae										
Melia azedarach L.	Ton Kadao	2	2	0.04	0.0004	157.0	19349	0.54	0.30	0.13
Sandoricum koetjape (Burm.f.) Merrill	Ton Tong	4	2	0.04	0.0007	571.1	255908	0.54	0.59	1.72
Moraceae										
Artocarpus sp.	Ton Makmee	17	9	0.17	0.0031	537.3	226497	2.44	2.52	1.53
Ficus drupacea Thunberg	Ton Meepaa	4	3	0.06	0.0007	323.6	82181	0.81	0.59	0.55
Ficus septica Burn.f. var. septica	Ton Makdua pong	3	1	0.02	0.0006	182.2	26037	0.27	0.44	0.18
Streblus asper Lour	Ton Somphor	7	3	0.06	0.0013	129.1	13080	0.81	1.04	0.09
Streblus ilicifolius (Kurz.) Corn	Ton Nam khom	1	1	0.02	0.0002	15.7	193	0.27	0.15	0.00
Myrsinaceae										
Ardisia evonymifolia Pitard	Kok Ta khouang	7	3	0.06	0.0013	46.2	1672	0.81	1.04	0.01
Myrtaceae										
Eucalyptus sp.	Ton vik	12	1	0.02	0.0022	766.4	460796	0.27	1.78	3.10
Syzygium cinereum Kurz Chant. & Parn	Ton Makva	8	7	0.13	0.0015	726.2	413792	1.90	1.19	2.79
Syzygium zeylanicum (L.) DC.	Ton Sa mek	6	3	0.06	0.0011	75.4	4466	0.81	0.89	0.03
Syzygium gratum (Wight) S.N. Mitra	Ton Sa mekkhao	12	4	0.07	0.0022	190.5	28467	1.08	1.78	0.19
Syzygium tinctorium (Gagn.) Merr. ex Pierre	Mai Va dong	5	3	0.06	0.0009	207.7	33846	0.81	0.74	0.23

Remarks:

- Asterisk (*) - dominant species based on total RBA of a species for all zones of the park
- O- occurrence of species per 54 plots; F- frequency/54 plots; D - density per 5400 m^2; DBH - diameter at breast height (cm); BA- basal area; RF- relative frequency; RD - relative density; RBA - relative basal area.

Table 1. Species composition in Dong Na Tard Provincial Protected Area (Continued)

Family/Species	Local name	NO. OF INDIV.	O	F	D	DBH cm	BA cm^2	RF (%)	RD (%)	RBA (%)
Pinaceae										
Keteleeria evelyniana Master	Mai Hing	2	1	0.02	0.0004	75.0	4416	0.27	0.30	0.03
Ziziphus cambodiana Pierre	Ton Makkhom	17	12	0.22	0.0031	356.4	99650	3.25	2.52	0.67
Rosaceae										
Pyrus pashia Buch. Ham. ex D. Don	Ton Makchong	1	1	0.02	0.0002	15.7	193	0.27	0.15	0.00
Rubus multibracteus Lev. & Vaniot	Ton Maktoum	2	1	0.02	0.0004	157.0	19349	0.27	0.30	0.13
Rubiaceae										
Prismatomeri stetandra (Roxburgh) K. Schum	Ton Yor dong	2	1	0.02	0.0004	9.0	64	0.27	0.30	0.00
Sapindaceae										
Lepisanthes rubiginosa (Roxburgh) Leenh	Ton MakHouad	8	7	0.13	0.0015	228.3	40889	1.90	1.19	0.28
Solanaceae										
Solanum torvum Swartz	KhaengFaa	8	3	0.06	0.0015	190.3	28418	0.81	1.19	0.19
Sterculiaceae										
Heritiera javanica (Blume) Kosterm	Mai Hao	2	2	0.04	0.0004	257.3	51926	0.54	0.30	0.35
Sterculia sp.	Portae	4	1	0.02	0.0007	50.2	1981	0.27	0.59	0.01
Stilaginaceae										
Antidesma bunius Sprengel	Mak Mao	2	1	0.02	0.0004	8.9	62	0.27	0.30	0.00
Symplocaceae										
Symplocos racemosa Roxburgh	Mai Muad ae	6	3	0.06	0.0011	77.3	4683	0.81	0.89	0.03
Tiliaceae										
Peltace	Ton Si siet	1	1	0.02	0.0002	62.8	3096	0.27	0.15	0.02
Verbenaceae										
Tectona grandis Linn	Mai Sak	38	5	0.09	0.0070	932.9	682788	1.36	5.63	4.60*
Vitex pinnata L.	Mai Tin nok	3	1	0.02	0.0006	78.5	4837	0.27	0.44	0.03
Zingiberaceae										
Curcuma alisamatifolia Gagnepain	Phak Warn	3	2	0.04	0.0006	93.4	6842	0.54	0.44	0.05
Alpinia sp.	Khapaa	2	1	0.02	0.0004	22.0	379	0.27	0.30	0.00
Total		**675**			**0.125**	**2,2551.2**	**14,842,481.0**	**100**	**100**	**100**

Remarks:

- Asterisk (*) - dominant species based on total RBA of a species for all zones of the park
- O- occurrence of species per 54 plots; F- frequency/54 plots; D - density per 5400 m^2; DBH - diameter at breast height (cm); BA- basal area; RF- relative frequency; RD - relative density; RBA - relative basal area.

3.3 Structural differences in the forest zones

Zone I and Zone III (Fig. 4(a) and (c)) had the highest species density (D), frequency (F), and species diversity index (*H'*) as the distance unit from the road increased, while the Zone II (Fig. 4(b)) situated closely to the road had the lowest species density (D) and species diversity index (H'). Further, most of disturbed plots were found in Zones IV, V, and VI (Fig. 4(d), (e) and (f)) while only one plot was found in Zone I (Table 2). However, the DBHmax of plant species was low in the Zones II, IV, and V because the species were newest regenerated. These zones were geographically situated in the lowland where the species can be easily accessed and gathered by unauthorized people.

3.4 Correlations of plant diversity with environmental variables

The results revealed that the distance from road was positively correlated with RBA but maybe no correlation with RF (Fig. 5(a)). Similarly, the elevation was also positively correlated with RBA and RF (Fig. 5(b)), while the number of plots disturbed by human activities and slope were negatively correlated with RD, RF, and RBA (Fig. 5(c) and (d)).

Since species diversity was negatively correlated to the human disturbance and slope (Fig. 5(c) and (d)), most plants in Zones II, IV, V and VI had low value of species diversity (*H'*) and abundance (Table 2). This was similar to the observation of Giliba *et al*. (2011) where the distance of the Bereku Forest Reserve in Tanzania showed a unit increase in distance between homestead and the woodland. The elevation was a slightly positive correlation to species diversity (Fig. 5(b)) because range of altitude from 150 to 200 masl (Table 2) could not affect the growth of plants. Although landscape of Dong Na Tard PPA was quite flat plain, the topography led to change in its slope along a certain distance which negatively impacts on plant diversity (Fig. 5(d)). Davies *et al*. (2007) suggested that slope was the only non-soil factor to be at least moderately correlated with plant species composition.

Determination of environmental factors responsible for spatial distribution of species can give useful information for conservation planning (O'dea, 2014; Dalle *et al*., 2014) especially in determining buffer zone of the park. Understanding relationships between plant species and environmental variables aids in the biodiversity management, restoration and development of ecosystems. Therefore, forest managers and development planners need to integrate and use these data in planning and implementing sustainable utilization of plant diversity in the Dong Na Tard PPA.

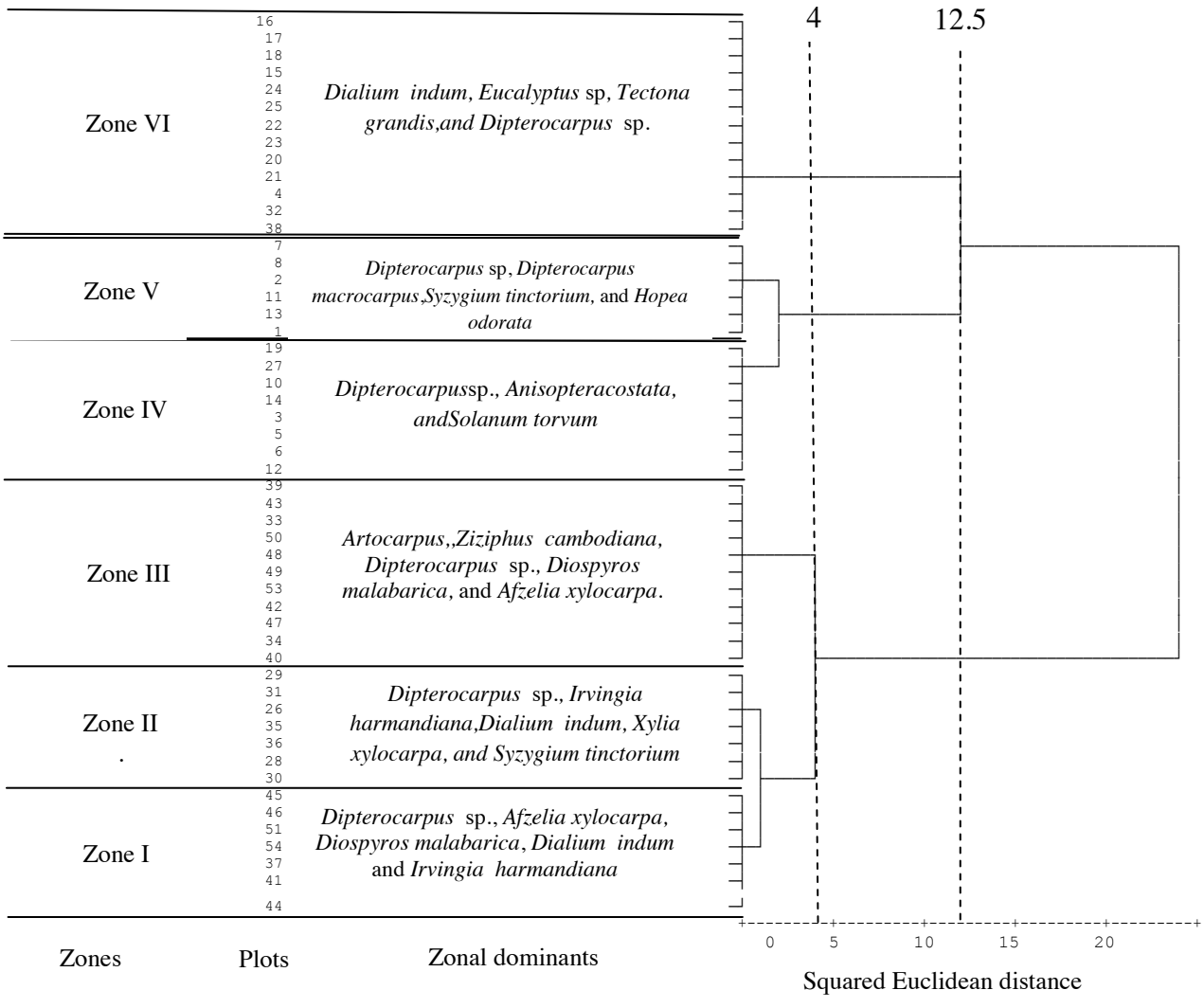

Figure 3. Forest zones in Dong Na Tard PPA. Dendrogram of fifty-four plots obtained by the Ward's method based on relative basal area (RBA). Each zone was named by co-dominant species.

4. Conclusions

The present study was designed to provide information on species composition, its zonation and the correlation of selected environmental variables with species data. The plant species were distributed in six forest zones of Dong Na Tard PPA. Each forest zone was dominated by *Dipterocarpus* sp., along with other codominant species. This means that the forest is quite intact with dipterocarps, a characteristic dominant in many tropical forest ecosystems. This means that the local people are using the resource sustainably though there are evidences of destruction in some parts of the park which the local government and the park administrators have to look into, in order to sustain the rich dipterocarp biodiversity in the area.

The species biodiversity in the various forest zones in the park, were shown to be correlated with some environmental variables. The species RBA was higher with the increase in distance from the road and other forms of possible access that may endanger the species. The distance however, seemed not to affect species occurrences (RF). This implied that management has to limit constructing of access roads to the forest zones. Species RBA, RF and RD were also influenced by elevation. The higher the elevation, the higher were the

Table 2. Dominant species based on relative basal area of a species in each zone

	ZONES					
	I	II	III	IV	V	VI
Altitudes (masl)	150-180	160-180	160-180	150-180	160-179	160-200
No. of plots	8	7	11	8	7	13
No. of individuals	127	78	195	86	85	104
No. of species	35	21	42	27	25	21
Species density (No. area^{-1})	0.159	0.111	0.177	0.108	0.121	0.8
Species diversity *H*'	2.22	1.77	2.67	1.57	1.76	0.66
DBHmax (cm)	145	100	150	100	100	120
Maximum height (m)	50	40	48	45	45	45
Relative density (RD) (%)	18.81	11.56	28.89	12.74	12.59	15.41
Relative frequency (RF) (%)	22.1	15.3	19.3	17.1	18.1	8.2
Relative basal area (RBA) (%)	24.31	4.99	29.64	12.22	13.52	15.32
No. of plot disturbed	1	2	2	3	3	3
Dominant species based on RBA						
Afzelia xylocarpa (Kurz) Craib	6.58	8.77				
Anisoptera costata Korth				14.16		
Artocarpus sp.		19.354				
Dialium indum L.			11.67			7.692
Diospyros malabarica (Desr.) Kostel	6.345	13.225				
Dipterocarpus sp Roxburgh ex G	10.588	13.718	24.745	56.737	37.041	22.082
Eucalyptus sp.						7.692
Hopea odorata Roxb					5.446	
Irvingia harmandiana Oliv. ex A. Benn	5.81		15.017			
Peltophorum dasyrachis Kurz						7.689
Pterocarpus macrocarpus Kurz					15.104	
Solanum torvum Swartz				8.356		
Syzygium tinctorium (Gagn)Merr. ex Pierre			5.678		6.094	
Tectona grandis Linn						36.764
Xylia xylocarpa Roxb Taub			10.235			
Ziziphus cambodiana Pierre		15.264				

values of species data. This was understandable since it is more difficult to access and disturb biodiversity in higher elevations. Slope, as an environmental variable, did not influence species data that much. Species diversity index (Shannon Wiener), RBA and RD were negatively affected by human activities. It is therefore imperative to minimize all these disturbances in order to protect the rich biodiversity at Dong Na Tard PPA. Thus, Zone I and Zone III should be considered as core areas for conservation. Furthermore, reforestation and enrichment planting (Zone II and Zone VI) should be carried out to allow regeneration of threatened species within the park.

Acknowledgements

The authors would like to extend sincere gratitude to the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) for financial support and guidance. Also, we are deeply grateful to the students and faculty members of Savannakhet University, technical staff of Provincial Natural resources and Environment, Provincial Agriculture and Forestry Office, and village representatives who participated in our study.

Figure 4(a). Species composition in forest. Zone I. *Dipterocarpus* sp–*Afzelia xylocarpa–Diospyros malabarica* were dominants. Two KIIs demonstrated the DBHmax of a tree during the field surveys

Figure 4(b). Species composition in forest Zone II. *Artocarpus* sp- *Ziziphus cambodiana-Dipterocarpus* sp. were dominants. Most of the plant species present were near the edge of rice fields.

Figure 4(c). Species composition in forest Zone III. *Dipterocarpus sp.-Irvingia harmandiana-Dialium indum* were dominants. The photo showed the highest DBHmax found in this zone.

Figure 4(d). Species composition in forest Zone IV. *Dipterocarpus* sp–*Anisoptera costata–Solanum torvum* zone were the most dominants and several regenerants of *Dipterocarpus* sp were found in the plots as well.

Figure 4(e). Species composition in forest Zone V. *Dipterocarpus* sp.-*Dipteroarpus macrocarpus-Syzygium tinctorium* were dominants. Most of the tree species were still young, an evidence of previous disturbances in the zone.

Figure 4(f). Species composition in forest Zone VI. *Tectona grandis-Eucalyptus* sp. plantation. Although this zone was located nearest residential areas, a number of individuals were high because there were forest plantations

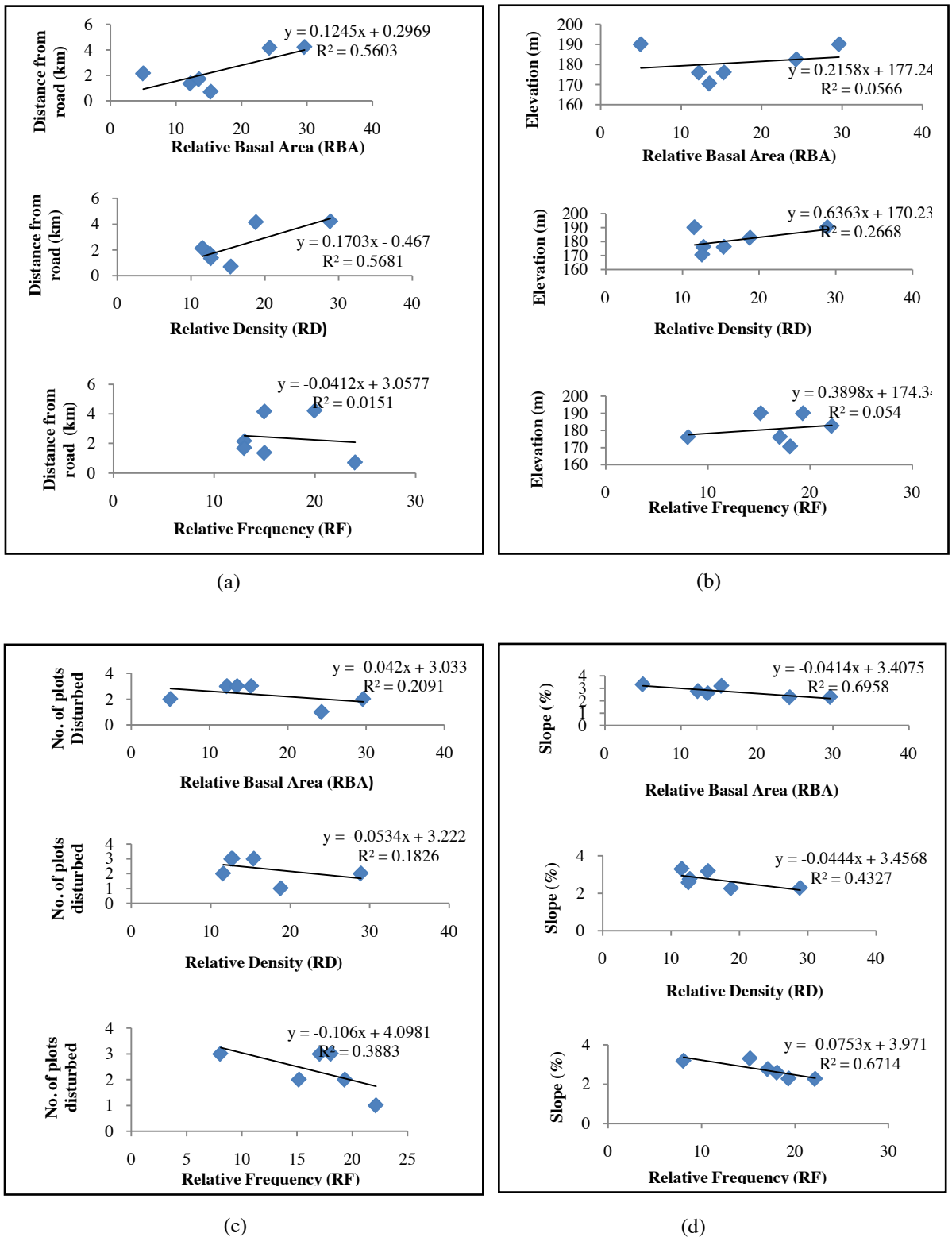

Figure 5. The correlation between plant species (RBA, RD, and RF) and environmental variables (distance from road (a), elevation (b), plot disturbed (c), and slope (d)) in Dong Na Tard Provincial Protected Area

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Received 2 August 2016
Accepted 5 September 2016

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