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Diversity of Vascular Plants in Deciduous Dipterocarp Forest at Thammasat University, Lampang Campus, Lampang Province, Thailand

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ABSTRACT

A study on the species diversity of vascular plants was carried out in the deciduous dipterocarp forest at Thammasat University, Lampang Campus, Lampang Province from November 2018 to October 2019. One hundred and twenty-one plant species, belonging to 45 families and 99 genera were documented, which included 16 exotic species. The three most commonly encountered families were Fabaceae (23 species), Malvaceae (9 species), and Convolvulaceae (8 species). The most diverse species were *Cratoxylum cochinchinense*, *C. formosum* subsp. *pruniflorum*, *Dipterocarpus obtusifolius*, *D. tuberculatus*, and *Garcinia nigrolineata*. A schematic profile of the vegetation with three layers was illustrated. Abundance, habits, and habitats were recorded. Flowering and fruiting phenology of each species was observed. Concerning species conservation, the remnant forests on the campus should be conserved and revitalized, as well as used as a natural learning center of the University, before the inhabiting species permanently disappear.

Keywords: Lampang; Phenology; Profile; Vascular plant; Vegetation

1. Introduction

Thailand is one of the countries most rich in biodiversity in Southeast Asia; this biodiversity variability differs between various parts of the country [1-3]. Thailand is situated in the center of tropical Asia, located in the Indo-Burmese hotspot in the north and the Sundaland hotspot in the south (two of the six most diverse and threatened biodiversity hotspots in the world) [4]. Northern Thailand is geographically characterized by several mountain ranges; it is mainly influenced by Indo-Burmese floristic elements. Typical forests are deciduous

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dipterocarp, mixed deciduous, dry evergreen, and montane (with two subtypes as lower and upper montane forests). Pines and rhododendrons are typical at higher elevations, while Dipterocarpaceae occurs at lower elevations [3].

There have been several studies on plant species diversity, floristic composition and vegetation, including establishing guidelines for forest management across the northern mountain ranges, for example at Doi Inthanon [5-9], Doi Suthep [10-14], Doi Chiang Dao [15-16], and Doi Khun Tan [17-18]. There are only a few studies, to date, of plant vegetation in the plain areas [19].

Lampang province is located in the middle of Northern Thailand. Topography is generally a plateau surrounded by high mountains with a river basin in the center of the province. The statistics from the Royal Forest Department in 2018 showed that Lampang province had forest areas covering 70.31% of the province, which is the third highest percentage after Mae Hong Son (85.99%), and Tak (72.10%). However, studies of plants in the province have mostly been conducted in the Forest National Park, Demonstration Forest, and arboretums, e.g., Chae Son National Park [20-24], Mae-Huad Demonstration Forest [25-26], and Hang Chat Arboretum [27]. Lampang province is rich in forest resources and supports a large variety of ecosystems, landscapes and habitats. However, most are also greatly threatened by human activity. The development of urban centers and agricultural expansion cause forest fragmentation of the plain areas. Thus, research on plant diversity and vegetation structure in these plain habitats located among fragmentation areas should be done urgently, before these forests and the information therein is permanently destroyed.

The Thammasat University, Lampang campus is located in Hang Chat District, Lampang Province. It is only 10 kilometers from the Hang Chat Arboretum and 30 kilometers from Doi Khun Tan National Park. It covers approximately 0.58 km^2 and the deciduous dipterocarp forest within has still been maintained. Thus, this area is one of the most suitable plain areas for studying plant species diversity and composition, particularly in this forest type.

Therefore, the present study aims to document the diversity of vascular plants in the deciduous dipterocarp forest at Thammasat University, Lampang Campus, Lampang Province.

2. Materials and Methods

2.1 Study site

2.1.1 Location

The diversity of vascular plants was investigated at Thammasat University, Lampang Campus, Hang Chat District, Lampang Province, located between latitude 18º19'1.6" N, and longitude 99º23'52.2" E (Fig. 1). It covers approximately 0.58 km^2 of land with deciduous dipterocarp forest scattered throughout. The present study was conducted in this forest type in the University, especially among four selected fragmentation sites (A-D) which encompass about 17,404.86 m^2, 6,545.75 m^2, 15,729.62 m^2 and 4,381.23 m^2, respectively (Fig. 2). The study area is around 30 km from Doi Khun Tan National Park, which is located in the Khun Tan mountain range. The topology of the study area is flat and at an elevation of 257-267 m msl. The soil is a loamy sand with a pH ranging around 5.6-7.5. The climate is tropical with three distinct seasons, namely Rainy or southwest monsoon season (mid-May to mid-October), Winter or northeast monsoon season (mid- October to mid-February), and Summer or pre- monsoon season (mid-February to mid-May).

2.2 Data collection

2.2.1 Floristic study

All plant specimens with reproductive organs were collected twice a month from November 2018 to October 2019, and all collections were prepared as described by Bridson & Forman [28].

The abundance of each species among selected sites was estimated by the percentage cover following Kent & Coker [29] and the percentage cover values were given average scores as follows: 5 = most abundant (76-100%), 4 = more abundant (51-75%), 3 = common (26-50%), 2 = few (6-25%), 1 = rare (1-5%), 0 = absent.

Sorensen's test is used to measure the species similarities and differences among the compared fragmentation sites based on their presence or absence and associations. A widely used similarity coefficient proposed by Sørensen [30] taken the form:

$$IS\,(\%) = 100 \times 2c/(a+b)$$

where *IS* (similarity index) is a percentage of the total number of taxa in both sites, with possible values ranging from 0 (none in common) to 100 (all taxa shared); *c* is the number of plant taxa common to both sites; *a* is the number of taxa in one site; *b* is the number of taxa in the other site.

Plant habits were observed and classified as follows: climber, herbaceous plant, undershrub, scandent shrub, shrub, tree, or (terrestrial/epiphyte) orchid. Plant natural habitats were also noted.

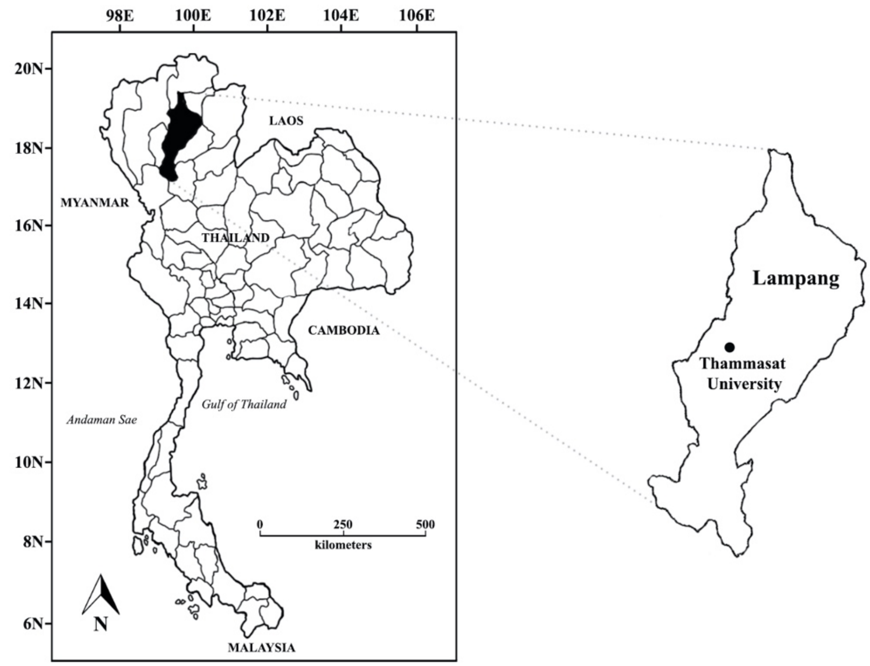


Fig. 1. Map of Thailand showing the location of Thammasat University, Lampang Campus in Hang Chat District, Lampang Province, Northern Thailand.

Fig. 2. Map showing the four selected fragmentation sites (A-D) in the deciduous dipterocarp forest at Thammasat University, Lampang Campus, Lampang Province.

Flowering and fruiting phenology of each species was documented through surveys, conducted twice a month at the same time of plant collections. The examination of reproductive organs in herbaceous plants, climbers, and the crowns of trees and shrubs (with aid of binoculars), were taken by a slow walk through the sites with frequent stops for clear observation.

2.2.2 Laboratory study

All plant collections were identified using keys and descriptions from taxonomic literature, e.g., Flora of Thailand, Flora of China, manuals, monographs, as well as research papers, including the appropriate taxonomic websites. Additionally, identifications were confirmed by comparing specimens with already known specimens from various herbaria. Scientific names and author abbreviations follow International Plant Names Index, The Plant List, and Tem Smitinand's Thai Plant Names, Revised Edition [31]. Voucher specimens have been deposited at the Biotechnology Laboratory of Thammasat University, Lampang Campus, Lampang Province.

2.2.3 Vegetation study

A rough sketch diagram of the characteristics and position of each plant species in the forest habitat was drawn in a field book. Then, a schematic diagram of a structural profile based on the vascular plant species in deciduous dipterocarp forest on the campus was illustrated.

3. Results and Discussion

3.1 Species richness and composition

One hundred and twenty-one species of vascular plants belonging to 99 genera, and 45 families in the deciduous dipterocarp forest on the campus were identified and listed in Table 1. Some species are shown in Fig. 3. One of the most diverse families in the present study is Fabaceae (23 species). The other commonly encountered families were Malvaceae (9 species), Convolvulaceae (8 species), Lamiaceae and Apocynaceae (7 species each), and Asteraceae and Rubiaceae (5 species each). *Dipterocarpus obtusifolius* and *D. tuberculatus*, which represented the only two species of Dipterocarpaceae, are regarded as important tree components of the forest followed by *Cratoxylum cochinchinense*.

Table 1. List of vascular plants occurring in deciduous dipterocarp forest at Thammasat University, Lampang Campus, Lampang Province.

Family	Scientific name	Habit[1]	Fragmentation sites[2]			
			A	B	C	D
Acanthaceae	*Andrographis paniculata* (Burm.f.) Wall. ex Nees	H	1	0	0	0
	Asystasia gangetica (L.) T. Anderson	H	2	1	1	0
	Barleria cristata L.	US	0	1	0	0
Amaranthaceae	*Alternanthera sessilis* (L.) R.Br. ex DC.	H	0	1	0	1
Anacardiaceae	*Anacardium occidentale* L.	ExT	0	0	3	1
Annonaceae	*Ellipeiopsis cherrevensis* (Pierre ex Finet & Gagnep.) R.E.Fr.	US	1	0	2	0
Apocynaceae	*Amphineurion marginatum* (Roxb.) D.J. Middleton	C	0	1	0	0
	Holarrhena pubescens Wall. ex G. Don	S	0	0	1	3
	Hoya kerrii Craib	C	1	0	0	0
	Ichnocarpus frutescens (L.) W.T. Aiton	C	2	2	1	3
	Streptocaulon juventas (Lour.) Merr.	C	0	0	3	1
	Telosma pallida (Roxb.) Craib	C	1	0	0	1
	Toxocarpus villosus (Blume) Decne.	C	2	2	0	0
Aristolochiaceae	*Aristolochia taga*la Cham.	C	1	0	1	0
Asteraceae	*Bidens pilosa* L.	ExH	2	1	0	3
	Chromolaena odorata (L.) R.M. King & H. Rob.	ExH	2	3	1	3
	Mikania micrantha Kunth	C	3	3	3	3
	Praxelis clematidea (Griseb.) R.M. King & H. Rob.	ExH	2	0	2	1
	Tridax procumbens L.	ExH	2	2	0	2
Capparaceae	*Capparis sepiaria* L.	C	0	0	1	0
	C. zeylanica L.	C	0	0	1	0
Chrysobalanaceae	*Parinari anamensis* Hance	T	2	0	1	0
Cleomaceae	*Cleome rutidosperma* DC.	H	0	0	1	2
Clusiaceae	*Garcinia nigrolineata* Planch. ex T. Anderson	T	4	1	0	0
	Mammea siamensis (Miq.) T. Anderson	T	1	0	0	0
Commelinaceae	*Commelina benghalensis* L.	H	1	1	0	0
	Murdannia gigantea (Vahl) G. Brückn.	H	0	0	2	0
	M. nudiflora (L.) Brenan	H	1	0	0	0
Connaraceae	*Ellipanthus tomentosus* Kurz	T	0	0	1	0
Convolvulaceae	*Argyreia osyrensis* (Roth) Choisy	ScanS	0	1	0	1
	Evolvulus alsinoides var. *decumbens* (R.Br.) Ooststr.	H	1	0	0	0
	E. nummularius (L.) L.	H	1	1	0	1
	Ipomoea obscura (L.) Ker Gawl.	C	1	0	0	1
	I. pes-tigridis L.	C	2	0	0	1
	Merremia bambusetorum Kerr	C	0	0	0	1
	M. hirta (L.) Merr.	H	1	0	0	0
	M. vitifolia (Burm.f.) Hallier f.	C	0	0	1	0

Family	Scientific name	Habit[1]	Fragmentation sites[2]			
			A	B	C	D
Cucurbitaceae	*Momordica charantia* L.	C	0	0	0	1
	Solena heterophylla Lour.	C	0	0	1	0
Dilleniaceae	*Dillenia aurea* Sm.	T	1	1	2	0
	D. obovata (Blume) Hoogland	T	1	0	2	0
Diptorocarpaceae	*Dipterocarpus obtusifolius* Teijsm. ex Miq.	T	4	3	4	2
	D. tuberculatus Roxb.	T	2	1	4	2
Ebenaceae	*Diospyros ehretioides* Wall. ex G. Don	T	2	0	2	0
Erythroxylaceae	*Erythroxylum cuneatum* (Miq.) Kurz	S	0	0	1	0
Euphorbiaceae	*Euphorbia heterophylla* L.	ExH	1	0	0	0
	E. hirta L.	H	1	1	1	1
Fabaceae	*Aeschynomene americana* L.	ExUS	1	0	0	0
	Butea monosperma (Lam.) Taub.	T	0	0	0	1
	Caesalpinia furfuracea (Prain) Hattink	C	1	0	0	0
	Calopogonium mucunoides Desv.	C	0	0	1	0
	Centrosema pubescens Benth.	ExC	3	3	1	3
	Chamaecrista pumila (Lam.) K. Larsen	H	1	0	0	0
	Crotalaria alata Buch.-Ham. ex D. Don	US	1	0	0	0
	C. incana L.	ExH	1	0	1	0
	Desmodium triflorum (L.) DC.	H	1	0	0	1
	D. velutinum (Willd.) DC. subsp. *velutinum*	US	2	0	1	0
	Dunbaria bella Prian	C	0	2	0	0
	D. punctata (Wight & Arn.) Benth.	C	1	0	1	0
	Flemingia stricta Roxb. ex W.T. Aiton	S	2	0	3	1
	Indigofera cassioides Rottler ex DC.	S	2	0	0	0
	I. hirsuta L.	US	2	0	0	2
	Mimosa diplotricha C. Wright ex. Sauvalle	ExH	2	0	0	2
	M. pudica L.	ExH	1	1	0	1
	Phyllodium pulchellum (L.) Desv.	S	1	0	1	0
	Pueraria phaseoloides (Roxb.) Benth.	C	1	0	0	0
	Senna hirsuta (L.) H.S. Irwin & Barneby	ExUS	1	0	0	0
	Sindora siamensis Teijsm. ex Miq. var. *siamensis*	T	1	0	0	0
	Stylosanthes humilis Humb., Bonpl. & Kunth	ExH	1	0	2	0
	Tephrosia vestita Vogel	US	1	0	2	0
Hypericaceae	*Cratoxylum cochinchinense* (Lour.) Blume	T	3	3	3	1
	C. formosum (Jacq.) Benth. & Hook.f. ex Dyer subsp. *pruniflorum* (Kurz) Gogelein	T	2	4	2	0
Lamiaceae	*Clerodendrum paniculatum* L.	S	0	0	0	1
	Hyptis brevipes Poit.	S	1	0	0	0
	H. suaveolens (L.) Poit.	S	2	0	2	0
	Leucas aspera (Willd.) Link	H	1	0	0	0
	L. decemdentata (Willd.) Sm.	H	0	0	1	0
	Premna herbacea Roxb.	US	0	1	0	0
	Rotheca serrata (L.) Steane & Mabb.	S	1	1	0	1
Leeaceae	*Leea indica* (Burm.f.) Merr.	S	1	0	1	0
Linderniaceae	*Lindernia ciliata* (Colsm.) Pennell	H	1	0	0	0
	L. crustacea (L.) F. Muell. var. *crustacea*	H	1	0	0	1
Malvaceae	*Corchorus aestuans* L.	H	0	1	0	0
	Helicteres lanceolata A.DC. var. *gagnepainiana* (Craib) Phengklai	S	0	1	0	0
	H. lanceolata A.DC. var. *lanceolata*	S	0	1	0	0

Family	Scientific name	Habit[1]	Fragmentation sites[2]			
			A	B	C	D
Malvaceae	*Sida acuta* Burm.f.	US	1	0	0	0
	S. cordata (Burm.f.) Borss. Waalk.	US	1	0	0	0
	S. cordifolia L.	US	2	0	2	0
	Triumfetta pilosa Roth	H	2	0	2	2
	Urena rigida Wall. ex. Mast.	US	1	0	2	0
	Waltheria indica L.	US	1	0	0	0
Melastomataceae	*Memecylon scutellatum* (Lour.) Hook. & Arn. var. *scutellatum*	S	2	1	3	0
Ochnaceae	*Ochna integerrima* (Lour.) Merr.	S	2	0	3	0
Olacaceae	*Olax psittacorum* (Lam.) Vahl	C	0	0	1	0
Oleaceae	*Jasminum elongatum* (P.J. Bergius) Willd.	ScanS	1	0	0	0
Onagraceae	*Ludwigia hyssopifolia* (G. Don) Exell	H	2	0	0	1
Orchidaceae	*Eulophia graminea* Lindl.	TerO	0	1	0	0
	Geodorum recurvum (Roxb.) Alston	TerO	0	0	1	0
Oxalidaceae	*Biophytum umbraculum* Welw.	H	0	0	2	0
Passifloraceae	*Passiflora foetida* L.	ExC	0	0	1	1
Phyllanthaceae	*Antidesma ghaesembilla* Gaertn.	S	1	0	0	0
	Phyllanthus urinaria L.	H	1	0	0	0
	P. virgatus G. Forst.	H	2	2	0	0
	Sauropus androgynus (L.) Merr.	S	0	1	0	0
Polygalaceae	*Polygala elongata* Klein ex Willd.	H	2	0	1	0
Rhamnaceae	*Ventilago denticulata* Willd.	C	0	0	1	1
	Ziziphus oenoplia (L.) Mill. var. *oenoplia*	C	1	0	0	1
Rubiaceae	*Catunaregam spathulifolia* Tirveng.	T	1	0	0	0
	Oldenlandia corymbosa L.	H	0	0	0	2
	Paederia pilifera Hook.f.	C	1	0	0	1
	Spermacoce ocymoides Burm.f.	ExH	1	1	0	1
	Vangueria pubescens Kurz	US	0	1	1	0
Rutaceae	*Clausena excavata* Burm.f.	S	1	0	1	0
Salicaceae	*Casearia grewiifolia* Vent.	T	0	0	2	0
Simaroubaceae	*Brucea javanica* (L.) Merr.	S	2	0	2	1
	Eurycoma longifolia Jack	S	1	1	2	1
	Harrisonia perforata (Blanco) Merr.	ScanS	1	0	0	0
Smilacaceae	*Smilax luzonensis* C. Presl	C	0	0	1	0
Strychnaceae	*Strychnos nux-blanda* A.W. Hill	T	2	0	1	0
Thunbergiaceae	*Thunbergia fragrans* Roxb.	C	1	0	0	0
Verbenaceae	*Lantana camara* L.	ExC	2	1	0	0

[1]Habit: T = Tree, S = Shrub, ScanS = Scandent shrub, US = Undershrub, H = Herbaceous plant, C = Climber, TerO = Terrestrial orchid, Ex = Exotic plant.
[2]The abundance of each species among selected fragmentation sites: 5 = most abundant (76-100%), 4 = more abundant (51-75%), 3 = common (26-50%), 2 = few (6-25%), 1 = rare (1-5%), 0 = absent.

Fig. 3. Some vascular plant species occurring in deciduous dipterocarp forest at Thammasat University, Lampang Campus, Lampang Province. A: *Urena rigida*; B: *Toxocarpus villosus*; C: *Merremia bambusetorum*; D: *Mammea siamensis*; E: *Dillenia obovata*; F: *Diospyros ehretioides*; G: *Butea monosperma*; H: *Cratoxylum cochinchinense*; I: *Cratoxylum formosum* subsp. *pruniflorum*; J: *Indigofera hirsuta*; K: *Ellipanthus tomentosus*; L: *Vangueria pubescens*; M: *Holarrhena pubescens*; N: *Sida cordifolia*; O: *Commelina benghalensis*. Photographed by V. Keawnunchai.

Among the 121 species, the highest number of species was found in study site A (84 species, 69.42%), followed by study site C (57 species, 47.11%), study site D (42 species, 34.71%), and finally study site B (36 species, 29.75%). These results are perhaps due to the differences in study site size, as larger areas usually bear more variety of their microhabitat than smaller ones (Fig. 2). Among these taxa, 9 species occurred in all study sites, i.e., *Centrosema pubescens*, *Chromolaena odorata*, *Cratoxylum cochinchinense*, *Dipterocarpus obtusifolius*, *D. tuberculatus*, *Euphorbia hirta*, *Eurycoma* *longifolia*, *Ichnocarpus frutescens*, and *Mikania micrantha.*

Consideration of the shared taxa among study sites was done with similarity indices, used expansively for niche overlap as well as in community similarity. The similarity index value for study sites A and C was highest (45.39%), followed by sites A and D (44.44%), sites B and D (43.59%), sites A and B (40%), sites C and D (38.38%), and sites B and C (30.11%). This is possibly because study site A is more similar in size to study site C and has a high microhabitat heterogeneity to study site C, more so than the others. According to Ellenberg [32], vegetation of all of these sites belong to the same community because the index values were higher than 25% , and they were considered as having moderate similarity by Sørensen coefficients, in the range of 26-50% [33].

Based on the vascular plant species in the present study, 21 species are similar to plant species found in Hang Chat Arboretum [27]. Hang Chat Arboretum is a forest protected area that covers approximately 0.32 km^2, located only about 10 kilometers from the University. Seventy plant species had been reported there. This shows that the forest fragments on the campus still contain high plant diversity. In comparison, the disturbed deciduous dipterocarp forest in the plain area at Kasetsart University, Chalermphrakiat Sakonnakhon Province Campus, 65 plant species were documented [34]. Dipterocarpaceae was reported to be an important family for forest structure, similar to the present study. However, the two main species, *Buchanania lanzan* Spreng and *Aporosa villosa* (Wall. ex Lindl.) Baill. , commonly found there as middle canopy trees, did not appear in the present study. This is perhaps due to these two species usually being located in xeric and disturbed areas [34]. Therefore, it can be confirmed that the small remnants of deciduous dipterocarp forest on the campus are less disturbed areas, which have the potential for species conservation.

This forest was classified as a deciduous dipterocarp forest following Santisuk [35], based on the species composition. In the present study, the forest is composed of trees with straight stems, sparsely distributed, and crown cover that is more or less open on three layers (Fig. 4). The top canopy is over 10 m high, with the dominant species being *Dipterocarpus obtusifolius*, *D. tuberculatus*, and *Sindora siamensis* var. *siamensis*. The middle canopy is around 5-10 m high, with important species being *Garcinia nigrolineata*, *Anacardium occidentale*, *Parinari anamensis*, *Dillenia aurea*, and *Strychnos nux-blanda*. The shrub canopy is less than 5 m high, which consists of *Cratoxylum cochinchinense*, *C. formosum* subsp. *pruniflorum*, *Diospyros ehretioides*, and *Memecylon scutellatum* var. *scutellatum*. The understory and the forest floor are generally composed of tree saplings, climbers, and common species such as *Ellipanthus tomentosus*, *Flemingia stricta*, *Holarrhena pubescens*, *Indigofera cassioides*, *I. hirsuta*, *Ochna integerrima*, *Phyllodium pulchellum*, *Sida* spp. , and *Urena rigida crustacea* var. *crustacea*, *Murdannia gigantea*, *Spermacoce ocymoides,* and *Stylosanthes humilis*.

3.2 Habit and habitat diversity

Among the vascular taxa in the present study, the most abundant habit is herbaceous plants (35 species, 28.93%), followed by climbers (30 species, 24.79%), shrubs (19 species, 15.70%), trees (17 species, 14.05%), undershrubs (15 species, 12.40%), scandent shrubs (3 species, 2.48%), and terrestrial orchids (2 species, 1.65%) (Fig. 5). Among these taxa, 16 species (13.22%) are exotic species.

KEY: **1**. *Urena rigida* Wall. ex. Mast.; **2**. *Ichnocarpus frutescens* (L.) W.T. Aiton; **3**. *Indigofera cassioides* Rottler ex DC.; **4**. *Indigofera hirsuta* L.; **5**. *Flemingia stricta* Roxb. ex W.T. Aiton; **6**. *Toxocarpus villosus* (Blume) Decne.; **7**. *Centrosema pubescens* Benth.; **8**. *Sida cordifolia* L.; **9**. *Ipomoea obscura* (L.) Ker Gawl.; **10**. *Eurycoma longifolia* Jack; **11**. *Ellipeiopsis cherrevensis* (Pierre ex Finet & Gagnep.) R.E. Fr.; **12**. *Phyllanthus virgatus* G. Forst.; **13**. *Murdannia gigantea* (Vahl) G. Brückn.; **14**. *Vangueria pubescens* Kurz.; **15**. *Triumfetta pilosa* Roth; **16**. *Merremia bambusetorum* Kerr; **17**. *Argyreia osyrensis* (Roth) Choisy; **18**. *Eulophia graminea* Lindl.; **19**. *Clerodendrum paniculatum* L.; **20**. *Brucea javanica* (L.) Merr.; **21**. *Ziziphus oenoplia* (L.) Mill. var. *oenoplia*; **22**. *Ochna integerrima* (Lour.) Merr.; **23**. *Chromolaena odorata* (L.) R.M. King & H. Rob.; **24**. *Cratoxylum formosum* (Jacq.) Benth. & Hook.f. ex Dyer subsp. *pruniflorum* (Kurz) Gogelein; **25**. *Cratoxylum cochinchinense* (Lour.) Blume; **26**. *Garcinia nigrolineata* Planch. ex T. Anderson; **27**. *Parinari anamensis* Hance; **28**. *Anacardium occidentale* L.; **29**. *Dillenia aurea* Sm.; **30**. *Dillenia obovata* (Blume) Hoogland; **31**. *Memecylon scutellatum* (Lour.) Hook. & Arn. var. *scutellatum*; **32**. *Strychnos nux-blanda* A.W. Hill; **33**. *Sindora siamensis* Teijsm. ex Miq. var. *siamensis*; **34**. *Dipterocarpus tuberculatus* Roxb.; **35**. *Dipterocarpus obtusifolius* Teijsm. ex Miq.

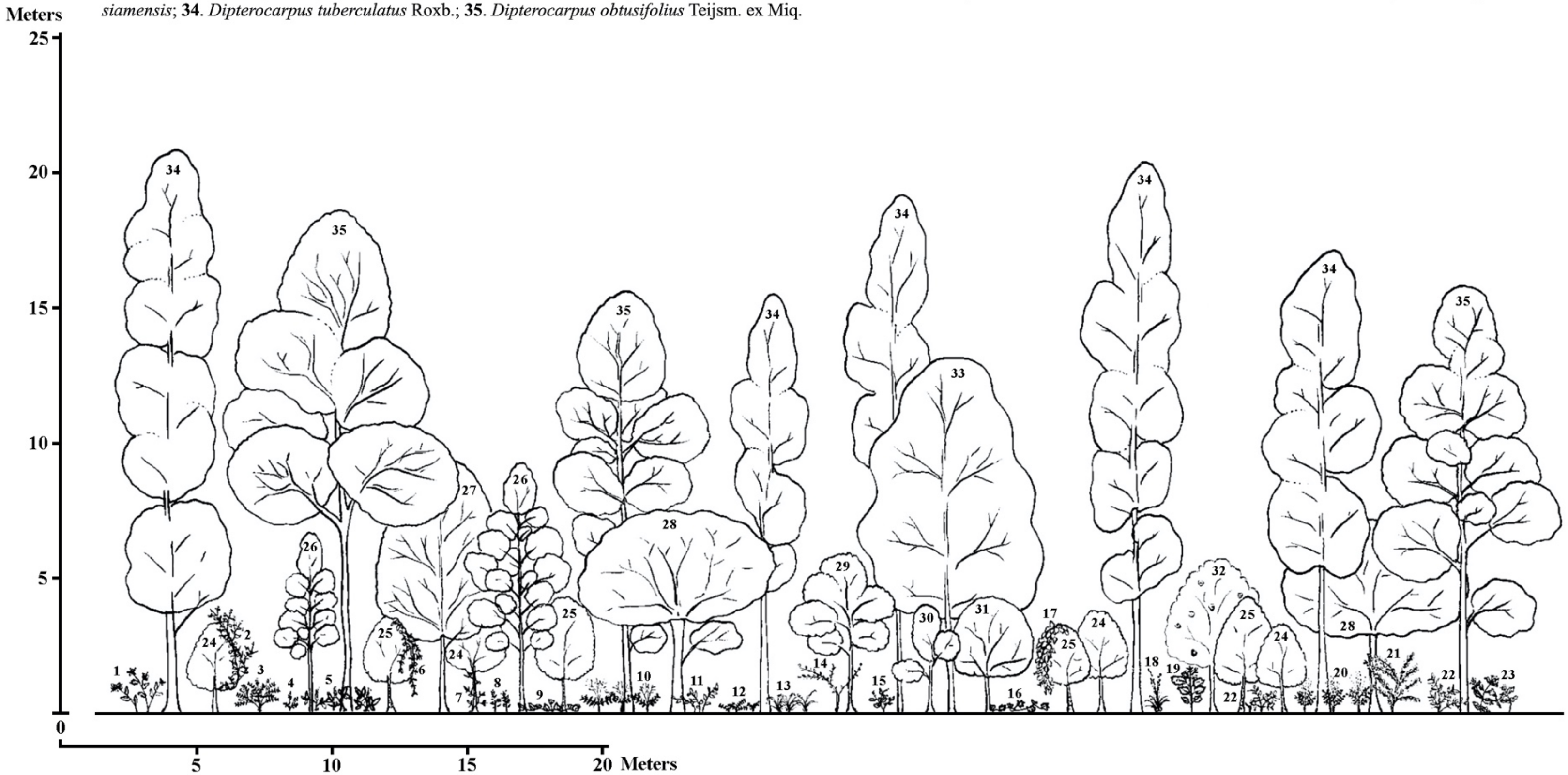


Fig. 4. Schematic diagram of a structural profile showing the vegetation of deciduous dipterocarp forest at Thammasat University, Lampang Campus, Lampang Province.

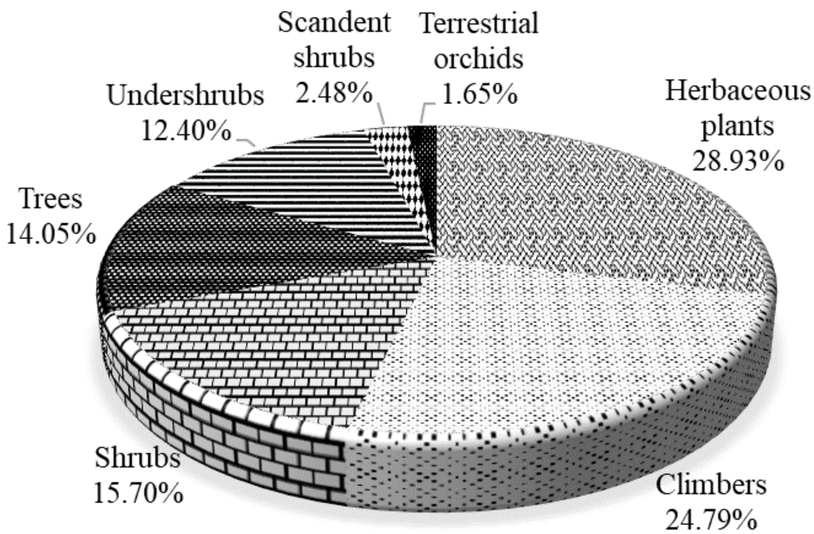


Fig. 5. Pie chart showing the percentage of vascular plant habits in deciduous dipterocarp forest at Thammasat University, Lampang Campus, Lampang Province.

Herbaceous plant was the most abundant habit found in the present study, probably due to the niche variability among the different fragmentation sites. Several species of herbaceous plants usually occupy wet loamy sand soil and fully exposed areas, e.g., *Alternanthera sessilis*, *Desmodium triflorum*, *Evolvulus alsinoides* var. *decumbens*, *Phyllanthus virgatus*, *Polygala elongate,* and *Sauropus androgynus*. Whereas some prefer more shaded areas, e.g., *Crotalaria incana*, *Evolvulus nummularius*, *Leucas aspera*, *Lindernia Mikania micrantha*, *Centrosema pubescens,* and *Ichnocarpus frutescens* are the most common climber species. The climbers usually climb up to the top of the plant canopies; however, some of them climb on the ground, especially in open areas. Therefore, climbing plants are considered the greatest sun-loving plants in the present study, e.g., *Dunbaria punctata*, *Ipomoea obscura*, *I. pes-tigridis, Merremia bambusetorum*, *M. hirta*, *M. vitifolia*, *Streptocaulon juventas,* and *Toxocarpus villosus*.

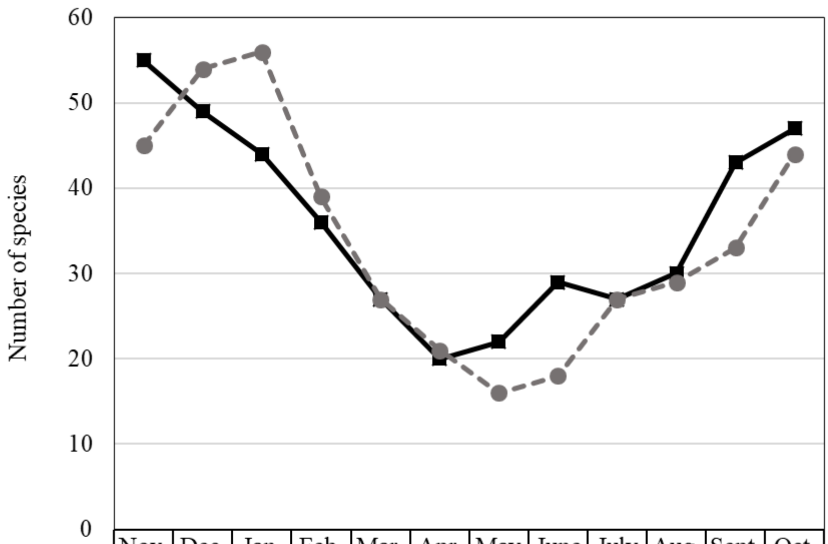
Within this survey, the most diverse shrubs and trees species are *Cratoxylum cochinchinense*, *C. formosum* subsp. *pruniflorum*, *Dipterocarpus obtusifolius*, *D. Tuberculatus,* and *Garcinia nigrolineata*.

Three species of scandent shrub, i. e., *Argyreia osyrensis*, *Harrisonia perforate,* and *Jasminum elongatum* are found in the present study. Considering terrestrial orchids, there were only two populations of *Eulophia graminea,* and one individual of *Geodorum recurvum* on the campus. This result might be due to a lack of appropriate pollinators.

In addition, there are several species that typically colonize at the forest fringes, especially tree species including *Cratoxylum cochinchinense, C. formosum* subsp. *pruniflorum*, and *Sindora siamensis* var. *siamensis*, shrub species including *Brucea* *javanica*, *Memecylon scutellatum* var. *scutellatum*, *Senna hirsuta*, and *Sida acuta*, herbaceous species including *Asystasia gangetica*, *Bidens pilosa*, *Crotalaria incana*, *Mikania micrantha*, *Mimosa pudica*, *Praxelis clematidea*, *Tridax procumbens*, and climbers including *Ipomoea obscura*, *I. pes-tigridis*, *Merremia bambusetorum*, *M. hirta,* and *M. vitifolia*. Most of the exotic species are obviously present in this habitat. The abundance of herbaceous plants and climbers at the fringes is likely due to the high light availability and humidity along the borders [36]. However, the construction of a new stadium and central cafeteria on the campus in 2018-2019 had caused the loss of some plant species, i.e., *Crotalaria incana*, *Senna hirsuta*, and *Sida acuta* from this habitat. It is noteworthy that the occurrence of forest fires every summer might have had a direct negative impact on plant diversity along the fringes as well.

3.3 Flowering and fruiting phenology

The periods of flowering and fruiting of all 121 vascular plant species fluctuate year-round (Fig. 6). However, the highest species richness for both flowering and fruiting periods was in the winter season, particularly in November and January, respectively. The most abundant flowering month was November (55 species, 45.45%), followed by December (49 species, 40.50%) and then October (47 species, 38.84%). The lowest amount of flowering was April (20 species, 16.53%). Number of fruiting species was the most abundant in January (56 species, 46.28%), followed by December (54 species, 44. 63%) and then November (45 species, 37.19%). Whereas, the lowest amount of fruiting species was May (16 species, 13.22%).



	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Flowering	55	49	44	36	27	20	22	29	27	30	43	47
Fruiting	45	54	56	39	27	21	16	18	27	29	33	44

Fig. 6. Seasonal variation of flowering and fruiting periods of vascular plants in deciduous dipterocarp forest at Thammasat University, Lampang Campus, Lampang Province.

These results show that the flowering and fruiting periods vary from species to species. Vascular plants in the present study typically produced flowers and fruits in the late rainy season and winter, especially in October to January. Then, the number of flowering and fruiting species decreased from the late winter to dry season until increased rainfall during the rainy season, at which point the flowering and fruiting species gradually rose up again. Even though many plant species produce flowers and fruits in the rainy and winter seasons, some species formed flowers and fruits only in the dry season, e.g., *Capparis sepiaria*, *C. zeylanica*, *Dillenia aurea*, *Ellipanthus tomentosus*, *Harrisonia perforata*, *Holarrhena pubescens*, *Ochna integerrima*, *Smilax luzonensis*, etc.

The number of fruiting species was associated with the number of flowering species. These results show that the most abundant flowering month was November, then the highest fruiting occurred later in December and January. This is probably due to these flowering plants being pollinated and then going on to produce fruit in the following months.

November had the highest amount of flowers blooming, perhaps because of the season changing. Seasonal changes can affect many conditions such as precipitation, light intensity and temperature. The changing of season from rainy to winter leads to diminished rainfall, lower light intensity, and falling temperatures. These environmental factors produce the overlapping conditions suitable for numerous plant species to produce flowers. This season changing not only influences the flowering and fruiting of plants, but is also key to the existence of some plants. In xeric conditions, several herbaceous plants struggle to survive, consequently the number of flowering plants decreases during the dry season. Unsurprisingly, some exotic species produce flowers and fruits all year round, i.e., *Bidens pilosa*, *Praxelis clematidea*, and *Tridax procumbens*.

Comparing to other studies in seasonally dry tropical forests, flowering is often observed to change during the late dry to the early wet season [37-40], which is similar to southern Thailand. There, flowering occurs at the end of the dry season, and the peak of fruiting occurs early in the wet season [41-42]. However, those results differ from the present study, which may be due to a difference in local seasonal changes, elevation and species composition.

3.4 Adaptation strategies

The deciduous dipterocarp forest on the campus is an open canopy area. It is exposed to long dry periods with high temperatures during daytime, particularly in the summer. This means that vascular plants in the area are exposed to water stress for a period of the year. Thus, plants have had to evolve adaptations for better survival and reproduction.

Generally, plant adaptations for drought stress can be divided into three categories: drought escape, drought avoidance and drought tolerance [43-44]. Drought escape is the ability of plants to complete their life cycles before facing drought. Drought avoidance is the ability to maintain higher water content in tissue, despite the water content in the soil being reduced. From field investigations, these two strategies are known to have been adopted by herbaceous plants, especially annual plants. There are some plant species that disappear from the study area during the dry period, e.g., *Corchorus aestuans*, *Lindernia ciliata*, *L. crustacea* var. *crustacea*, *Sida* spp., etc. This may be a result of decreasing occurrences of species in the late winter and summer. Drought tolerance is the ability of plants to bear low water content in their tissue through adaptive traits. In this forest, plants have adopted this strategy through various processes, for example, decreasing the transpiration rate by defoliation in *Butea* *monosperma*, *Dipterocarpus obtusifolius* and *D. tuberculatus*, succulence in leaves in *Hoya kerrii* and a thick waxy cuticle in *Garcinia nigrolineata*, *Memecylon scutellatum* var. *scutellatum,* and *Smilax luzonensis*.

4. Conclusion

In summary, 121 vascular plant species belonging to 45 families and 99 genera have been found in the deciduous dipterocarp forests on the campus. The results indicate that the forest fragments in the University have the ability to maintain species diversity. However, the biodiversity loss based on both anthropogenic and fire disturbances are concerning. The rapid growth of the University within recent years and severe fires occurring every summer might cause the loss of important native species. Therefore, the present study is not only filling the gaps in knowledge on local species diversity in the plain deciduous dipterocarp forest, but is also providing essential information for species conservation, and furthermore, improving the value of these small forest remnants by allowing them to serve as a source of education and inspiration for the University and beyond.

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