

The floodplain vegetation of the Trang River basin, peninsular Thailand: the threatened remnants of the freshwater swamp vegetation

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ABSTRACT. The study of the scattered remnants of the floodplain vegetation in the Trang River basin, peninsular Thailand was carried out from November 2008 to January 2010. One hundred and sixty species of vascular plants were recorded. The five most common families were Cyperaceae (22 species), Poaceae (12 species), Rubiaceae (10 species), Fabaceae and Phyllanthaceae (9 species each). Based on floristic compositions, nine association types were described. The spatial variation and differences in habitat distribution among these associations are explained by differences in successional stages due to the history of land uses and water regime. Moreover, the expected vegetation of the floodplain areas, reconstructed from the existing remnants left as isolated fragmentations, was proposed.

KEY WORDS: Floodplain vegetation, peninsular Thailand.

INTRODUCTION

Floodplains are flat lands adjacent to streams or rivers, subjected to periodic flooding (Finlayson & Moser, 1991). Due to this periodic flooding, plant species inhabiting these environments need to have special modifications which enable either tolerance of these changes, through physiology or morphology, and/or avoidance through life history traits (Capon, 2005). Thus, the floodplain areas are unique and interesting habitats in terms of flora, plant morphological/physiological adaptations and vegetation structures, as well as vegetation dynamics. This floodplain vegetation, one of the least explored wetlands in Thailand, is not only botanically important, but also serves as an important habitat for both terrestrial and aquatic fauna.

Trang River is a short river (123 km length) near the west coast of peninsular Thailand. This river is interesting, because it is the only river in the western coast of peninsular Thailand that runs through a large basin. This basin is naturally flooded annually. At the western coast of Thailand, floodplains are uncommon due to the generally steep gradient of the surface through which major rivers flow. A larger floodplain can be found along Trang River only.

In spite of its biological importance there is scarce information on the plant species composition of the floodplain areas in peninsular Thailand. Besides, the floodplain vegetation in peninsular Thailand is among the most threatened habitats as it is subjected to human disturbances such as irrigation projects, agriculture, tourism, etc. Therefore, this study is aimed at giving an account of the floristic composition of plant communities in the floodplain areas in peninsular Thailand. Remnant patches of floodplain vegetation are very interesting as all of them have never been inventoried. The study on vegetation structure and floristic composition of this unique wetland vegetation of the floodplains along the Trang River basin, west coast of peninsular Thailand is thus necessarily and urgently needed before this vegetation disappears.

MATERIAL AND METHODS

Study Area and Study Plots

Field surveys were conducted in the floodplain areas of the Trang River, Trang province, located near the west coast of peninsular Thailand (7° 30' 13"– 7° 34' 20" N and 99° 31' 40" – 99° 35' 40" E).

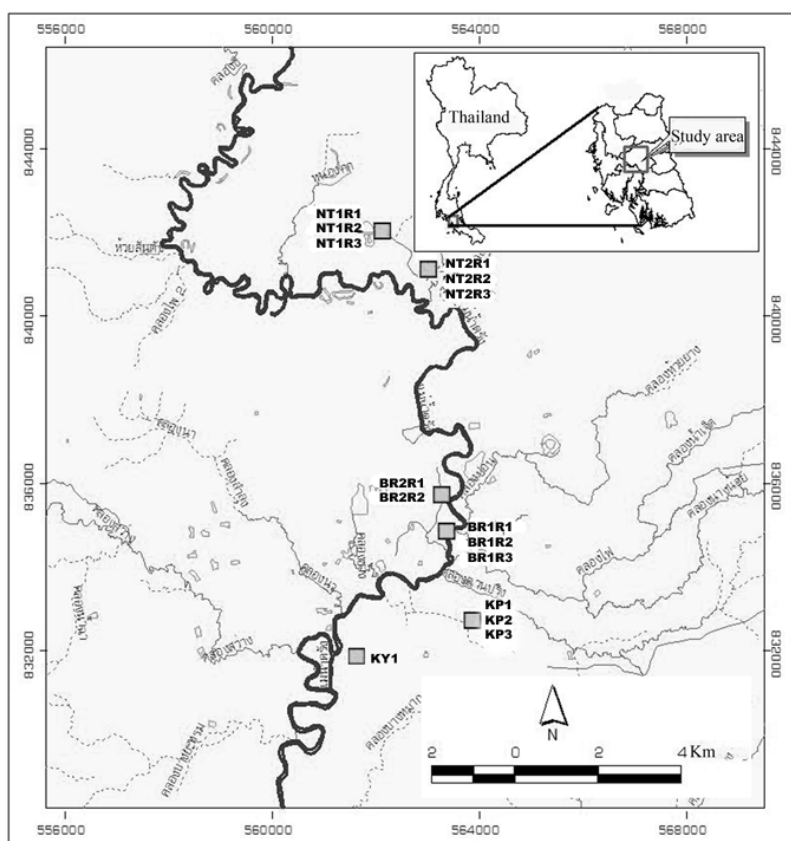
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The climate of the area is tropical monsoon (Am) according to Köppen's classification (Kottek et al., 2006) with a mean temperature of 27.4 °C and an average annual rainfall of 2,187.8 mm (during 1961–1990). The heaviest rainfall is in September with average monthly rainfall of about 352 mm (Thai Meteorological Department, 2010). The relative humidity ranges from 62% in the dry season to 96% in wet season (Thai Marine Meteorological Center, 2010). The mean annual runoff is 2,203.42 million m³ (during 2005–2009) and is the highest during October to December and lowest during January to April (Hydrology and Water Management Center of Southern Region, 2011).

Since the drainage area of the Trang River basin is rather small and narrow, and almost all of the floodplain vegetation has been modified by various human activities, only some isolated patches of remnant vegetation have been left near the river

channel. The most remote study plot is only around two kilometers distant from the river bank (Map 1). This is not far enough to reach both the lateral gradient as well as the flood gradient due to the increased elevation from the main channel to the upland areas. Thus, the differences in depth, duration, and frequency of the flood regime among the study sites vary due to the existing topographic relief modified by human activities, i.e., landfills for various agricultural purposes (oil palm and rice fields, etc.).

Fifteen study plots were selected within the remnant patches of the floodplain vegetation (Map 1). The characteristics of each study plot are shown in Table 1. Due to the lack of a proper hydrological station in the Trang River basin, the flood durations in the present study were estimated by field observations.



Map 1. The Trang River basin showing locations of the study plots.

Data collection and vegetation classification

Study plots were selected in accordance with the Braun-Branquet approach (Kent & Coker, 1994) within the remnants of the “natural” floodplain vegetation and inundation range from rarely to permanently flooded (Table 1). In this case, according to van der Maarel (2005) the term “natural vegetation” means a system of largely spontaneous growing plants they can be both “primary” as well as “secondary” vegetations. Each selected plot was assumed as a representative area of a particular community type which is distinctly separated from the surrounding vegetation in term of floristic composition and structure. One 50 x 50 m plot, six 20 x 20 m plots and five 10 x 10 m plots were used as woodland plot (canopy > 15 m high), shrubland plots and grassland plots respectively, except for BR1R3, BR2R2 and NT2R1 plots, which are scattered termite hills and have an area of less than 5 x 5 m each.

Data collection was carried out once a month from November 2008 to January 2010 in order

to cover all seasons, fluctuations of rain-fall and inundation. All vascular plant species within each study plot were recorded in order to make a complete species list. Abundance was measured by cover-abundance estimation using the Domin-Krajina scale (Kent & Coker, 1994). Cluster analysis was performed with PC-ORD software version 5.19 (McCune & Mefford, 2006) using Euclidean distance measure and Ward’s method (Ward, 1963) as have been recommended by Kent & Coker (1994) in order to classify the similar study plots into groups. Each of these groups would then be characterized as a given association type named in accordance with the dominant species and physiognomy.

Plant family classification of angiosperms follows APGIII (Angiosperm Phylogeny Group, 2009). Names of major clades within the angiosperms followed Simpson (2010). All voucher specimens collected were deposited at Prince of Songkla University Herbarium (PSU).

Table 1. Locations of study plots and their habitat characteristic along the Trang River floodplain.

Study plot reference number	Map reference	Altitude (m)	Site description	Flood duration time	Water depth (cm)
BR1R1	N 7° 33' 16" E 99° 34' 45"	10	Old rice field	Sept.–Nov.	ca 30
BR1R2	N 7° 33' 16" E 99° 34' 45"	10	Old rice field	April–Nov.	ca 30
BR1R3	N 7° 33' 16" E 99° 34' 45"	10	Termite hills	rarely	
BR2R1	N 7° 33' 35" E 99° 34' 45"	11	Old rice field	Aug.–Nov.	ca 30
BR2R2	N 7° 33' 35" E 99° 34' 45"	11	Termite hills	rarely	
NT2R3	N 7° 35' 06" E 99° 35' 20"	12	Old rice field	April–Nov.	ca 30
KP1	N 7° 32' 14" E 99° 34' 51"	15	Disturbed forest	Sept.–Nov.	ca 30
KP2	N 7° 32' 11" E 99° 37' 52"	15	Chopped	Sept.–Nov.	ca 30
KP3	N 7° 32' 11" E 99° 37' 52"	15	Primary vegetation	Sept.–Nov.	up to 100
KY1	N 7° 31' 35" E 99° 33' 14"	9	Old rice field	Throughout the year	up to 100
NT1R1	N 7° 34' 57" E 99° 35' 10"	14	Old rice field	April–Nov.	ca 30
NT1R2	N 7° 34' 57" E 99° 35' 10"	14	Old rice field	Through year	up to 100
NT1R3	N 7° 34' 57" E 99° 35' 10"	14	Disturbed forest	rarely	
NT2R1	N 7° 35' 06" E 99° 35' 20"	12	Termite hills	rarely	
NT2R2	N 7° 35' 06" E 99° 35' 20"	12	Old rice field	Sept.–Nov.	ca 30

Relative abundance of life forms of association types

In order to explain spatial variation in composition and structure among association types based on vegetation classification, all vascular plant species found on the Trang River floodplain were assigned to various growth strategies/life forms categories. This classification is based on the assumption that differences in plant morphology and life strategy would then reflect the different adaptation to various environmental conditions. Thus, if the dominant growth strategies/life forms of each association type were investigated and compared with the environmental factors such as history of land uses, flood duration and water depth, these may help clarifying spatial variation among association types.

The abundance of each species of each community type was measured using its percentage cover of crown area. The relative abundance of each life form in each community type was then calculated by summing the percentage cover of the species in the same growth strategy/life form. Finally a relative abundance of growth strategies/life-forms in each community type was expressed as percentage.

The plant species were divided into broad categories of annual and perennial. The former contains all vascular plant species which complete their life-cycle within one year and survive the unfavorable period as seeds. Some species which are usually regarded as perennial in other habitats were included in the annual category if in the floodplain they survive only one year. The perennial category, in this study, means all vascular plant species which live for more than one year, although some species may disappear during unfavorable periods but they remain their underground stems or rootstocks, i.e., rhizomes, corms. The perennial plants were subdivided into terrestrial and aquatic ones. The aquatic plants are those who cannot live beyond wetland habitat for any significant period of time because most desiccate readily when exposed to air (Tiner, 1991). The aquatic plants were divided, following Finlayson et al. (1989), into emergent(e), floating-leaved anchored(f), submerged anchored(r), free floating submerged(b), and free floating(d). The terrestrial plants were classified into trees(t), shrubs(s), woody climbers(w),

vines(v), epiphytes(e), geophytes(g), and herbs(h). Likewise the annual plants were also subdivided into terrestrial and aquatic categories. The annual terrestrial plant means the species which survive flood period as seeds, while the category of annual aquatic plant implies species which disappear in the dry period/or survive the long dry spell as seeds.

RESULTS AND DISCUSSION

Plant diversity

A total of 160 species of vascular plants belonging to 129 genera in 60 families are identified and listed in Table 2. Among these, seven species are ferns and 153 species are angiosperms. The most common families of Eudicots are Rubiaceae (10 species, 6.25% of total flora), Fabaceae and Phyllanthaceae (9 species each, 5.6%) respectively. Species belonging to Cyperaceae (22 species, 13.8 %) and Poaceae (12 species, 7.5%) are among the most diverse group of Monocots. In this study, only two species of Magnoliids were found. In the case of ferns, Pteridaceae (3 species, 1.9%) is the largest family.

It is not surprising to witness the preponderance of the largest families of Monocots mentioned in the floodplain vegetation. As regards to the Thai flora, Poaceae (600 species) and Cyperaceae (248 species) are also among the largest families (Office of the Forest Herbarium, 2011; Simpson & Koyama, 1998). The elements of both Cyperaceae and Poaceae are usually common in the floodplain or freshwater swamp vegetation as many of them are both aquatic and terrestrial herbs. Concerning the rest of plants beside the Monocots, the members of family Phyllanthaceae are among the majority of pioneer plants in the scattered patches of shrubland associations (see Table 2). However, Rubiaceae and Fabaceae with several life forms and habits are found in several types of associations as trees, shrubs and herbs. Thus, these families are the most diverse in the floodplain vegetation.

The vegetation of the Trang River floodplain

The Trang River floodplain vegetation was classified into nine association types using the Cluster analysis (Fig. 1). Naming of the association types were mainly based on physiognomy of the dominant species. These association types were recognized as follows.

Table 2. List of plant species in study plots. Abundance was measured by cover-abundance estimation using the Domin-Krajina scale.

Family	Scientific name	Life form ¹	Plots reference number ²															Voucher ³
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Ferns																		
Lygodiaceae	<i>Lygodium microphyllum</i> (Cav.) R. Br.	Ptv	1			1	1	1	1	1	1	1	1	*			Patt. 220	
Ophioglossaceae	<i>Helminthostachys zeylanica</i> (L.) Hook.	Pth							*								Patt. 471	
Polypodiaceae	<i>Drynaria quercifolia</i> (L.) J. Sm.	Pte						2									Patt. 283	
	<i>Pyrrosia piloselloides</i> (L.) M.G. Prince	Pte						2									Patt. 219	
Pteridaceae	<i>Adiantum</i> sp.	Pth						1				1						
	<i>Ceratopteris thalictroides</i> (L.) Brongn.	Aae		3														
	<i>Acrostichum aureum</i> L.	Pae					4											
Eudicots																		
Acanthaceae	<i>Staurogyne</i> sp.	Ath											2				Patt. 562	
Amaranthaceae	<i>Alternanthera sessilis</i> (L.) R. Br. ex DC.	Aae								2							Patt. 408	
Apocynaceae	<i>Aganosma marginata</i> (Roxb.) G. Don	Pts							3								Patt. 240	
	<i>Atherandra acutifolia</i> Decne.	Ptv											1				Patt. 565	
Apocynaceae	<i>Hoya parasitica</i> (Roxb.) Wall. ex Wight	Ptv						1									Patt. 217	
	<i>Taxocarpus</i> sp.	Ptv							2								Patt. 458	
	<i>Ichnocarpus frutescens</i> (L.) W.T. Aitonr	Ptv							1								Patt. 165	
	<i>Tylophora indica</i> (Burm. F.) Merr	Ptv						1									Patt. 224	
	<i>Tylophora tenuis</i> Blume	Ptv						2	2								Patt. 234	
	<i>Wrightia religiosa</i> (Teijsm. & Binn.) Kurz	Pts								2							Patt. 181	

¹Aab = annual, aquatic submerged; Aad = annual, aquatic free floating; Aae = annual, aquatic emergent; Ath = annual, terrestrial herbs; Atv = annual, terrestrial vines; Pa/tw = perennial, aquatic/terrestrial woody climbers; Pae = perennial, aquatic emergent; Pag = perennial, aquatic geophytes; Pas = perennial, aquatic shrubs; Pa/ts = perennial, aquatic/terrestrial shrubs; Pa/tt = perennial, aquatic/terrestrial trees; Pte = perennial, terrestrial epiphytes; Pth = perennial, terrestrial shrubs; Ptt = perennial, terrestrial trees; Ptv = perennial, terrestrial vines; Ptw = perennial, terrestrial woody climbers.

²1=NT2R3(*Eleocharis-Fimbristylis* grassland); 2=KPI(*Paspalum-Cynodon-Hymenachene* grassland); 3=BR1R2(*Utricularia-Eriocaulon* grassland); 4=NT1R2, 5=KY1(*Actinoscirpus* grassland); 6=KP3(*Barringtonia-Lagerstroemia-Nauclaea* woodland); 7=NT1R3, 8=NT2R1, 9=BR2R2(*Lagerstroemia-Streblus-Ziziphus* shrubland); 10=NT1R1, 11=KP2(*Mitragyna* shrubland); 12=NT2R2, 13=BR1R1, 14 BR2R1(*Mitragyna-Lagerstroemia-Glochidion* shrubland); 15 BR1R3 (*Streblus-Ziziphus-Adenanthera* shrubland).

³No voucher is available for many plant species which were damaged during transportation or processing.

Family	Scientific name	Life form ¹	Plots reference number ²															Voucher ³
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Asteraceae	<i>Eclipta prostrata</i> (L.) L.	Pth									2	*						Patt. 350
Balsaminaceae	<i>Hydrocera angustifolia</i> Blume	Aae	2								3							Patt. 342
Bignoniaceae	<i>Dolichandrone columnaris</i> Santisuk	Ptt													3			Patt. 268
Boraginaceae	<i>Heliotropium indicum</i> L.	Ath									2	3						Patt. 235
Campanulaceae	<i>Lobelia alsinoides</i> Lam.	Aae	3													2		Patt. 453
Cleomaceae	<i>Cleome rutidosperma</i> DC.	Ath						2				1						Patt. 284
Combretaceae	<i>Combretum trifoliatum</i> Vent.	Pts						3	1		5	3			4			Patt. 178
	<i>Terminalia calamansanai</i> Rolfe	Ptt							5	3								Patt. 557
Convolvulaceae	<i>Aniseia martinicensis</i> (Jacq.) Choisy	Atv	1			1	1	1	1	1	1	1	1	1	1	1		Patt. 236
	<i>Merremia hirta</i> (L.) Merr.	Atv	1								1		1					Patt. 244
Dilleniaceae	<i>Dillenia hookeri</i> Pierre	Pts														1		Patt. 401
	<i>Tetracera loureiri</i> (Finet & Gagnep.) Pierre ex Craib	Ptw			3			3	3	3	3	3	3	3	3	3		Patt. 337
Droseraceae	<i>Drosera indica</i> L.	Aae			4													Patt. 374
Euphorbiaceae	<i>Croton caudatus</i> Geiseler	Pts							4			3			2	4		Patt. 215
	<i>Shirakiopsis indica</i> (Willd.) Esser	Pa/tt						3										Patt. 358
Fabaceae	<i>Acacia pennata</i> (L.) Willd.	Pts													3			Patt. 567
	<i>Aeschynomene indica</i> L.	Pas					3											
	<i>Adenanthera pavonina</i> L.	Pts															5	Patt. 456
	<i>Derris elliptica</i> (Wall.) Benth.	Ptw						2								3		
	<i>Derris scandens</i> (Roxb.) Benth.	Pa/ tw						2			2							
	<i>Derris</i> sp	Pa/ tw						3										Patt. 461
	<i>Flemingia macrophylla</i> (Willd.) Merr.	Pts													3			Patt. 566
	<i>Flemingia strobilifera</i> (L.) W.T.Aiton	Pts									2					3		Patt. 197
	<i>Sesbania javanica</i> Miq.	Pas										3						Patt. 381

Family	Scientific name	Life form ¹	Plots reference number ²															Voucher ³
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Hydrophyllaceae	<i>Hydrolea zeylanica</i> (L.) Vahl	Aae										1						Patt. 176
Lamiaceae	<i>Clerodendrum paniculatum</i> L.	Pts							*									
	<i>Glossocarya linnaei</i> Benth. & Hook. f.	Pts						2										Patt. 348
	<i>Premna annulata</i> H.R. Fletcher	Ptw							2									Patt. 244-1
	<i>Vitex glabrata</i> R. Br.	Ptt						4										Patt. 260
Lecythidaceae	<i>Barringtonia acutangula</i> (L.) Gaertn.	Ptt					7	5	7	3	3	6	4	4				Patt. 196
Lentibulariaceae	<i>Utricularia auria</i> Lour.	Aad										1						
	<i>Utricularia bifida</i> L.	Aae			6													Patt. 288
	<i>Utricularia caerulea</i> L.	Aae			5													Patt. 373
	<i>Macrosolen cochinchinensis</i> (Lour.) Tiegh.	Pte						1										Patt. 194
Lythraceae	<i>Lagerstroemia floribunda</i> Jack	Ptt						8		7				4	8			Patt. 362
	<i>Lagerstroemia speciosa</i> (L.) Pers.	Ptt					8	4										Patt. 246
	<i>Melastoma malabathricum</i> L.	Pts						3	1				3	2				Patt. 189
Moraceae	<i>Ficus hispida</i> L.f.	Pts					3	4										
	<i>Maclura cochinchinensis</i> (Lour.) Corner	Pts						2										Patt. 261
	<i>Streblus asper</i> Lour.	Pts					5	3	7	7							8	Patt. 227
	<i>Streblus perakensis</i> Corner	Pts					3											Patt. 223
Malvaceae	<i>Melochia corchorifolia</i> L.	Ath	1					1			2							Patt. 275
	<i>Microcos tomentosa</i> Sm.	Pts						3					3	3	3			Patt. 344
	<i>Pentapetes phoenicea</i> L.	Aae											3					Patt. 167
	<i>Sida rhombifolia</i> L.	Pts						2										Patt. 462
	<i>Urena lobata</i> L.	Pts						4		2	2	2		2				Patt. 239
Myrtaceae	<i>Syzygium</i> sp.	Ptt							4									Patt. 355
Olacaceae	<i>Olax scandens</i> Roxb.	Ptw						2							2			Patt. 241

Family	Scientific name	Life form ¹	Plots reference number ²															Voucher ³
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Rubiaceae	<i>Paederia foetida</i> L.	Atv						2	2			2						Patt. 472
	<i>Tamilnadia uliginosa</i> (Retz.) Tirveng. & Sastre	Ptt											2	4	2			Patt. 245
Sapindaceae	<i>Allophylus cobbe</i> (L.) Raeusch.	Pts						3	3	3		3						Patt. 285
	<i>Lepisanthes rubiginosa</i> (Roxb.) Leenh.	Ptt											1					Patt. 190
Scrophulariaceae	<i>Linnophila erecta</i> Benth.	Aae										2						Patt. 411
	<i>Linnophila laxa</i> Benth.	Ath			3													Patt. 507
	<i>Lindernia ciliata</i> (Colsm.) Pennell	Aae														2		Patt. 372
	<i>Lindernia crustacea</i> (L.) F. Muell.	Aae	4	3												2		Patt. 433
Stylidiaceae	<i>Stylidium tenellum</i> Sw. ex Willd.	Aae			3													Patt. 508
Urticaceae	<i>Pouzolzia zeylanica</i> (L.) Benn. & R.Br.	Ath	3											2				Patt. 563
Vitaceae	<i>Leea rubra</i> Blume ex Spreng.	Pts					3	3	3	3	2	5	3	4	6			Patt. 264
MAGNOLIIDS																		
Annonaceae	<i>Uvaria rufa</i> Blume	Ptw					3		4	3					3		3	Patt. 262
Lauraceae	<i>Litsea</i> sp.	Ptt							4									Patt. 343
MONOCOTS																		
Alismataceae	<i>Limncharis flava</i> (L.) Buchenau	Aae			1						3							Patt. 173
Araceae	<i>Lasia spinosa</i> (L.) Thwaites	Pag					2											
	<i>Typhonium flagelliforme</i> (Lodd.) Blume	Aae							1	1			2	2	1			Patt. 204
Amaryllidaceae	<i>Crinum amoenum</i> Roxb. ex Ker Gawl.	Pag							1	1			2	2				Patt. 184
Commelinaceae	<i>Commelina diffusa</i> Burm. f.	Pth	1	1	1	1	2					1	1		1			Patt. 387
	<i>Cyanotis axillaris</i> (L.) D. Don ex Sweet	Pth	1	1	1	1	2					1	1		1			Patt. 232
	<i>Murdannia nudiflora</i> (L.) Brenan	Pth	2	2	2													Patt. 388
Cyperaceae	<i>Actinoscirpus grossus</i> (L.f.) Goetgh. & D.A. Simpson	Pae				10	8				1							Patt. 401
	<i>Cyperus babakan</i> Steud.	Pae	3	2	2							1	2					Patt. 405
	<i>Cyperus compactus</i> Retz.	Pae	1									1		*				Patt. 186

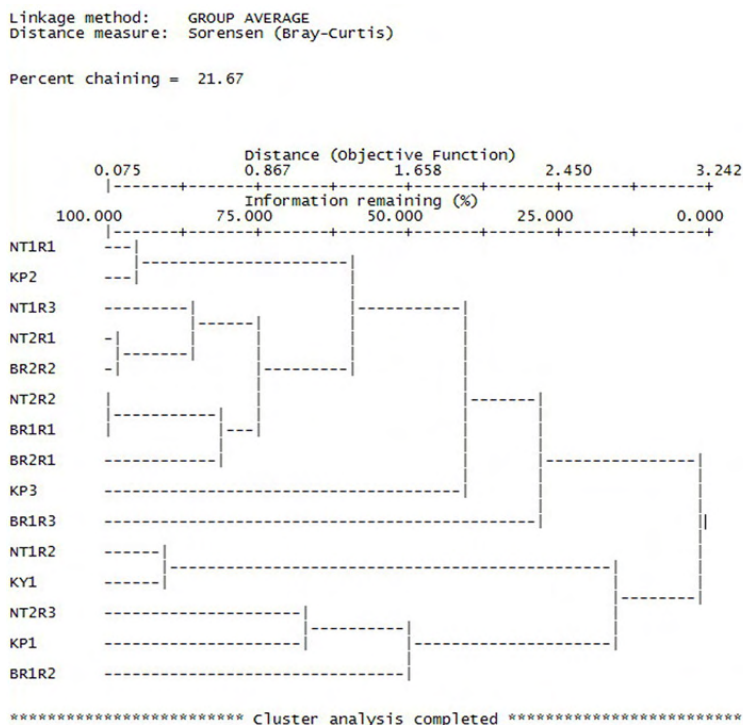


Figure 1. Cluster analysis dendrogram based on similarity of plant species composition and their abundance among the study sites.

1. *Actinoscirpus* grassland (NT1R2 and KY1)

It could be found in the old rice fields which are flooded permanently by up to 1 m deep water. A strand flora is remarkably formed by the emergent aquatic herbs. The dominant species is *Actinoscirpus grossus*, which formed more or less pure stands in this association. Minor species are also interspersed among many aquatic herbs: *Acrostichum aureum*, *Lobelia alsinoides*, *Ludwigia octovalvis*, *Ottelia alismoides*, *Persicaria attenuata*, etc.

2. *Utricularia-Eriocaulon* grassland (BR1R2)

In the areas which are inundated for eight months by up to 30 cm deep water, the association is dominated by annual aquatic plants and some of which are usually found in the bog and nitrogen deficient areas, e.g., *Drosera indica*, *Eriocaulon truncatum*, *E. xeranthemum*, *Fimbristylis miliacea*, *F. schoenoides*, *Salomonina longiciliata*, *Stylidium tenellum*, *Utricularia bifida*, *U. caerulea*. However, in relatively dry areas, *Fimbristylis acuminata* is plentiful. In the dry season the wet grasslands seasonally dry out, and most plants above ground are entirely withered.

3. *Eleocharis-Fimbristylis* grassland (NT2R3)

This is a herbaceous plant community, seemingly dominated by annual species. It is found in the areas which are subjected to relatively longer period of inundation (up to 30 cm deep water) for about nine months. During the wet season, the association is dominated by many annual aquatic species, i.e., *Fimbristylis miliacea*, *Hydrolea zeylanica*, *Hymenachne acutigluma*. Perennial aquatic plants are also plentiful, e.g., *Eleocharis acutangula*, *Fimbristylis umbellaris* and *Scleria poiformis*, etc. During the dry period, the terrestrial annual herbs, e.g., *Eragrostis* sp., *Isachne globosa*, *Sacciolepis indica* are increasingly abundant.

4. *Paspalum-Cynodon-Hymenachene* grassland (KP1)

In the seasonally flooded areas, which are inundated for three months, the seasonally dynamic association is mainly composed of annual herbs. In the dry period, the association is dominated by annual terrestrial herbs, e.g., *Borreria alata*, *Cynodon dactylon*, *Kyllinga brevifolia*, *Panicum* sp., *Paspalum conjugatum*, *P. longifolium*. During

flooded period, annual terrestrial herbs are replaced by annual aquatic plants, e.g., *Persicaria attenuata*, *Cyperus haspan*, *Cyperus pilosus* and *Hymenachne acutigluma*.

5. *Mitragyna* shrubland (NT1R1, KP2) (Fig. 3)

The *Mitragyna* association is found in the disturbed floodplain areas and old rice fields, where inundation is evident for 3–8 months. This association is dominated by shrubs and small trees species. The canopy is continuous, 2–13 to (rarely) 15 m high and has no trace of layering. The dominant

species is *Mitragyna diversifolia* which forms almost pure stands. The other components are small shrubs such as *Glochidion rubrum*, *Leea rubra*, and include the seedlings and saplings of *Barringtonia acutangula* and some scandent species, e.g., *Combretum trifoliatum*. Epiphytes and climbers are rare. The existence of ground cover species is seasonally dynamic. It is composed mainly of perennial and annual sedges and grasses. Many of them are also found in *Eleocharis-Fimbristylis* grassland.

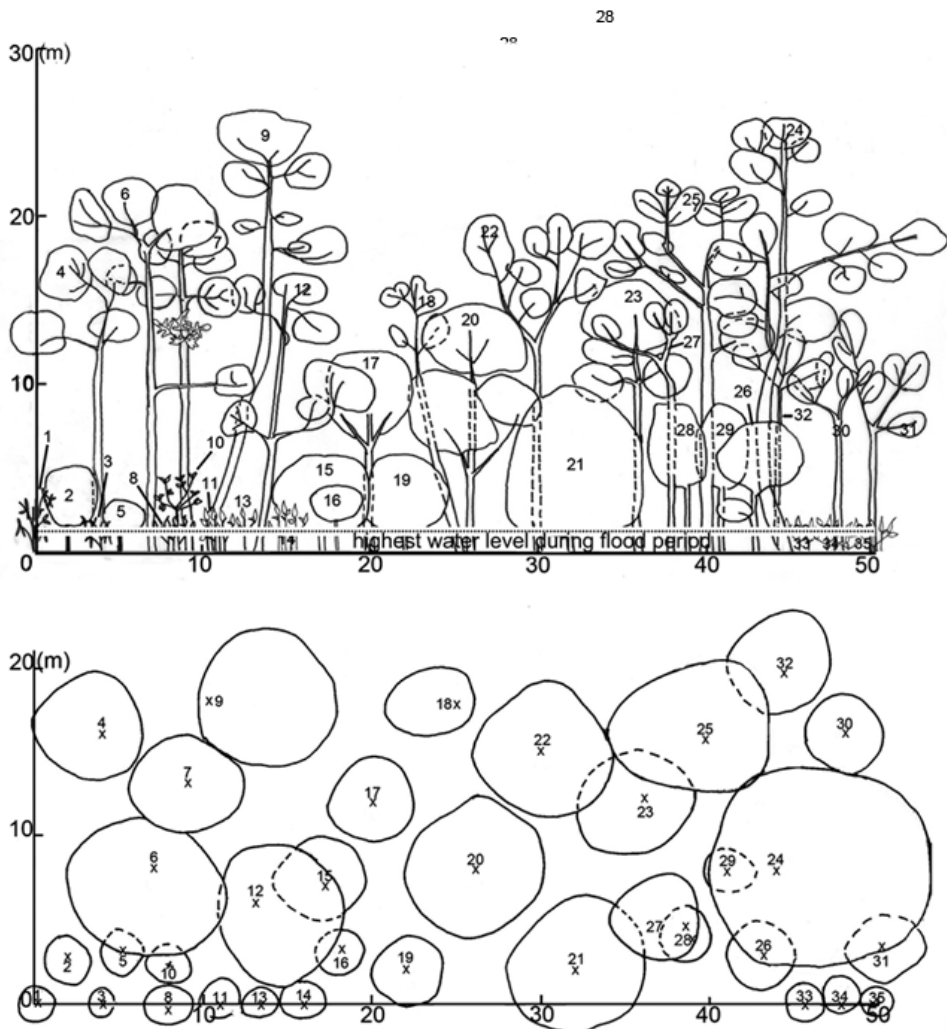


Figure 2. Profile diagram of the *Barringtonia-Lagerstroemia-Nauclea* woodland

1,3= *Combretum trifoliatum*; 2,5,16,17,19–22,26,28–29= *Barringtonia acutangula*; 4,24–25,30–32= *Nauclea orientalis*; 6–7,9,12,18,23,27= *Lagerstroemia speciosa*; 8,11,13–14,33–35= *Schumannianthus dichotomus*; 10= *Mitragyna diversifolia*; 15= *Xanthophyllum eurhynchum*

6. *Mitragyna-Lagerstroemia-Glochidion* shrubland (NT2R2, BR1R1, BR2R1) (Fig. 4)

This association seems to be an intermediate between *Lagerstroemia-Streblus-Ziziphus* shrubland and *Mitragyna* shrubland. It is found on the old rice fields which are flooded for 3–8 months. The species composition is similar to those two former mentioned associations, but different in the relative abundance (see Table 2). The dominant species are *Antidesma ghaesembilla*, *Glochidion rubrum*, *Lagerstroemia floribunda*, *Leea rubra*, *Mitragyna diversifolia*, and *Ziziphus oenoplia*. The ground cover composition varies from a plot with no ground cover to a plot where annual aquatic plants such as *Cyperus haspan*, *Cyperus pulcherrimus*, *Fimbristylis miliacea*, are dominant during inundation periods. During dry periods, those species are replaced by terrestrial herb species, e.g., *Paspalum longifolium* and *Cynodon dactylon*, etc.

7. *Barringtonia-Lagerstroemia-Nauclea* woodland (KP3) (Fig. 2)

This association is composed mainly of tree species occurring in the areas which would be more or less flooded for about three months. The association is two-storied. The upper layer is 15–20 m high with rather continuous crown canopies, consisting mostly of tree species, e.g., *Barringtonia acutangula*, *Lagerstroemia speciosa* and *Nauclea orientalis*. The lower layer is varying from 3–5 m height with many shrubs such as *Streblus asper*, *Kailarsenia campanula* and the saplings of *B. acutangula*, etc. In the areas under the relatively dense canopies of the upper layer, the ground cover is scarce. Whilst in the areas with relatively open upper layer, a pure stand of *Schumannianthus dichotomus* are occurring as a majority together with *Combretum trifoliatum* and also seedlings of *B. acutangula*. The epiphytes and climbers are

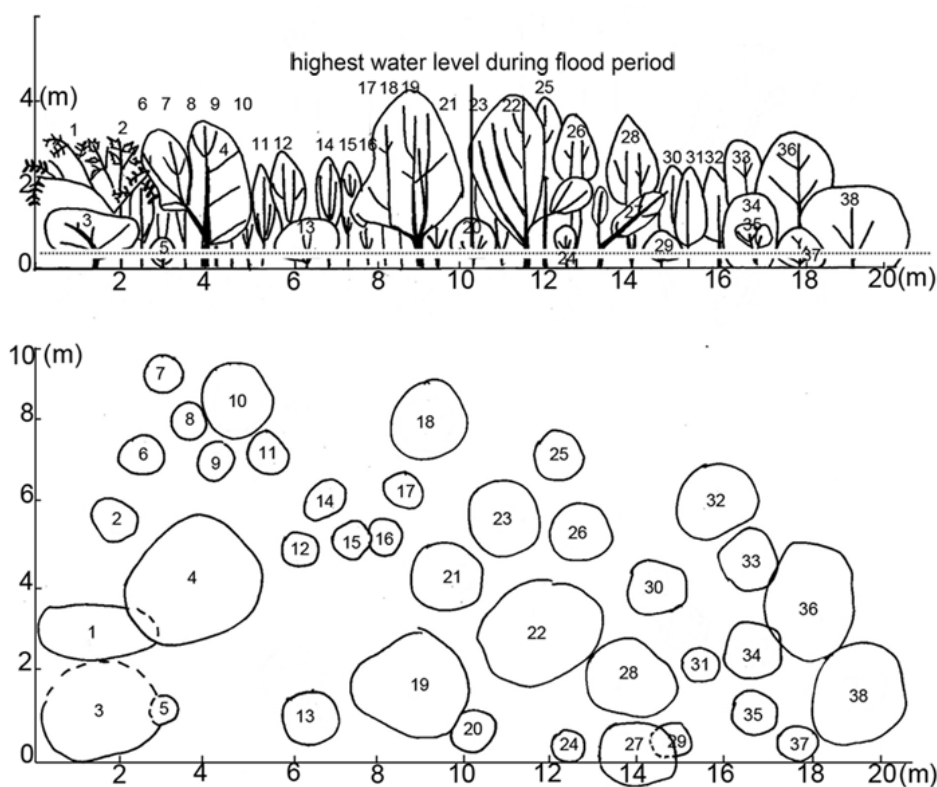


Figure 3. Profile diagram of the *Mitragyna-Lagerstroemia-Glochidion* shrubland

1,11= *Barringtonia acutangula*; 2,3,6–7,9,10,12–14,16–20,28–35,37,39,41= *Mitragyna diversifolia*; 4= *Taminaldia uliginosa*; 5,36= *Leea rubra*; 8,22= *Lagerstroemia floribunda*; 15,23,27,40,42= *Glochidion rubrum*; 21,26,38= *Antidesma ghaesembilla*; 24,25= *Ziziphus oenoplia*

relatively rich in this association when compared with other floodplain association types. The following species are found: *Dendrobium crumenatum*, *Drynaria quercifolia*, *Hoya parasitica*, *Micropera pallida*, *Pyrrhosia piloselloides*.

8. *Lagerstroemia-Streblus-Ziziphus* shrubland (NT1R3, NT2R1, BR2R2)

Along the fringe of the floodplain where inundation seldom occurs and on the termite hills which are confined to the old semi-permanent flooded rice fields, the association is mainly composed of shrub and tree species. These species are also common in other dry-land vegetation types, e.g., *Antidesma ghaesembilla*, *Lagerstroemia floribunda*,

Melastoma malabathricum, *Microcos tomentosa*, *Streblus asper* and *Ziziphus oenoplia*. The ground cover is rather scarce, however, some species can be encountered, although in low abundance, e.g., *Helminthostachys zeylanica*, *Melochia corchorifolia*, *Typhonium flagelliforme* etc.

9. *Streblus-Ziziphus-Adenanthera* shrubland (BR1R3)

This association type is found on the termite hills in the floodplain areas and mainly composed of shrub species which usually found on other dry areas. Only seven plant species are found, i.e., *Adenanthera pavonina*, *Gloriosa superba*, *Microcos tomentosa*, *Stemona* sp., *Streblus asper*, *Uvaria*

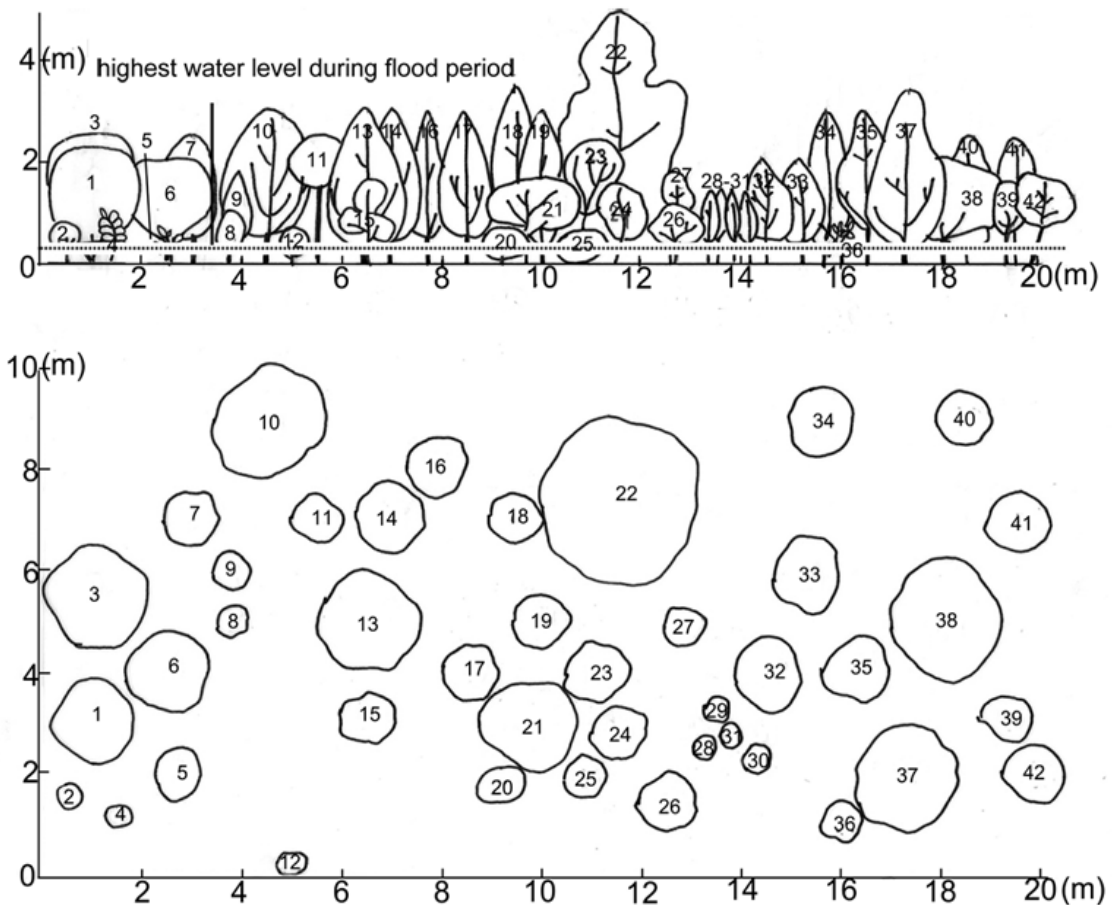


Figure 4. Profile diagram of the *Mitragyna-Lagerstroemia-Glochidion* shrubland

1,11= *Barringtonia acutangula*; 2,3,6-7,9,10,12-14,16-20,28-35,37,39,41= *Mitragyna diversifolia*; 4= *Tamilnadia uliginosa*; 5,36= *Leea rubra*; 8,22= *Lagerstroemia floribunda*; 15,23,27,40,42= *Glochidion rubrum*; 21,26,38= *Antidesma ghaesembilla*; 24,25= *Ziziphus oenoplia*

rufa and *Ziziphus oenopolia*. The mentioned association type of vegetation can also be considered as a part of *Lagerstroemia-Streblus-Ziziphus* shrubland which is left fragmented on the termite hills in the floodplain areas as five of seven species belong to the *Lagerstroemia-Streblus-Ziziphus* shrubland.

Relative abundance of life forms and spatial variation in composition and structure among the association types of the Trang-River floodplain vegetation

According to the nine association types classified above, the relative abundance of life forms in each association types are performed in percentage in Table 3. Based on these data, the association types according to vegetation classification could be categorized into three main groups according to the dominant life forms, i.e., (1) the association dominated by annual herbs which are composed of *Paspalum-Cynodon-Hymenachene* grassland, *Utricularia-Eriocaulon* grassland, and *Eleocharis-Fimbristylis* grassland; (2) The association dominated by perennial herbs that is *Actinoscirpus* grassland; (3) The association dominated by perennial woody species which are composed of *Mitragyna* shrubland, *Mitragyna-Lagerstroemia-Glochidion* shrubland, *Lagerstroemia-Streblus-Ziziphus* shrubland, *Barringtonia-Lagerstroemia-Nauclea* woodland and *Streblus-Ziziphus-Adenanthera* shrubland.

It is usually found that stands of the vegetations with completely different floristic composition may have similar structure and life form as a consequence of an interaction of the complexity of similar environmental factors. Therefore, the spatial variation within the floodplain vegetation of Trang River is briefly discussed in accordance with these three main groups as follows:

1. The association dominated by annual herbs

This group was found in the disturbed and inundated areas which last for 3–4 and 8 months. According to Odum (1969), the small size of plants, the rapid rate of growth and the short life cycle are the characteristics of organisms in the early stage of succession. This may indicate that they are developing in the early stage of succession. Moreover, it is noticeable that these associations are found in the areas where seasonally inundation

occurs. Due to the alternation period of drying and inundation, the plants with annual life-form have more advantage as it could complete their life cycle prior to unfavorable periods (depending on whether they are aquatic or terrestrial species) and leave their seeds to establish in the next favorable season. This trait also renders them to readily colonize the unoccupied land following a disturbance. Therefore this life-form is predominant in the areas with frequent disturbances and unpredictable environment (see also Finlayson et al., 1989; Capon, 2005).

2. The association dominated by perennial herbs

The association dominated by perennial herbs is found in the disturbed and inundated areas all year round. They may be developing in the early stage of succession similar to the former one. However, the difference in physical setting between these two association types is the water regime. In the *Actinoscirpus* grassland the soils never completely dry out even during the dry season, the condition which is suitable for aquatic plant species. Due to the relatively stable environmental condition, compared to the association dominated by annual herbs, the perennial aquatic plant species in this association have enough time to complete their life cycle. Hence, in this condition the predominant perennial species have more advantage over the annual herbs. This reveals the role of flood duration in differentiating the species composition and structure between these two association types.

3. The association dominated by perennial woody species

This group is found in the varying habitats of semi-permanently flooded areas, the seasonally flooded areas and the infrequently flooded areas. However, only *Barringtonia-Lagerstroemia-Nauclea* woodland is considered to be “primary vegetation”, which has long been existed in the study areas originally. It has relatively complex structure, e.g., 2-layered canopy, dominated by larger trees and rich in epiphytes compared with other types of association in the Trang River floodplain. In any case, more information on the vegetation history is, therefore, needed in order to confirm this observation.

However, in the disturbed floodplain areas, the associations of the *Mitragyna* shrubland and

Table 3. Percentage cover of life forms in each association type along the Trang River floodplain.

Life forms ¹		Association types ²								
		1	2	3	4	5	6	7	8	9
Annual herbs	Aab				4			1		
	Aad							1		
	Aae	44	42	72	29	3	1	20	12	
	Ath	20	47	18		2	1	10	6	
	Atv	2			2	1	3	3	2	
Perennial herbs	Pae	29	6	7	40	5		10	3	
	Pag					2	1		1	
	Pte					9	1	1		
	Pth	5	5	3	9	1		3	2	
	Ptv				2	9	6	2	5	14
Woody species	Pa/tw					5	1			
	Pas				7			1		
	Pa/ts					3	4		2	
	Pa/tt					3				
	Pts					29	48	28	39	76
	Ptt					23	25	18	21	
	Ptw				7	5	9	2	8	10

¹Aab = annual, aquatic submerged; Aad = annual, aquatic free floating; Aae = annual, aquatic emergent; Ath = annual, terrestrial herbs; Atv = annual, terrestrial vines; Pa/tw = perennial, aquatic/terrestrial woody climbers; Pae = perennial, aquatic emergent; Pag = perennial, aquatic geophytes; Pas = perennial, aquatic shrubs; Pa/ts = perennial, aquatic/terrestrial shrubs; Pa/tt = perennial, aquatic/terrestrial trees; Pte = perennial, terrestrial epiphytes; Pth = perennial, terrestrial herbs; Pts = perennial, terrestrial shrubs; Ptt = perennial, terrestrial trees; Ptv = perennial, terrestrial vines; Ptw = perennial, terrestrial woody climbers.

²1= *Eleocharis-Fimbristylis* grassland, 2= *Paspalum-Cynodon-Hymenachene* grassland, 3= *Utricularia-Eriocaulon* grassland, 4= *Actinoscirpus* grassland, 5= *Barringtonia-Lagerstroemia-Nauclea* woodland, 6= *Lagerstroemia-Streblus-Ziziphus* shrubland, 7= *Mitragyna* shrubland, 8= *Mitragyna-Lagerstroemia-Glochidion* shrubland, 9= *Streblus-Ziziphus-Adenantha* shrubland.

the *Mitragyna-Lagerstroemia-Glochidion* shrubland are found to replace of the *Barringtonia-Lagerstroemia-Nauclea* woodland. Noticeably, these shrubland communities share similar environmental conditions with other associations dominated by annual herbs. According to the appropriate duration of the secondary successional stages, the small tree and shrub species could well establish themselves and dominate in the woody vegetation, but not the annual species. Moreover, most of the ground cover species commonly found in both the *Mitragyna* shrubland and the main components of *Eleocharis-Fimbristylis* grassland may suggest that the *Eleocharis-Fimbristylis* grassland might has a potential to develop as the *Mitragyna* shrubland thereafter. In addition, the proliferation of the seedlings of *Barringtonia acutangula* in the *Mitragyna* shrubland may suggest that this association would likely be replaced by the *Barringtonia-Lagerstroemia-Nauclea* woodland thereafter. This suggests that the differences in varying successional stages due to the history of land uses in the study areas are responsible for the variations in floristic composition, structure and distribution among the association types.

Considering distribution of *Lagerstroemia-Streblus-Ziziphus* shrubland and the *Streblus-Ziziphus-Adenanthera* shrubland, these associations exist in the infrequently flooded areas formed by small mounds 1–2 m high, and scattered “termite mounds”. According to this rarely flooded condition, the *Lagerstroemia-Streblus-Ziziphus* shrubland and the *Streblus-Ziziphus-Adenanthera* shrubland are dominated by the terrestrial species (e.g., *Microcos tomentosa*, *Streblus asper*, *Ziziphus oenopolia*) which are common in some dry land habitats.

Expected original association types in the Trang River basin

The spatial variation and differences in habitat distribution among the association types in the present study might be explained primarily by different successional stages of secondary vegetation. Because most of the study sites were found on areas disturbed by humans (see Table 1), the variation among the association types along a lateral gradient seems to be the reflection of human disturbances rather than the natural processes (Fig. 5a). All of

the association types except the *Barringtonia-Lagerstroemia-Nauclea* woodland may be representing the transitional stages of succession. Generally, floodplains are characterized by dynamic of fluvial landforms and natural succession, which is usually associated with a particular kind of vegetation (Tepley et al., 2004; Wittmann et al., 2004). Secondary succession of the existing associations due to human activities in the floodplain vegetation of the Trang River may reflect natural-successional course due to this dynamic of fluvial landforms along the lateral gradient. Based on these data of the natural-successional courses, the expected associations of the floodplain vegetation of the Trang River basin are, therefore, proposed as follows.

The succession process could be initiated on the newly sedimentation site, e.g., the inner side of a curve of the river, abandoned meanders or the oxbow lakes. The early stage of succession was likely predominated by the herbaceous association. Either perennial or annual herbaceous associations could be expected at varying water depth and the seasonal dynamic of water regime. These herbaceous association would be able to trap the additional sediment and, therefore, providing suitable habitats for the later colonizers. Then, these types of association may be replaced by the *Mitragyna-Lagerstroemia-Glochidion* shrubland or the *Mitragyna* shrubland. Eventually, the successional process may end up with the *Barringtonia-Lagerstroemia-Nauclea* woodland. However, the so-called climax vegetation may be repeatedly disturbed by the natural erosion process of the flood and then the succession would resume again. Therefore, the varying association types along the lateral gradient in the natural floodplain may represent different successional stages (Fig. 5b).

However, as all remnant patches of the floodplain vegetation have been left nearby the river channel, the *Barringtonia-Lagerstroemia-Nauclea* woodland seems to be the only primary type of the typical freshwater swamp vegetation existed on this floodplain. Many more natural association types could have occurred in the past, especially, the association types located far apart from the river channel. The more intensive surveys in the similar floodplains in the peninsular Thailand are, therefore, needed for a comparative study.

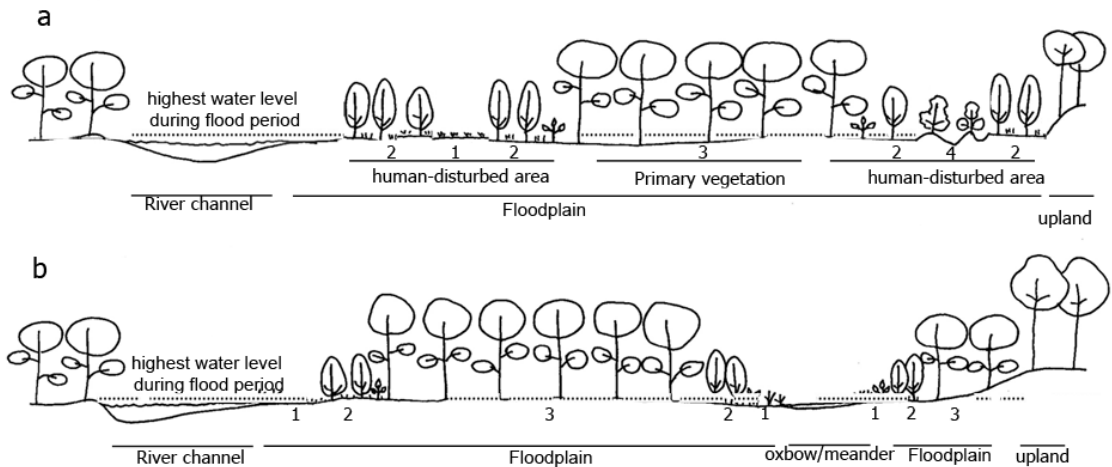


Figure 5. Varying associations of floodplain vegetation along a lateral gradient from river channel to elevated areas in the Trang-River basin, between a) spatial variation as a result of secondary succession due to human impact in actual vegetation and b) the expected vegetation of floodplain along the lateral gradient due to natural succession (note that different association types become established in relation to flood-level gradient).

1= the association dominated by annual species and/or the association dominated by perennial herbs, 2= *Mitragyna-Lagerstroemia-Glochidion* and/or the *Mitragyna* shrubland, 3= *Barringtonia-Lagerstroemia-Nauclea* woodland, 4= *Lagerstroemia-Streblus-Ziziphus* shrubland.

Conservation measures

The freshwater swamp or floodplain vegetation is not only important in terms of biodiversity and genetic resources of many specialized flora and fauna species, it provides also a number of non-timber forest products for local use and supports fisheries. So far, diverse vegetation types on the floodplains and alluvial plains in every region of Thailand have increasingly been threatened and degraded by various agricultural activities, especially rice fields, and para-rubber plantation. The loss of freshwater swamp vegetation includes the permanent loss where the altered areas are no longer possess wetland characteristics, or change from natural to semi-natural or unnatural. Today, the intensive and destructive land uses of this wetland ecosystem by people have reached a critical level that only a few remnant patches of the natural freshwater swamp vegetation are left in the floodplain areas of the Trang River basin. Unfortunately, almost all the floodplain areas of Trang River basin

have never been included in any protected area categories. Many of native plant species have already disappeared from their original wetland habitats. Furthermore, most of the floodplain areas in the river basins, the natural periodic flood has recently not taken place anymore, and some areas have altered to be permanently flooded due to the excessive irrigation systems. In the absence of flood, the native plants of natural floodplains are consequently replaced by the species of dry habitat. Whilst in the permanently flooded condition, the natural floodplain vegetation may change into aquatic plant communities as in the open water (see Middleton, 2002). If the natural water regime in maintaining the natural floodplain vegetation would not be taken into account for the irrigation projects managements as well as various agriculture activities together with the ignorance of the authorities concerns and the local inhabitants, this rare habitat would then disappear soon from the former river basins, at least in peninsular Thailand.

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REFERENCES

- Angiosperm Phylogeny Group (2009). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Botanical Journal of the Linnean Society* 161: 105–121.
- Capon, S.J. (2005). Flood variability and spatial variation in plant community composition and structure on a large arid floodplain. *Journal of Arid Environments* 60: 183–302.
- Finlayson, C.M., Bailey, B.J & Cowie, I.D. (1989). Macrophyte vegetation of the Magela creek flood plain, Alligator River region, Northern Territory. Office of the Supervising Scientist for the Alligator Rivers Region, Research Report No 5. Australian Government Publishing Service, Canberra, Australia.
- Finlayson, C.M. & Moser, M. (1991). *Wetlands. International Waterfowl and Wetlands Research Bureau*. Oxford, UK.
- Hydrology and Water Management Center for Southern Region (2011). The amount of runoff of Trang River at Ban Pak Mun, Muang Trang District, Trang province. URL: <http://hydro-8.com> (in Thai). Accessed 17 March 2011.
- Kent, M. & Coker, P. (1994). *Vegetation description and analysis*. John Wiley & Sons Ltd. Chichester, UK.
- Kottek, M., Grieser, J., Beck, C., Rudolf, B. & Rubel, F. (2006). World map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift* 15: 259–263.
- McCune, B. & Mefford, M.J. (2006). PC-ORD. Multivariate analysis of ecological data, Version 5.19. MjM Software Design. Gleneden Beach, Oregon, USA.
- Middleton, B. (2002). The flood pulse concept in wetland restoration. In: B. Middleton (ed.), *Flood pulsing in wetlands: Restoring the natural hydrological balance*, pp. 1–10. John Wiley & Son, Inc., New York, USA.
- Odum, E.P. (1969). The strategy of ecosystem development. *Science* 164: 262–270.
- Office of the Forest Herbarium (2011). *Flora of Thailand: Families under revision or not revised*. URL: http://web3.dnp.go.th/botany/Botany_Eng/FloraofThailand/flora_Eng_notRevised.html. Accessed 20 July 2011.
- Simpson, D.A. & Koyama, T. (1998). *Cyperaceae*. In: T. Santisuk & K. Larsen (eds.), *Flora of Thailand* 6(4): 247–485. The Forest Herbarium, Royal Forest Department, Bangkok.
- Simpson, M.G. (2010). *Plant Systematics*. 2nd ed. Elsevier, San Diego, USA.
- Tepley, A.J., Cohe, J.G. & Huberty, L. (2004). *Natural community abstract for floodplain forest*. Michigan Natural Features Inventory, Lansing, USA.
- Thai Marine Meteorological Center (2010). *Climate of Trang province*. URL: http://www.marine.tmd.go.th/thai/tus_type/trang.html (in Thai). Accessed 23 October 2010.
- Thai Meteorological Department (2010). *Climate of Trang Province*. URL: http://www.tmd.go.th/province_stat.php?StationNumber=48567 (in Thai). Accessed 23 March 2010.
- Tiner, R.W. (1991). The concept of a hydrophyte for wetland identification. *BioScience* 41: 236–247.
- Van der Maarel, E. (2005). *Vegetation ecology - an overview*. In: E. van der Maarel (ed.), *Vegetation Ecology*, pp. 1–51. Blackwell Science Ltd., Cornwall, UK.
- Ward, J.H. (1963). Hierarchical grouping to optimize an objective function. *American Statistical Association Journal* 58: 236–244.
- Wittmann, F., Junk, W.J., & Piedade, M.T.F. (2004). The Varzea forests in Amazonia: flooding and the highly dynamic geomorphology interact with natural forest succession. *Forest Ecology and Management* 196: 199–212.