BIODIVERSITAS
Volume 20, Number 8, August 2019
Pages: 2119-2127

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d200804

Species composition and structure of degraded mangrove vegetation in the Air Telang Protected Forest, South Sumatra, Indonesia

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Manuscript received: 12 February 2019. Revision accepted: 12 July 2019.

Abstract. *Eddy S, Ridho MR, Iskandar I, Mulyana A. 2019. Species composition and structure of degraded mangrove vegetation in the Air Telang Protected Forest, South Sumatra, Indonesia. Biodiversitas 20: 2119-2127.* Air Telang Protected Forest (ATPF) is one of the protected forests in the coastal area of South Sumatra, Indonesia which is around 12,660.9 hectares. This area is strategic because it borders directly with the Bangka Strait and adjacent to Sembilang National Park making it easy to access by the community. Various anthropogenic activities in the region such as residential, farming, agriculture, aquaculture, port and timber harvesting have led to degradation and loss of primary mangrove forest. This study aims to analyze the species composition and community structure of mangrove vegetation in the ATPF. The data were collected through observations at several point-centered samplings which were used to analyze the species composition and community structure of the vegetation and the physicochemical conditions of the environment. The species composition of this area consists of 20 species belonging to 14 families. The dominant species of tree, sapling and seedling stages are *Nypa fruticans*, *Rhizophora apiculata* and *Acrostichum aureum*, respectively. Overall species diversity index in this region is classified as very low, ranging from 0.00 to 0.73. Cluster analysis showed three types of vegetation structures in this region, namely *Cyperus-Acrostichum* type (shrub vegetation), *Acrostichum-Rhizophora* type (secondary forests) and *Nypa-Avicennia* (primary forests).

Keywords: Air Telang Protected Forest, mangrove degradation, vegetation structure

INTRODUCTION

Mangroves grow in the tropical and subtropical tidal zones of the world between approximately 30° N and 30° S latitudes and they protect the coast from various disturbances (Fatoyinbo et al. 2008; Giri et al. 2011; Peng et al. 2009). Mangrove habitats are characterized by variations in environmental factors, such as temperature, sedimentation and tidal flows (Nagelkerken et al. 2008).

Various anthropogenic pressures have caused the decrease in mangrove forest cover in diverse locations worldwide (Bryan et al. 2013; Dat and Yoshino 2013; Donders et al. 2008; Giri et al. 2008; Giri et al. 2011; Giri et al. 2014; Ilman et al. 2011; Jones et al. 2014; Komiyama 2014; Li et al. 2013; Nfotabong-Atheull et al. 2013; Thu and Populus 2007). Anthropogenic pressures on mangrove forest ecosystems will reduce forest cover and at the same time also reduce their functions. The mangrove forest degradation will increase coastal erosion and intrusion of seawater, and reduce the ability of coastal ecosystems in carrying out its functions (Berger et al. 2008; Onrizal and Kusmana 2008). The overlapping of interests in the utilization of mangrove forests by communities and governments will lead to conflicts and complicate their management (Walters et al. 2008). In addition, conservation of mangrove forests inside and outside the marine protected areas faces two challenges: preventing illegal timber extraction, and reducing clearance of surrounding forests and buffer zones (Blanco-Libreros and Estrada-Urrea 2015).

Air Telang Protected Forest (ATPF) is one of the protected forests in South Sumatra, Indonesia. It is a coastal protected area that has some vegetation such as mangrove forests. ATPF position is strategic because it directly borders the Banyuasin River and Bangka Strait and is adjacent to Sembilang National Park. However, several parts of this region have transformed due to human activities, such as establishment of settlements, farming, agriculture, aquaculture, port operations and logging (Eddy et al. 2017). In addition, since 2014 a Special Economic Zone (SEZ) has been established around this area by the Indonesian government. Disturbances in forest structure, faunal diversity, and services to humans are caused owing to lack of proper understanding of the consequences of specific activities such as selective logging and reclamation of mangrove forests (Blanco et al. 2012).

Our research was focused on examining the structure and composition of vegetation in ATPF and physicochemical conditions of the habitats. The study of the structure and composition of degraded mangrove forests is very important to provide more comprehensive perspective of the existing conditions of mangrove forest and at the same time to determine the causes of mangrove degradation. In addition, this study will also contribute towards formulating a strategic action plan for on-site mangrove management.

MATERIALS AND METHODS

Study area

Air Telang Protected Forest (ATPF) is a coastal protected forest area dominated by mangroves. This area is located in Muara Telang and Banyuasin II Sub-districts, Banyuasin District, South Sumatra Province, Indonesia which covers about 12,660.87 ha (Figure 1). Its boundaries are as follows: (i) Bangka Strait and Banyuasin River at the north boundary, (ii) Muara Telang Sub-district and Banyuasin II Sub-district at the east boundary, (iii) Muara Telang Sub-district at the south boundary, and (iv) Banyuasin River at the west boundary (Department of Forestry and Plantation of the Banyuasin District 2010).

Materials and methods

The data were collected based on the observation of vegetation characteristics and physicochemical conditions of the study sites from February 2015 to June 2016. Vegetation sampling locations were determined by purposive sampling method that was based on the classification of image processing map and field surveys, for natural succession areas and also for restoration results. The sampling locations consisted of bushes and mangroves vegetation, but not plant cultivation areas. The sampling location consisted of 8 transects (Figure 1) with the criteria as presented in Table 1. Each sampling site has a 100m long line transect that is created from west to east (Figure 1). Plant observation plots were made on each transect with different sizes, based on the life-forms. Plot size for seedlings was 1 × 1 m^2, for saplings n5 × 5 m^2 and 10 × 10 m^2 size for trees (Mueller-Dombois and Ellenberg 1974).

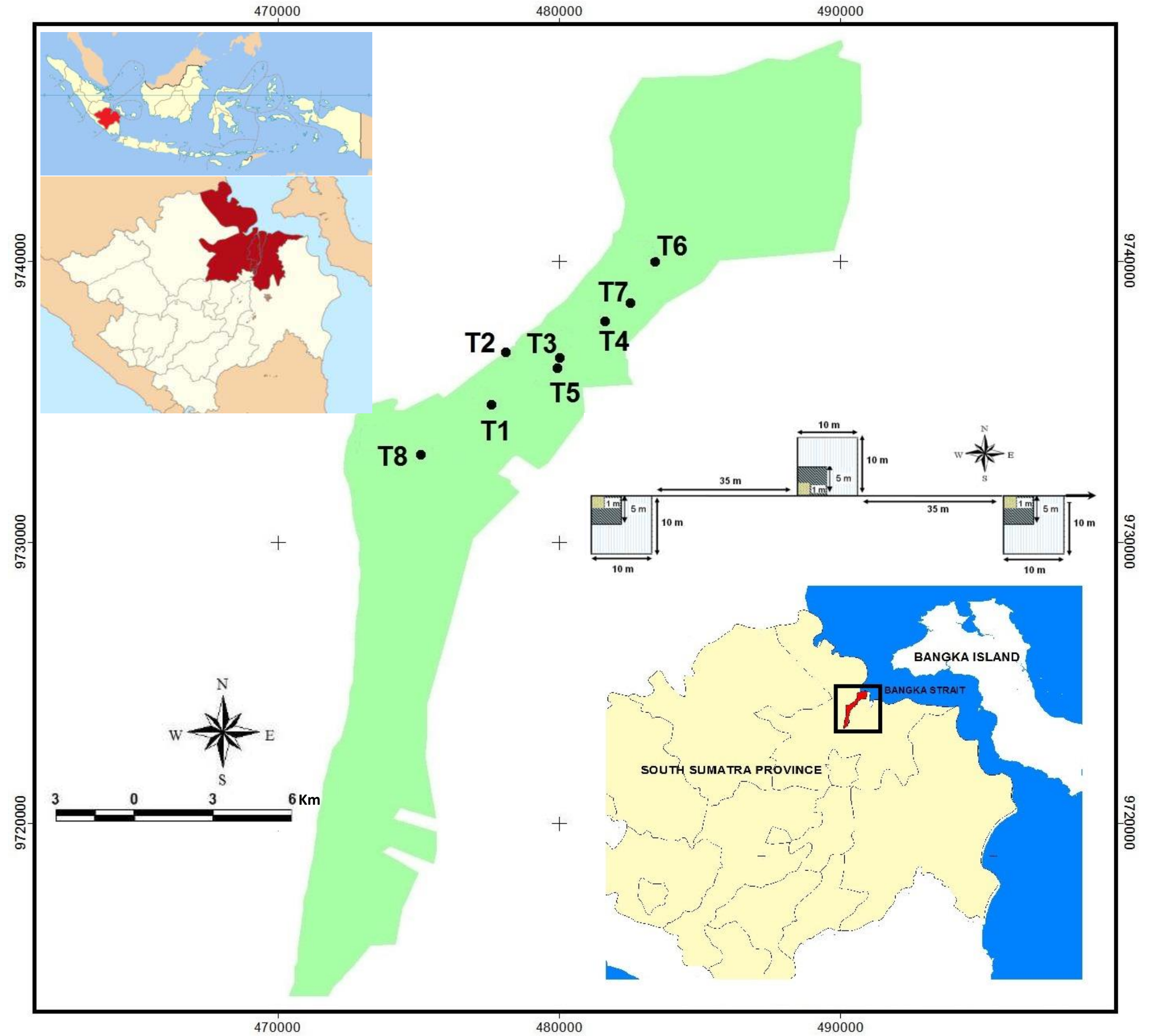

Figure 1. Location of sampling points for study of vegetation and physicochemical variables in the Air Telang Protected Forest (ATPF) area of Muara Telang and Banyuasin II Sub-districts, Banyuasin District, South Sumatra, Indonesia (insert: Design of sample plots by transect line method)

Table 1. General vegetation characteristics of sampling sites in the Air Telang Protected Forest, Banyuasin District, Indonesia

Study site	Vegetation category	Disturbance type	Area status	Soil character
T1	Primary forest	Aquaculture	Natural succession	Muddy
T2	Primary forest	(none)	Natural succession	Muddy
T3	Secondary forest	Illegal logging	Natural succession	Muddy
T4	Secondary forest	Illegal logging	Natural succession	Muddy
T5	Shrub	Burning	Natural succession	Dry
T6	Disturbed primary forest	Illegal logging	Natural succession	Muddy
T7	Disturbed primary forest	Illegal logging	Natural succession	Muddy
T8	Secondary forest	Illegal logging	Restoration	Muddy

Table 2. Species diversity in the Air Telang Protected Forest, Banyuasin District, Indonesia

Species	Local name	Familia	Species type
Acanthus ilicifolius	Jeruju	Acanthaceae	True mangrove
Avicennia alba	Api-api	Acanthaceae	True mangrove
Sarcolobus globosa	(None)	Apocynaceae	True mangrove
Calamus sp	Rotan	Arecaceae	Mangrove associate
Nypa fruticans	Nipah	Arecaceae	True mangrove
Oncosperma tigillarium	Nibung	Arecaceae	Mangrove associate
Mikania micrantha	Sambung rambut	Asteraceae	Mangrove associate
Pluchea indica	Beluntas	Asteraceae	Mangrove associate
Cyperus rotundus	Rumput teki	Cyperaceae	Mangrove associate
Excoecaria agallocha	Buta-buta	Euphorbiaceae	True mangrove
Derris trifoliata	Tuba laut	Fabaceae	Mangrove associate
Sonneratia alba	Pedada/perepat	Lythraceae	True mangrove
Melastoma candidum	Senduduk	Melastomataceae	Mangrove associate
Xylocarpus granatum	Boli	Meliaceae	True mangrove
Nephrolepis sp	Paku	Nephrolepidaceae	Mangrove associate
Eragrostis sp	Rumput jarum	Poaceae	Mangrove associate
Imperata cylindrica	Alang-alang	Poaceae	Mangrove associate
Acrostichum aureum	Paku laut	Pteridaceae	True mangrove
Bruguiera cylindrica	Tomok	Rhizophoraceae	True mangrove
Rhizophora apiculata	Bakau	Rhizophoraceae	True mangrove

Physico-chemical l data f including soil pH, soil texture and soil organic carbon content was studied for soils of each transect. Soils samples tested were surface soils collected from 0-20 cm depth. For soil texture measurement, Hydrometer Method (Gee and Bauder 1986) was used whereas the organic carbon content measurement was according to Walkley and Black's Wet Oxidation Methods (Allison 1960).

The observed vegetation parameters for trees consisted of species, number of trees, diameter at breast height (DBH) and basal area, while for the seedlings and saplings was the species and numbers. Vegetation data were analyzed to obtain a density (individuals/ha), dominance (m^2 ha^{-1}) and frequency (%) (Kent and Coker 1992). Importance Value Index (IVI) was determined by the relative value of density, dominance and frequency (Neelo et al. 2015). The species diversity was determined by using the Shannon Diversity Index (Odum 1998; Krebs 1989; Magurran 2004). H' values can be categorized as very high if H'≥ 4, high if H'≥ 3-4, moderate if H'≥ 2-3, low if H'≥ 1-2 and very low H'≤ 1 (Barbour et al. 1999; Djufri et al. 2016).

The data obtained for soil physicochemical properties as well as vegetation features were further subjected to cluster analysis. The result obtained was in the form of a dendrogram which explained the influence of environmental factors on the formation of vegetation structure. The cluster analysis result is being used to study the degree of similarity of constituent components between one vegetation and another (Onrizal and Mansor 2016; Zelený and Schaffers 2012).

RESULTS AND DISCUSSION

Species composition

The total species diversity of all of the 8 sampling areas consisted of 20 species of plants belonging to 14 families (Table 2). There were 10 species of true mangroves, namely *Acanthus ilicifolius*, *Avicennia alba*, *Sarcolobus globosa*, *Nypa fruticans*, *Excoecaria agallocha*, *Sonneratia alba*, *Xylocarpus granatum*, *Acrostichum aureum*, *Bruguiera cylindrica*, and *Rhizophora apiculata*. Others were mangrove associate species which were rarely found in the mangrove forest vegetation.

Table 3. Growth stages of species in the study sites of Air Telang Protected Forest (ATPF) of, Banyuasin District, South Sumatra, Indonesia

Species	Study site							
	T1	T2	T3	T4	T5	T6	T7	T8
A. ilicifolius	c	-	-	-	-	-	-	c
A. aureum	-	c	c	c	c	c	c	c
A. alba	a, b, c	a, b, c	-	-	-	-	-	a, b
B. cylindrica	-	a, c	a	-	-	-	-	-
Calamus sp.	-	-	b	-	-	-	b, c	-
C. rotundus	-	-	-	-	c	-	-	-
D. trifoliata	c	-	c	c	-	-	-	c
Eragrostis sp.	-	-	-	-	c	-	-	c
E. agallocha	-	a	a, b	a, b, c		a, b	-	-
I. cylindrica	-	-	-	-	c	-	-	-
M. candidum	-	-	-	-	c	-	-	-
M. micrantha	-	-	-	-	c	-	-	-
Nephrolepis sp.	-	-	c	c	-	-	-	-
N. fruticans	a, c	a	-	a	-	a, b	a	-
O. tigillarium	-	-	a	-	-	-	-	-
P. indica	-	-	-	-	c	-	-	c
R. apiculata	-	a, b, c	a	a, b	-	a, b	a, b	c
S. globosa	-	-	-	c	c	-	-	-
S. alba	-	-	-	-	-	-	-	a
X. granatum	-	a, b	-	-	-	-	a, b	-
Total	4	7	8	7	8	4	5	8

Note: a = trees, b = saplings, c = seedlings

Table 4. Species Number (S), Shannon diversity index (H'), density (ind./ha) and basal area (m²/ha) for each life-forms in the study sites of Air Telang Protected Forest (ATPF) of, Banyuasin District, South Sumatra, Indonesia

Study site	Tree		Sapling		Seedling		Density (ind./ha)			Basal area
	S	H'	S	H'	S	H'	Tree	Sapling	Seedling	(m^2 ha^{-1})
T1	2	0.28	1	0.00	4	0.56	467	1,067	83,333	55.4
T2	6	0.62	3	0.42	4	0.45	767	1,867	53,333	132.2
T3	4	0.49	2	0.28	3	0.46	767	1,467	273,333	25.8
T4	3	0.47	2	0.30	5	0.45	1,000	3,200	390,000	97.8
T5	0	0.00	0	0.00	8	0.73	0	0	766,667	0.0
T6	3	0.48	3	0.20	1	0.00	1,033	3,200	316,667	86.6
T7	3	0.25	3	0.22	2	0.12	867	2,800	486,667	52.5
T8	2	0.20	1	0.00	6	0.63	200	267	370,000	2.1

Table 3 shows the occurrence of different growth stages, such as trees, saplings, and seedlings of the species in the sampling sites. Study sites T3, T5, and T8 have the highest number of species (8 species) whereas T1 and T6 have the lowest number of species (4 species). *A. alba*, *N. fruticans*, *E. agallocha*, and *R. apiculata* are the species that were found in all growth stages (tree, sapling and seedling) in the study sites.

Vegetation structure

The number of species (S) and diversity index (H') vary in the 8 sampling sites, for each growth level (Table 4). Overall H' for the growth level of tree, sapling and seedling stages are classified as very low (<1). T2 is a primary forest that has the highest species number for tree level (6 species) with the highest H' value of 0.62. T2 also has the highest H' value for sapling level which is 0.42 as well as T6 and T7 with three species, respectively. Meanwhile, for the seedling level, T5 has the largest species number that is 8 species with the highest H' value of 0.73.

Vegetation density and basal area are shown in Table 4. Sites T6 (primary forest) and T4 (secondary forest) have the highest tree density of 1,033 and 1,000 individuals/ha, respectively and they also showed the highest saplings density (3,200 ind./ha). T5 does not have any trees and saplings, but highest seedlings with 766,667 ind./ha. The highest basal area of 132.2 m^2 ha^{-1} was recorded in T2 (primary forest) which is followed by T4 with 97.8 m^2ha^{-1}.

Physico-chemical features of soil and water

Physical and chemical features of soil and water are presented in Table 5. The soil in the study area showed multiform textures, varying from a smooth texture with more clay to rough texture with more sand. Among the soil particles, e percentage of sand was lowest with an average of 25.17%, while the percentage of silt and clay was almost the same with an average of 37.38% and 37.45%, respectively. C-organic content of the soil surface (0-20 cm depth) in the study area is ranged from 1.56% to 4.72% with an average of 2.62% which is classified as moderate. Water salinity ranged from 8% to 25‰ with an average of 19‰. The pH of soil ranged from 5.20 to 6.40 with an average of 6.08, while the water pH was around 5.05 to 6.50 with an average of 5.80, both of which are classified as slightly sour.

Grouping based on vegetative structures

Dendrogram shown as Figure 2 is the result of cluster analysis of the eight sampling points based on the physicochemical properties of soil and water, and vegetation data. The results of this cluster analysis produced three types based on dominant and co-dominant species. Each type was named according to the average value Important Value Index (IVI) of the most dominant species in each group (Table 6).

Group I was *Acrostichum-Rhizophora* type which was represented by sampling sites T3, T4, T6, T7, and T8; Group II was *Nypa-Avicennia* type represented by T1 and T2, and Group III was *Cyperus-Acrostichum* type represented by site T5. The first group can be further categorized into two, namely disturbed primary forest (T6 and T7) and secondary forest (T3, T4, and T8). Group II is classified only as primary forest (T1 and T2). Group III represented by site T5 is a shrub.

Discussion

Dominant species

Nypa fruticans, *R. apiculata*, *A. alba*, *E. agallocha*, *A. aureum*, *C. rotundus* and *Nephrolepis* sp. were dominant species in several sampling points based on IVI (%) of each species (Table 6). *N. fruticans* and *R. apiculata* were the dominant species at tree level; *R. apiculata*, *A. alba* and *E. agallocha* are dominant species at saplings stage; *N. fruticans*, *A. aureum*, *C. rotundus*, and *Nephrolepis* sp. are dominant species at seedlings stage.

Nypa fruticans was the dominant species at tree level in four sampling points and also dominant in one sampling point for seedlings. This species is found in five sampling points (62.5% of the total sampling points) where trees were found in all these five sampling points, while only saplings and seedlings were found in only one sampling point (Table 3). *R. apiculata* was the dominant species in two sampling points for tree level and at three sampling points for saplings stage. This species was present at six sampling points (75% of the total sampling points), trees were found in five sampling points, saplings in four sampling points and seedlings in two sampling points.

Avicennia alba was the dominant species in two sampling points for saplings stage. This species was found only in three sampling points (37.5% of the total sampling point) where both trees and saplings were found, meanwhile, seedling stage was found in only two sampling points. *E. agallocha* was the dominant species in two sampling points for saplings level. This species was found in four sampling points (50% of the total sampling points), trees were found in all the four sampling points, saplings were found in three sampling points and seedlings in a single sampling point.

Table 5. Physico-chemical properties of water and soil in different sampling sites of Air Telang Protected Forest (ATPF), Banyuasin District, South Sumatra, Indonesia

Study site	Water		Soil				
	Salinity (‰)	pH	pH	C-org. (%)	Soil texture (%)		
					Sand	Silt	Clay
T1	18	6.20	5.20	2.38	32.15	38.75	29.10
T2	23	5.10	6.25	2.50	41.04	40.02	18.94
T3	19	5.05	6.10	1.56	25.21	29.90	44.89
T4	21	6.05	6.40	4.72	25.82	42.05	32.13
T5	8	6.40	6.20	2.69	40.75	24.93	34.32
T6	20	5.50	5.70	2.11	7.69	44.54	47.77
T7	19	5.60	6.40	3.20	15.51	38.28	46.21
T8	25	6.50	6.40	1.79	13.18	40.57	46.25

Table 6. Three dominant species based on IVI of each growth stage of all vegetation types (*Acrostichum-Rhizophora*, *Nypa-Avicennia*, and *Cyperus-Acrostichum*)

Acrostichum-Rhizophora type

Life-forms	Species	IVI (%)					Mean
		T3	T4	T6	T7	T8	
Seedling	*A. aureum*	60.2	98.3	200.0	166.8	62.6	117.6
	Nephrolepis sp	79.7	34.6	-	-	-	22.9
	D. trifoliata	60.2	22.7	-	-	30.2	22.6
Sapling	*R. apiculata*	-	94.2	147.5	145.7	-	77.5
	E. agallocha	103.0	105.8	24.2	-	-	46.6
	A. alba	-	-	-	-	200.0	40.0
Tree	*R. apiculata*	125.3	88.2	83.0	185.1	-	96.3
	N. fruticans	-	129.3	143.3	90.2	-	72.6
	E. agallocha	109.7	82.5	73.7	-	-	53.2

Nypa-Avicennia type

Life-forms	Species	IVI (%)		Mean
		T1	T2	
Seedling	*A. aureum*	-	106.3	53.1
	A. alba	57.0	47.9	52.5
	N. fruticans	77.5	-	38.8
Sapling	*A. alba*	200.0	39.3	119.6
	R. apiculata	-	107.1	53.6
	X. granatum	-	53.6	26.8
Tree	*N. fruticans*	205.4	150.9	178.1
	A. alba	94.6	14.0	54.3
	R. apiculata	-	63.6	31.8

Cyperus-Acrostichum type

Life-forms	Species	IVI (%)	Mean
		T5	
Seedling	*C. rotundus*	47.8	47.8
	A. aureum	47.3	47.3
	P. indica	30.4	30.4

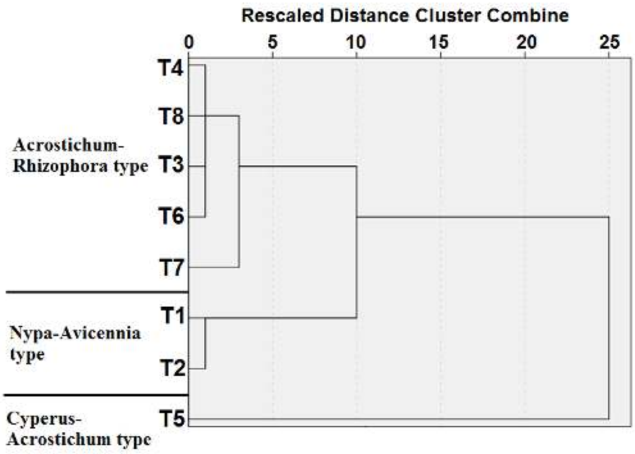

Figure 2. Three types of dominant and co-dominant species based on cluster analysis based on physico-chemical properties of soil and water, and vegetation data

Acrostichum aureum was the dominant species in five sampling points for seedlings. This is a cover species that was found in seven sampling points (87.5% of the total sampling points). *C. rotundus* and *Nephrolepis* sp. which are also the cover plant species, were dominant in one each sampling point for the seedling stage. *C. rotundus* was found in only one sampling point (12.5% of the total sampling points) and *Nephrolepis* sp. was found in two sampling points (25% of the total sampling points).

Based on average IVI value, *N. fruticans* was the most dominant species for tree level (average IVI value 89.9%), *R. apiculata* was the most dominant species for sapling level (IVI value 61.8%) and *A. aureum* was the most dominant species for seedling stage (IVI value 92.7%). *N. fruticans* was the most dominant tree plant species and it was present in more than 50% of the total sampling points, in all growth levels. This was expected because a disturbed mangrove forest, such as the one at ATPF area, will be generally dominated by *N. fruticans* which is the indicator species. In the disturbed mangrove forests, this species invades all of the mangrove zones, starting from the zone close to the sea (seaward zone), middle zone (mid zone) and the zone near the mainland (landward zone). *N. fruticans* invasion occurs easily in the open area with less of mangrove cover because this plant produces a lot of fruits in bunches which floats spreads by the tidal flow. Later, it competes with other species of this region which are displaced permanently (Akpakpan et al. 2012). Their invasion gradually replaces mangroves which can cause habitat changes and fish productivity decline (Okpiliya et al. 2013).

Rhizophora apiculata also showed high dominance and was spread in more than 50% of all sampling points, in all growth stages. It is a true mangrove species that can grow in the mid-zone of a mangrove forest area (Laulikitnont 2014). This species has rod-shaped roots (taproot) which is suitable for establishment of the trees in the less stable muddy soil.

Acrostichum aureum is a fern which is classified as a true mangrove plant with high dominance and spread in almost all sampling points. This species is found in disturbed mangrove forest land, such as felled mangrove forest area (Giesen et al. 2007). It is commonly found in the open areas that are directly exposed to sunlight. Its presence may inhibit the regeneration of other mangrove species.

Physico-chemical conditions of soil and water

High clay content indicated that the soil in this area has a high cation exchange capacity (CEC) value. This is because the clay fraction has a large negative charge (Dharmawan and Siregar 2008). Soil with high CEC value has a high ability to keep nutrients so that the nutrients in the soil are not easily washed away by water flow.

Different types of soil can affect the distribution of mangrove species. Stable soil is not eroded and has an ideal depth to support the mangrove growth optimally. The degraded mangrove forests have soil texture with sand, silt and clay contents of 45%, 30%, and 25%, respectively while the soils of natural mangrove forests have 44%, 36% and 20% of these contents (Eugene et al. 2016).

C-organic content of soil in the study area was high. This was highly affected by the presence of litter that can increase soil biomass. High mangrove vegetation density will increase litter fall that will further increase C-organic content. Mean plant carbon stocks of mangrove forests with high, medium and low canopy thickness were 161, 47, and 10 Mg/ha, respectively (Kauffman et al. 2014).

Water salinity of the study area showed a wide range between 8% and 25‰. This happened because this area was still affected by freshwater from the Banyuasin and Telang rivers and also saltwater from Bangka Strait. Mangrove vegetation consists of halophytic plants that can grow in high salinity water through adaptive mechanisms in order to reduce competition with other vascular plants. But extreme salinity (> 50 %) can threaten all species of mangrove vegetation (Alongi 2009).

The soil in the study area showed an almost neutral pH due to salt influence. The existence of Al and H acid cations were pressured by Na and K base cations so it can flow out of the complex exchange and leached causing the higher Na and K cations in the soil (Dharmawan and Siregar 2008). The base cation content in the soil causes the soil pH value to rise close to neutral. The research of Mukhlisi and Sidiyasa (2014) also showed slightly acidic soil pH range (5.0 to 6.5) in Mangrove Information Centre (PIM) Berau, East Kalimantan.

Water in the ATPF area also had a slightly acidic pH. Water pH measurement results showed a lower average value than the soil pH. This may be due to the fact that ATPF Region is a mangrove forest area which is located along with the upstream of the estuary of Banyuasin river so that the water pH is still influenced by river water which tends to be acidic. The water pH in the Awat-Awat mangrove forests, Lawas Sarawak, between disturbed mangrove forests and natural was not significantly different and the average was 7.07 and 6.84, respectively (Gandaseca et al. 2016).

Figure 3. Three types of vegetation structures of Air Telang Protected Forest (ATPF), Banyuasin District, South Sumatra, Indonesia. A. *Cyperus-Acrostichum* type, B. *Acrostichum-Rhizophora* type, C. *Nypa-Avicennia* type

Density and diversity

T6 has the highest tree density of 1,033 ind./ha and followed by T4 with 1,000 ind./ha with the basal area of 86.6 and 97.8 m^2 ha^{-1} (Table 4), respectively. Although the tree level density in both transects was the highest, these two transects had only three tree species, namely *R. apiculata*, *E. agallocha* and *N. fruticans*. This was in accordance with the features of disturbed primary forest or secondary forests, with a high tree density but small stem diameter and canopy cover as well as low species diversity.

T4 and T6 were not only had highest trees but also had the highest saplings (3,200 ind./ha.). Both of these transects also had saplings and trees of similar species, of two species in T4 (*R. apiculata* and *E. agallocha*) and three species in T6 (*R. apiculata*, *E. agallocha* and *N. fruticans*). T5 was a transect that did not have any trees and saplings, but it had highest seedlings, i.e. 7,66,667 ind./ha. It can be acceptable because T5 was a transect with shrub vegetation. It was dominated by grasses such as *C. rotundus* and *A. aureum*.

Low H' value in all sampling points for the three growth levels indicated that the species diversity is low. H' value for tree-level across transects ranged from 0.00 to 0.62. Tree level species were not found in T5 so the H' value was 0. This happened because T5 was vegetation composed of shrubs, dominated by only cover plants. There were six species in T2, belonging to 5 families which were the highest species number compared to other transects. This was understandable since T2 represented primary forest vegetation dominated by trees.

H' for the sapling level was ranging from 0.00 to 0.42. The H 'value for T1, T5 and T8 were equal to 0.0, although only one species was found in T1 and T8 and there were no species in T5. This has happened because H' is an index that shows the diversity of a community so that will have a value greater than 0 if there is diversity of at least two species. There were three species in T2 classified into 3 families and the highest H' value for saplings level as compared to other transects, although T6 and T7 have similar species number with T2. This is because the H' value does not depend only on the number of species in the community, but also on the proportion of each species in the community.

H' values of seedlings ranged from 0.00 to 0.73. Only one species was found in T6 while eight species in T5 belonging to six families. T6 was disturbed primary forest vegetation where the only existed cover plant was *A. aureum*. The maximum species for seedlings stage was found in T5 as compared to other transects. This was due to T5 was vegetation composed of shrubs and dominated by cover plants.

Species diversity index for the three growth levels of the vegetation (tree, sapling and seedling) in ATPF was categorized as very low. This is because this area has been degraded by various anthropogenic activities, such as settlements, farming, agriculture, aquaculture, port operations, and logging.

Type of vegetation structure

The degree of similarity between the constituent components of one vegetation with another can be determined by cluster analysis that is useful to determine the groups of vegetative structure in the ATPF area. Inequality in size or vegetation diversity was determined using Squared Euclidean Distances where the position of each transect in the dendrogram described the distance between transects, meant that the adjacent transects connected by a connection line indicated the distance between both transects was closer than the other (Arrijani et al. 2006).

The cluster analysis results and vegetative structures grouping based on two dominant species showed that the vegetation in ATPF area may be categorized into three groups (Figure 2), i.e. *Acrostichum-Rhizophora* type (Group I), *Nypa-Avicennia* type (Group II) and *Cyperus-Acrostichum* type (Group III). Disturbed primary forest vegetation and secondary forests are in group I and are suffered by logging. T8 was an area that was restored through mangroves planting in 2011, while T3, T4, T6, and T7 were the natural succession area. In group II, T1 was the result of natural succession of abandoned pond for over 10 years and it has been a primary forest. Meanwhile, T2 was a natural forest located at the Banyuasin Riverside. Group III represented by T5 was a traditional plantation by the community and then left for about 2 years. T5 was the only sampling location that has dry land character, while the other locations were muddy.

Cyperus-Acrostichum type was shrub vegetation formed due to land clearing with burning by the community for the plantations and then left vacant (Figure 3a). The vegetation structure of this group can be said at the invasion stage where there are various plant species inhabited here as a result of the fruit invasion, seed and cover plant spore carried by animals, water or wind. The development of pioneer species is determined by the filtration/sedimentation, patterns of currents and tides, as well as the availability of propagules and seed from the surrounding wood (Djohan 2007). However, distribution of seedlings may be disrupted due to burning (Zhao et al. 2012).

Acrostichum-Rhizophora type consisted of disturbed primary forests and secondary forests. The Characteristics were the presence of trees with small DBH and shrubs in the forest floor (Figure 3b). The presence of shrubs was due to the openings in the canopy cover of large trees because of logging which allows the penetration of sunlight to the forest floor promoting the growth and development of cover plants (shrubs). According to Biswas et al. (2012), there are two dominant processes that affect mangrove forest succession after disruption. First is the limitation of propagules due to the damage of mature trees that is capable of producing seed. The second is the formation of a barrier to the spread of propagules as the result of biological invasions by several species of lower plants (shrubs, herbs, and climbers).

Nypa-Avicennia type (Group II) can be categorized as primary forests (Figure 3c). This type was included in stable stage and climax and indicated by the dominance of trees with large diameter and less of cover plants. This vegetation structure has reached stability and harmonious relationship among members of community as indicated by an unchanged community structure, and the dynamic equilibrium with its environment. The climax in mangrove forests is an edaphic climax (Odum 1998). This is caused by the climate influence (sunlight, air temperature, air humidity, and precipitation) and the dominant edaphic influence (growing substrate) due to the intensive sedimentation in the mangrove forests. Succession in the mangrove forest is very active due to the movement of tidal currents that allow the entry of sediments and the invasion of various species from different locations with different adaptations (Setyawan et al. 2005).

Three types of vegetation structures found in the ATPF area namely *Cyperus-Acrostichum*, *Acrostichum-Rhizophora* and *Nypa-Avicennia* have different constituent species. This is due to the influence of environmental factors, especially the soil condition, sea level rise, tidal inundation, salinity, temperature as well as nutrients (Laulikitnont 2014; Nagelkerken et al. 2008). The soil condition and tidal inundation determine the distribution of mangrove species (Strauch et al. 2012). Mangrove forest vegetation structure and its distribution are also dependent on geomorphology and habitat changes (Cunha-Lignon et al. 2009), because mangrove forest consists of unique plants that have morphological and physiological adaptability to the environmental changes (Chakraborty 2013; DasGupta and Shaw 2013; Motamedi et al. 2014). Moreover, the anthropogenic activities in coastal wetlands also have an impact on the changes of structure and function of wetlands that leads to the loss of habitat, changes in hydrology and sedimentation, declining quality of water, as well as change of nutrient and pollutant dynamics that have an impact on composition change of mangrove forest vegetation (Lee et al. 2006; Satyanarayana et al. 2013). The increasing anthropogenic pressure will slower the succession process because of the loss of root mass that is important in holding the propagules (Di Nitto et al. 2008).

ACKNOWLEDGEMENTS

The first author is grateful to the Universitas PGRI Palembang and the Kementerian Riset Teknologi dan Pendidikan Tinggi, Republic of Indonesia, for funding this research.

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