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Status of coastal forests of the Northern Sumatra in 2005 (after 2004's tsunami catastrophe)

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Abstract. *Onrizal, Mansor M. 2015. Status of coastal forests of the Northern Sumatra in 2005 (after 2004's tsunami catastrophe). Biodiversitas 17: 44-54.* The first intensive ecological study of coastal vegetation including mangrove, littoral and peat swamp forests after the 2004 tsunami catastrophe in Northern Sumatra was conducted from January to December 2005 where 16 sampling sites along 2960km coastline in Northern Sumatra were selected. In each site, one quadrate of 100 m x 100 m was established and divided into 10 m x 10 m subplots where all standing trees of ≥ 2 cm diameter at breast height (DBH) were identified to species level and measured. Overall 54,871 standing trees were recorded in 16 sites comprising 84 species in 65 genera and 37 families. Mangrove trees *Rhizophora apiculata* and *R. mucronata* were widely distributed and are dominant in most of the sampling sites. This indicated that these species have stronger resilient compared to other species. The highest value of Shannon-Wiener index of species and Evenness index of species was 3.03 and 0.85, respectively. It means that some sites were rich in biodiversity which harbors various species of plants. Subsequently, undisturbed coastal forests including mangroves, littoral forests and peat swamp forests characterized by dense stands, mixed species and structures play an important role in coastal protection against tsunami. Therefore, the coastal vegetation is needed to conserve the biodiversity and to maintain the production capacity as part of sustainable and longlasting vegetation bioshield.

Keywords: Biodiversity, bioshield, resilient species, natural hazard, integrated coastal forest management system

INTRODUCTION

On 26th December 2004, a mega-thrust earthquake of magnitude ranges from 9.1 to 9.3 on Richter scale occurred off the northwestern coast of Northern Sumatra, Indonesia (Bilham 2005; Chen et al.2005; Lay et al. 2005; Ghobarah et al. 2006; Subarya et al. 2006; Chlieh et al. 2007). This huge earthquake triggered giant tsunami waves, which the combined destructive impact of the earthquake and the tsunami was enormous to the coastlines and its inhabitants lining coastal shores of the Indian Ocean, both Asia and Africa. The earthquake and tsunami not only caused human fatalities and hardship. They also caused destruction of the coastal vegetation and natural resources.

To date, there are limited publications on Northern Sumatra coastal vegetation particularly in peer-reviewed journals before the 26th December 2004 Indian Ocean tsunami disaster. Whitten et al. (1997) provided information and accounts on ecology of Sumatra, however the facts related to the ecology of Northern Sumatra coastal vegetation was still lacking information. According to Kartawinata (1990, 2005), the ecological studies of natural vegetation in Northern Sumatra are rare with only four studies were conducted in last six decades. All of them are in tropical lowland forests which three of them located at Gunung Leuser National Park (GLNP), and one of them was at Batang Gadis National Park (BGNP).

Northern Sumatra coastal studies increased after the tsunami catastrophic; however most of them are about coastal geo-morphological studies focusing on earthquake and tsunami. Ammon et al.(2005), Bilham (2005), Borrero (2005a, 2005b), Borrero et al. (2006a, 2006b), Lay et al. (2005), Subarya et al. (2006), Natawidjaja and Triyoso (2007), Kayanne et al. (2007), Kusuma et al. (2008) and Meilianda et al. (2010) studied on the impact of tsunami and earthquake on coastal deformation and destruction. Campbell et al. (2007) and Hagan et al. (2007) studied the impact of tsunami and earthquake on coral reef in Northern Sumatra. Descriptive study on Aceh coastal impact and recovery from tsunami was done by Wong (2009). Some articles on coastal vegetation and resource destructions by tsunami mainly based on remote sensing and geographic information system. Chen et al. (2005), Shofiyati et al. (2005), Iverson and Prasad (2007), and Liew et al. (2010) provided such examples. It should be noted that coastal vegetation studies in Northern Sumatra were very limited, both before and after the Indian Ocean tsunami disaster. Consequently, the ecology of coastal vegetation in Northern Sumatra is mostly unknown.

The aim of this study is to assess the coastal vegetation communities and diversity at affected areas by tsunami in Northern Sumatra.

MATERIALS AND METHOD

Study sites

The 16 study sites have been established from January to December 2005 (Table 1) along 2960-km coastline in Northern Sumatra (Figure 1). One sample plot 100 m x 100 m (1 ha) was established in each study site. Each plot was divided into 10 m x 10 m subplots; therefore, there are 100 subplots within each sample plot.

Data collection

The most effective and acceptable method to study and quantify species diversity and vegetation communities is plot sampling method (e.g. Condit et al. 1996, Shimida 1984). All trees (or woody plant) greater than 2 cm DBH were identified and measured. The tree diameter was measured (a) at 20 cm above the highest prop-roots for *Rhizophora* species, (b) whereas for tree when the stem forked below 130 cm, individual 'branches' in a clump were treated as separate stems, or (c) at 1.3 m above ground level (diameter at breast-height; DBH) for tree species without stilt roots, (c) except for mangrove palm of *Nypa fruticans*, which the diameter was by measuring the diameter of clump.

Table 1. Study sites of coastal vegetation after the 2004 tsunami

Site code	Location	Coastal region	Forest type
S01	Deah Gelumpang, Banda Aceh	North coast	Mangroves
S02	Gampong Jawa, Banda Aceh	North coast	Mangroves
S03	Neuhen, Aceh Besar	North coast	Mangroves
S04	Ujung Batee, Aceh Besar	North coast	Littoral forests
S05	Lhok Nga, Aceh Besar	West coast	Littoral forests
S06	Lhok Bubon, Aceh Barat	West coast	Mangroves
S07	Rawa Singkil, Aceh Singkil	West coast	Peat swamp forests
S08	Rawa Singkil, Aceh Singkil	West coast	Mangroves
S09	Tabuyung, Madina	West coast	Mangroves
S10	Pasar Lahewa, Nias Utara	Offshore	Mangroves
S11	Teluk Belukar, Gunung Sitoli	Offshore	Mangroves
S12	Sirombu, Nias Barat	Offshore	Agroforests
S13	Sirombu, Nias Barat	Offshore	Mangroves
S14	Kuala Pekanbaro, Sigli	East coast	Mangroves
S15	Kuala Keureutou, Aceh Utara	East coast	Agroforests
S16	Jaring Halus, Langkat	East Coast	Mangroves

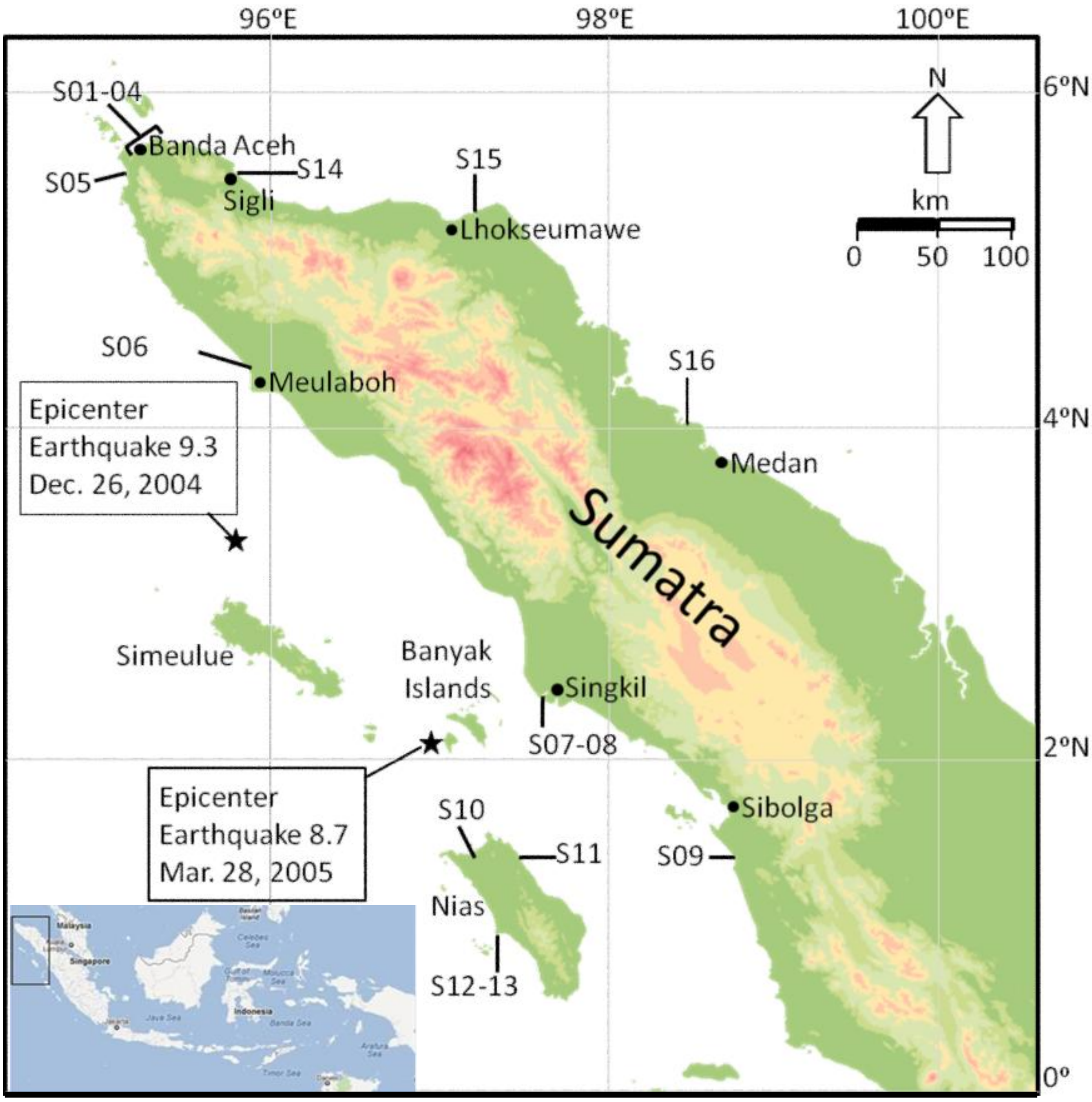

Figure 1. Distribution of study sites along Northern Sumatra coasts

Data analysis

Stem density (individuals/ha), basal area (m^2/ha) and Importance Value Indices (IVI) were calculated for each sampling sites. To determine the dominant species (in term of phytosociological position in a vegetation community), the IVI from Curtis and McIntosh (1951) and Magurran (2004) was adopted. The IVI of each species for tree stage was calculated by summing the relative density, relative frequency and relative dominance. From the data collected, a species diversity analysis using statistical software MVSP (Multi Variate Statistical Programme) ver. 13.3d by Kovach Computing Services (2002) was conducted.

Stem density of coastal vegetation (individual/ha) of 16 study sites was used to distinguish the community structure by hierarchical clustering performed using the MVSP program ver. 13.3d by Kovach Computing Services (2002) following UPGMA method. In this case, to know the species indicator of each vegetation group, the IVI were calculated for each groups.

RESULTS AND DISCUSSION

Taxonomic composition

A total of 54,871 standing trees (i.e., 47,723 of DBH 2 to < 10 cm, and 7,148 DBH ≥ 10 cm) were recorded in 16 sites in Northern Sumatra coast immediately after the 2004 tsunami encompassing 84 species in 65 genera and 37 families. The species are indicated as persistent species and surviving against the natural catastrophic.

In term of number of species, the family of Rhizoporaceae (8.33% of total species) was recorded as family with largest number of species, followed by Arecaceae (7.14%), Euphorbiaceae, Lauraceae, and Malvaceae (each 5.95%). The families with highest individual count in 16 study sites were Rhizophoraceae (82.86%), followed by Arecaceae (7.43%) and Meliaceae (2.55%). The densities of other family have only less than 2%.

The species of *Rhizophora apiculata* was recorded as widest distribution (10 sampling sites or 62.5% of total sampling sites), following by *Rhizophora mucronata* (8 sampling sites or 50.0% of total sampling sites) and *Xylocarpus granatum* (7 sampling sites or 43.8% of total sampling sites). The others (74 species) were recorded at limited distribution that varied from 1 to 2 sampling sites.

Important Value Index

The dominant species varied between 16 study sites (Table 2). The mangrove tree *Rhizophora apiculata* was recorded as dominant species at 5 sites (31.25% of total sites), i.e., S08-11 and S16. Subsequently, the mangrove palm *Nypa fruticans* dominated three sites (18.75% of total sites), i.e., S02, S06, and S13. Three species, i.e., mangrove tree *Rhizophora mucronata,* littoral tree *Casuarina equisetifolia* and agroforest tree *Cocos nucifera* were found to be dominant in 2 sites. Lastly, the mangrove tree *Rhizophora stylosa* and peat swamp tree *Tetramerista glabra* were recorded as dominant species at each one site. The co-dominant species also varied between sites.

Diversity indices

The value of diversity indices has been listed in Table 3. The highest value for richness (*R*) was recorded from S07 (peat swamp forests at Singkil swamps, 6.74) and the lowest value was recorded from S05 (littoral forests, 0.00) where this site contained only one species immediately after tsunami disaster, namely *Casuarina equisetifolia*. For diversity (*H'*), the highest value was also recorded in S07 (3.03), followed by S11 (1.49), S08 (1.45) and S16 (1.36). The lowest value for diversity (*H'*) was recorded also in S05 (0.00). Subsequently, the highest value for evenness (*E*) was recorded at S16 (0.85), followed by S07 (0.76), S01 (0.73) and S11 (0.72), while the lowest for *E* value was recorded at S05 (0.00). The highest value for richness (*R*) and diversity (*H'*) recorded in S07, a peat swamp forests, compared to other sites, which was probably due to the naturally the forest type was richer compared to mangroves and littoral forest in the same size of plot.

Vegetation community

The result of cluster analysis allowed for a floristically (cluster group and indicator species) and ecologically (habitat/vegetation type) sound scheme of six main vegetation groups (A-F) of the 16 study sites. A UPGMA dendrogram is shown in Figure 2. Bray Curtis's coefficients for species dissimilarities are more than 0.8 between groups suggesting that one group contain many different species compared to other group, as shown in Figure 2.

The Group A contains three sites, namely S01, S03, and S14 and represented of mangrove forests along the affected coast by tsunami in Northern Sumatra. Two sites of them were situated at North Coast, and remaining site was in East Coast. Before tsunami, all sites were degraded mangroves surrounding the aquaculture ponds which the ponds were developed with conversion of mangrove forests. This group contains nine species, which the species indicator was *Rhizophora mucronata* having mean density and IVI were 115.7 individual/ha and 133.5%, respectively. The second species indicator in this group was *R. stylosa*, which the mean density and IVI were 112.7 individual/ha and 73.3% (Table 4). Therefore, this group is represented by *R. mucronata*-*R. stylosa* communities.

The Group B contains five sites, namely S08, S09, S10, S11 and S16. They represented of the healthy mangrove forests along the affected coast by tsunami in Northern Sumatra. Two sites (S08 and S09) were situated in the West Coast, two sites were situated in the Offshore (S10 and S11), and remaining site was in the East Coast (S16). Prior to tsunami, all sites were healthy mangroves and they were low or without disturbance both natural and anthropogenic factors. This group contains 18 species, which the species indicator was *Rhizophora apiculata* having mean density and IVI were 5,426.2 individual/ha and 140.4%, respectively. The IVI of others species was lower than 40%. In addition, *Dolichandrone spathacea* was recorded as the lowest IVI, i.e., 0.1% and it mean density was only 0.6 individual/ha (Table 4). Therefore, this group is represented by *R. apiculata* communities.

The Group C contains three sites, namely S02, S06 and S13. They represented of the landward zone of mangrove forests along the affected coast by tsunami in Northern Sumatra. Each site was distributed in North Coast (S02), West Coast (S06) and Offshore Coast (S13). Before tsunami, sea ward and mid ward of the mangrove forests were mostly converted to aquaculture ponds. This group contains nine species, which the species indicator was *Nypa fruticans* with mean density and IVI of 1,116.7 individual/ha and 58.9%, respectively. The IVI of others species was lower than 10%. In addition, *Xylocarpus granatum* and *Ceriops tagal* was recorded with the lowest IVI, i.e., 0.3% and its mean density was only 0.3 individual/ha (Table 4). Therefore, this group is represented by *N. fruticans* communities.

The Group D contains two sites, namely S04 and S05. They represented of the littoral forests along the affected coast by tsunami in Northern Sumatra. Site S04 was situated in the North Coast, and remaining site was in the West Coast. Prior to tsunami, the sites were as recreational areas. This group contains three species, where the species indicator was *Casuarina equisetifolia* having mean density and IVI were 173.0 individual/ha and 273.8%, respectively. The IVI of others species were only 19.4% for *Gliricidia sepium* and 6.8% for *Pterocarpus indicus* (Table 4). Therefore, this group is represented by *Casuarina equisetifolia* communities.

Table 2. List of dominant and co-dominant species at each sampling site of Northern Sumatra coast immediately after the 2004 tsunami disaster

Study site	Dominant species		Co-dominant species	
	Species	IVI (%)	Species	IVI (%)
S01	*Rhizophora mucronata*	173.4	*Xylocarpus granatum*	62.3
S02	*Nypa fruticans*	282.7	*Oncosperma tigillarium*	3.3
S03	*Rhizophora stylosa*	144.9	*Avicennia marina*	90.6
S04	*Casuarina equisetifolia*	269.3	*Gliricidia sepium*	22.6
S05	*Casuarina equisetifolia*	300.0	(None)	-
S06	*Nypa fruticans*	285.6	*Excoecaria agallocha*	4.2
S07	*Tetramerista glabra*	66.8	*Syzygium pycnanthum*	27.2
S08	*Rhizophora apiculata*	139.0	*Sonneratia caseolaris*	33.1
S09	*Rhizophora apiculata*	109.6	*Bruguiera parviflora*	80.1
S10	*Rhizophora apiculata*	207.2	*Bruguiera sexangula*	49.5
S11	*Rhizophora apiculata*	97.2	*Bruguiera sexangula*	79.2
S12	*Cocos nucifera*	282.3	*Arenga pinnata*	6.5
S13	*Nypa fruticans*	297.2	*Rhizophora apiculata*	1.4
S14	*Rhizophora mucronata*	248.6	*Avicennia marina*	33.6
S15	*Cocos nucifera*	278.9	*Mangifera indica*	6.7
S16	*Rhizophora apiculata*	134.0	*Xylocarpus granatum*	71.4

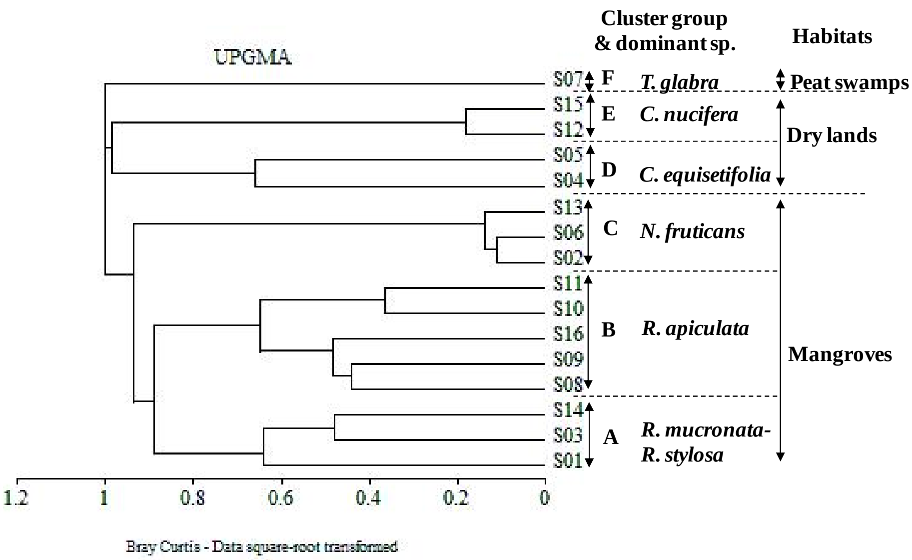

Figure 2. Dendrogram generated by cluster analysis of the 16 coastal forests investigated showing the species dissimilarities between the sampling sites. Six groups and three habitats can be distinguished; group (A) contains 3 sites of the mangrove forests, (B) contains five sites of the mangrove forests, (C) contains three sites of the mangrove forests, (D) contains two sites of coastal dry land vegetation, (E) contains two sites of coastal fry land vegetation, and (F) contains one site of peat swamp forests. See Table 1 for site acronyms.

Table 3. The value of indices in each sampling site

Study sites	Richness		H'	E	Vegetation type
	S	R			
S01	6	1.01	0.73	1.31	Mangroves
S02	7	0.84	0.04	0.09	Mangroves
S03	4	0.51	0.69	0.96	Mangroves
S04	3	0.34	0.33	0.36	Littoral forest
S05	1	0.00	0.00	0.00	Littoral forest
S06	6	0.70	0.05	0.08	Mangroves
S07	54	6.74	0.76	3.03	Peat swamp
S08	15	1.74	0.53	1.45	Mangroves
S09	7	0.76	0.68	1.33	Mangroves
S10	5	0.41	0.33	0.53	Mangroves
S11	8	0.70	0.72	1.49	Mangroves
S12	5	0.69	0.13	0.21	Agroforest
S13	3	0.29	0.03	0.04	Mangroves
S14	3	0.39	0.33	0.36	Mangroves
S15	6	0.98	0.13	0.24	Agroforest
S16	5	0.53	0.85	1.36	Mangroves

Note: S = species number, R = species richness index, H' = Shannon diversity index, E= evenness index

The Group E contains two sites, namely S12 and S15. They represented of the agroforest along the affected coast by tsunami in Northern Sumatra. Site S12 was situated in the Offshore, and remaining site was in the East Coast. Prior to tsunami, the sites were former littoral forests converted by inhabitant to coconut agroforest. This group contains eight species, which the species indicator was *Cocos nucifera*having mean density and important value index (IVI) were 335.0 individual/ha and 280.6%, respectively. The IVI of others species were lower than 10% (Table 4). Therefore, this group is represented by *Cocos nucifera*community.

The Group F contains only one site, namely S07. This site represented of the peat swamp forests along the affected coast by tsunami in Northern Sumatra, especially in the West Coast. Before tsunami, the site was low impact by human activities. This group contains 54 species, where the species indicator was *Tetramerista glabra*having mean density and important value index (IVI) of 621.0 ind./ha and 66.8%, respectively. The IVI of others species was about 10% or less (Table 4). In addition, there are four species which their density was only 1 ind./ha, namely *Garcinia celebica*, *Litsea resinosa*, *Mangifera griffithii*, and *Terminalia foetidissima*. The four latest species, i.e., *G. celebica*, *L. resinosa*, *M. griffithii*, and *T. foetidissima* were categorized as very rare species in the area. Therefore, this group is represented by *Tetramerista glabra* communities.

Discussion

Mangrove forests

According to Tomlinson (1986), Kusmana et al. (1992) and Whitten et al. (1997), the family of Rhizophoraceae represents the most common in mangrove forests, including in Sumatra. The analysis of tree flora immediately after the 2004 tsunami in 16 sites of affected area by tsunami in Northern Sumatra showed also the largest family was Rhizophoraceae both number of species and abundance

Table 4. Mean density (*D*, individual/ha), basal area (*BA*, m^2/ha), frequency (*F*, %) and important species index (*IVI*, %) of each member of Group A to F

Species	D	BA	F	IVI
Group A				
Rhizophora mucronata	115.7	0.750	14.0	133.5
Rhizophora stylosa	122.7	0.230	5.0	73.3
Avicennia marina	24.3	0.381	4.7	47.7
Xylocarpus granatum	12.0	0.065	2.7	17.2
Rhizophora apiculata	5.7	0.075	1.3	11.1
Avicenia officinalis	0.7	0.061	0.7	6.3
Thespesia populnea	6.7	0.015	0.3	4.3
Sonneratia alba	0.7	0.026	0.7	4.1
Excoecaria agallocha	2.7	0.008	0.3	2.6
Group B				
Rhizophora apiculata	5426.2	9.286	85.2	140.4
Bruguiera parviflora	1177.2	1.770	34.2	35.8
Bruguiera sexangula	1428.6	1.608	28	35.1
Xylocarpus granatum	257.4	2.101	31.8	26.7
Bruguiera gymnorrhiza	524.0	1.401	25.6	23.4
Rhizophora mucronata	386.4	0.931	9.8	12.9
Sonneratia caseolaris	22.4	1.098	2.8	7.0
Excoecaria agallocha	57.2	0.391	8	5.9
Aegiceras corniculatum	73.4	0.266	3.6	3.6
Heritiera littoralis	19.8	0.203	3.6	2.7
Nypa fruticans	5.2	0.436	0.6	2.5
Avicennia officinalis	3.0	0.139	1.2	1.2
Sonneratia alba	3.0	0.046	2	1.1
Avicennia marina	1.4	0.085	0.8	0.8
Oncosperma tigillarium	0.8	0.008	0.6	0.3
Ceriops tagal	7.4	0.006	0.2	0.2
Hibiscus tiliaceus	1.4	0.018	0.2	0.2
Dolichandone spathacea	0.6	0.009	0.2	0.1
Group C				
Nypa fruticans	1116.7	40.628	100.0	290.3
Rhizophora apiculata	3.0	0.094	2.0	2.3
Excoecaria agallocha	1.3	0.058	1.3	1.5
Sonneratia caseolaris	1.7	0.043	1.3	1.5
Avicennia marina	1.7	0.038	1.3	1.5
Rhizophora mucronata	1.3	0.017	1.3	1.4
Oncosperma tigillarium	1.7	0.056	0.7	0.9
Xylocarpus granatum	0.3	0.003	0.3	0.3
Ceriops tagal	0.3	0.001	0.3	0.3
Group D				
Casuarina equisetifolia	173.0	28.655	39.5	273.8
Gliricidia sepium	14.5	0.331	5	19.4
Pterocarpus indicus	2.5	0.043	2.5	6.8
Group E				
Cocos nucifera	335.0	23.607	99.0	280.6
Mangifera indica	3.0	0.560	2.5	5.4
Pandanus tectorius	4.5	0.026	3.5	4.6
Arenga pinnata	2.5	0.069	2.5	3.3
Sterculia foetida	0.5	0.340	0.5	2.0
Metroxylon sagu	1.5	0.212	0.5	1.7
Manilkara kauki	1.0	0.040	1.0	1.4
Gliricidia sepium	1.0	0.004	1.0	1.2
Group F				
Tetramerista glabra	621	21.380	98	66.8
Syzygium pycnanthum	296	4.319	82	27.2
Dactylocladus stenostachys	193	4.282	75	22.4
Gluta wallichii	99	5.590	43	17.0
Horsfieldia glabra	111	4.521	41	15.7
Shorea seminis	93	4.698	38	14.9
Litsea gracilipes	115	1.824	44	12.2
Shorea sp.	106	1.999	45	12.2
Sandoricum beccarianum	77	2.955	37	11.6
Litsea mappacea	111	0.957	43	10.6

within this family compared to other families. In addition, Rhizophoraceae was also mostly dominant in 8 sampling sites (72.7%) of 11 sampling sites in mangrove forests, where *R. apiculata* was dominant in 5 sampling sites, followed by *R. mucronata* (2 sampling sites) and *R. stylosa* (1 sampling site).

Rhizophora apiculata and *R. mucronata* as member of Rhizophoraceae family were also recorded as widest distribution and most dominant in several sampling sites. This indicated that these species have stronger ability compared to other species to defense against tsunami disaster. In this study, *Rhizophora* spp. was the strongest species as compared to other genera of mangroves. This is in concordance with the finding by Yanagisawa et al. (2010). The dense structures of prop roots of a *Rhizophora* tree that extending all around (Jayatissa et al. 2002) have contributed to the resistance of tsunami flow even in the soft ground of tidal flat. Meanwhile, other genera without prop roots were easily uprooted. Based on field survey in Sri Lanka and Andaman coast, Tanaka et al. (2007) reported that *Rhizophora apiculata* and *Rhizophora mucronata* were especially effective in providing protection from tsunami damage due to their complex aerial root structure. Similar findings were also reported by Dahdouh-Guebas et al. (2005) for mangroves in Sri Lanka, Kathiresan and Rajendran (2005) for mangroves in India, Yanagisawa et al. (2009a, 2009b) for mangrove in Thailand after the 2004 Indian Ocean tsunami. The previous study by Mazda *et al* (1997) found that the effect of the drag force on *Rhizophora* spp. by the wave was higher compared to *Kandelia candel* because *Kandelia candel* has no pneumatophores.

Baba (2004) and Dahdouh-Guebas et al. (2005) reported that other true mangrove representatives, such as *Sonneratia* spp., the stem of which can measure several meters in circumference which has wide prop or knee roots, also stood firm against the ocean surge. This study also found the large *Sonneratia alba* succeeded against tsunami (Figure 3).

According to Chapman (1976) and Tomascik et al. (1997), along estuarine creeks and in bays and lagoons, stilt-root forming *Rhizophora* spp. are normally the main colonizers. Under pristine, natural conditions, distinct zones with different mangrove associations can frequently be observed along gently sloping, accreting shores. These reflect the degree of tidal inundation but also the level of salinity in estuarine environments. Kusmana and Watanabe (1991) stated that *Avicennia* species and *Sonneratia alba*, generally, which occur seaward and genera of *Rhizophora* and *Bruguiera* that exist generally mid and landward. This is due to the fact that the aerial stilt roots of the *Avicennia* spp. and *Sonneratia alba* are more tolerant than pneumatophores of the *Rhizophora* spp. and *Bruguiera* spp. to long periods of submergence by flood water (Kathiresan and Bingham 2001).

The mangrove palm, *Nypa fruticans* was recorded as dominant species in 3 sampling sites of the 11 sampling sites in mangrove forests along the Northern Sumatra coast. The zone of *Nypa fruticans* was situated at land ward zone of mangroves, while the mid and sea ward zones of mangroves surrounding areas were converted to aquaculture ponds before tsunami disaster. According to Lugo and Snedaker (1974), Chapman (1976), Tomlinson (1986), Kusmana and Watanabe (1991), Laumonier (1997), Tomascik et al. (1997), Whitten et al. (1997) and Duke et al.(1998), *Nypa fruticans* commonly grow at the upper (land ward) zones reached only by spring tides (1-20 flooding per month). Similar with this result in Northern Sumatra coasts, Dahdouh-Guebas et al. (2005) also reported that *Nypa fruticans* colony was thriving well and were by its rhizomatous stem allowed new young leaves to emerge less than a month after the tsunami impact.

Species richness in each sampling sites of mangrove forests less than 12 months after tsunami varied from 3 to 15 species. There were 5 sampling sites containing species richness less than 5 species in 1 ha plots. Subsequently, 5 sampling sites contain 6-10 species in 1 ha plot. Only 1 sampling site contains more than 10 species. The species richness in some sampling sites was mostly lower than other mangroves in Indonesia compiled by Kusmana et al. (1992), i.e., between 8 to 14 species. The species richness was only for commercial tree species with dbh more than 10 cm. This is probably because most of mangrove forest areas in Northern Sumatra were converted into ponds and other uses prior to tsunami. Based on field research by Satyanarayana et al. (2010) in the Kelantan Delta, Malaysia, the mangroves in the areas were ecologically sensitive to anthropogenic perturbation, including the intense aquaculture trade. Therefore, mangrove plant was not only loss by land clearing for aquaculture ponds, but remaining mangrove plant was continually treated by pollution of aquaculture activities.

According to Dahdouh-Guebas (2006), mangrove forest exhibits a unique biodiversity with uncommon adaptations such as vivipary in trees (young plants develop while still attached to the parental tree). Mangroves are adapted to intertidal environmental conditions such as high-energy tidal action, high salt concentrations, and low levels of oxygen (hypoxia). In addition, Cochard et al. (2008) stated that resilience of a mangrove ecosystem is likely to be influenced by factors such rates of tree regeneration and seedling recruitment, and renewed sedimentation reversing soil losses during the hazardous event.

According to Cochard et al. (2008), unlike the exposed coasts in temperate zones, tropical ecosystems include habitats such as offshore barrier reefs, dense mangrove forests and high sand dunes stabilized by beach forest. As well as providing important natural resources for many communities, these ecosystems may represent an important insurance against tsunami hazards; but it is essential to properly evaluate the actual utility of these ‘‘insurance’’ assets.

Figure 3. Large stand of *Sonneratia alba* in Lhok Mee, East Coast of Northern Sumatra stood firm against the 2004 tsunami. Most of the trees have more than 1 m in dbh.

Figure 4. Sumatran orangutan populations stay in peat swamp forests in Singkil swamps. Some part of the forests were affected by tsunami, and the other hand the forests stood firm against the 2004 tsunami, and have capability in decreasing the impact of tsunami on coastal areas behind the forests.

Figure 5. The coastal belt of peat swamp forests wiped out in several sites in the West Coast of Northern Sumatra few years after the 2004 tsunami disaster. When tsunami struck, the peat swamp forests were functionally as barrier. Large areas of green belt were erased and loss. Therefore, an integrated approach was needed in term of economic and ecological uses, including natural hazard preparedness.

Peat swamp forests

A one ha sampling site of peat swamp forests (PSF) in West Coast of Northern Sumatra having 54 species of tree with dbh 2 cm and more. The species richness was higher than species richness of PSF at Pekan Forest Reserve, Pahang, Malaysia, i.e., 49 species reported by Hamzah et al. (2009). The species richness of this study was also higher than PSF in Riau, Indonesia, i.e., 43 species reported by Istomo (2002, 2006). On the other hand, the species richness value was lower than PSF at Selangor, Malaysia, i.e., 103 species reported by Ibrahim and Lepun (2004).

Based on this result, the PSF in Singkil swamp has high diversity, which the Shannon diversity and Richness Margalef indices reached 3.03 and 6.74, respectively. It indicated the PSF has rich plant species, which was important to support the nutrient cycle and food web surrounding the areas, including human and wildlife.

There was relatively limited research conducted on PSF in Sumatra, some of them were by Giesen et al. (1992), Laumonier (1997), Whitten et al. (1997), Istomo (2002, 2006), Giesen (2004). Giesen et al. (1992) stated that the PSF at Singkil swamps was the last remaining pristine PSF until 1992 in coastal areas of Northern Sumatra. The PSF in Singkil swamps represent the tropical lowland forests in Leuser ecosystem, main habitat of some endangered species, such as Sumatran orangutan (*Pongo abelii*), Sumatran tiger (*Panthera tigris sumatrae*) and Sumatran elephant (*Elephan maximus*). Some individuals and nests of Sumatran orangutan were recorded during this field work in Singkil swamps (Figure 4). If the forest become degraded and fragmented, the endangered species become extinct.

Along the west coast of Northern Sumatra between Tabuyung and Kuala Cangkoang, between Kuala Baru Singkil and Trumon, and between Lhok Kruet and Blangpidie, PSFs were the original dominant vegetation types. Except in between Kuala Baru Singkil and Trumon, large areas of PSFs have been logged and converted to various types of cultivated land, including oil palm plantations, predominantly in recent years. The large and healthy PSFs were mostly found in Singkil swamps were status as conservation forests and also managed by Aceh traditional forest management system, *Panglima Uteun*.

Similar with this observation result, Giesen et al. (1992), Rijksen et al. (1997) reported that the PSF in western coast of Northern Sumatra have probably formed behind coastal sand ridges in waterlogged conditions; this type of peatswamp has also been described as ‘‘shallow freshwater swamp’’ and ‘‘fringe aquaculture swamp”, for example PSFs in Singkil swamp. Subsequently, Whitten et al. (1997) explained that some peat swamp forests may also occupy coastal areas that were initially reclaimed by mangroves, these being replaced subsequently by freshwater peat vegetation during the course of succession; these types were most extensive on the east coast of Sumatra, while this research found the similar case in Singkil swamps which the areas received more fresh water input from large river (Giesen et al., 1992, Rijksen et al., 1997), one of them was Alas river.

According to Mansor (2004), Page (2004), Rieley (2004), the PSF has significant role, ecological, economical and social aspects. Mansor (2004) stated that the PSF was a significant habitat for rare and endangered species. As described previously, PSF in Singkil swamps was as main habitat for Sumatran orangutan and Sumatran tiger recorded as critically endangered species in IUCN red list. According to Wich et al. (2008), PSF in Singkil swamps were habitat about 1,660 population of Sumatran orangutan, and were recorded as the second highest population in the world.

Page (2004) stated that, PSF, as a forest, contributes to microclimate stabilization and to maintain of regional and global biodiversity; it also provides a range of economically important timber and non-timber product, including barks, resins and rattans. Rijksen et al. (1997) informed that the forests in Singkil swamps have important role in supporting the fishery production of estuarine which the production was approximately 360,000 ton per year. On the other hand, anthropogenic disturbance as impact of develop tropical peat swamps for short-term gain is increasing, whilst their long-time environmental importance is being ignored. Large areas of PSF in West Coast of Northern Sumatra were converted to oil palm plantations (Figure 5), including in affected area by tsunami soon after the tsunami disaster. It indicated the lack concerned of policy maker in land use setting. Therefore, an emphasis was needed for integrated approaches to the environmentally sustainable management of peat swamps incorporating principles of wise multiple uses.

Coastal dry land vegetation

Most of low land areas in Northern Sumatra were modified. Some of them were degraded and fragmented, including coastal dry land vegetation. Based on this research, littoral forests in affected area by tsunami contain only 1 to 3 species in 1 ha plots which the forest floor vegetation was totally dead or swept out by tsunami. It was probably due to (i) change in microhabitat as impact of tsunami flood which most of the plants in dry land coasts were non salt tolerance and/or (ii) the species richness of trees was also low prior to tsunami as impact of human disturbance. According to Onrizal and Kusmana (2004), the tree species number of littoral forests in Rambut Island, Jakarta was 22 species. Subsequently, Mansor and Othman (2003) recorded 109 plant species in coastal forest of Pantai Acheh Forest Reserve (PAFR), Penang, Malaysia, which species number varied from 17 species to 27 species in each quadrate measuring 10m x 10m. Therefore, the plant species in affected area by tsunami in Northern Sumatra was very lower than slightly disturbed or undisturbed coastal vegetation.

The other type in coastal dry land was agroforest dominated by coconut. Based on this study, the agroforest contains 5-6 species in 1 ha plots. The Richness Margalef index was between 0.3 and 0.7, and the evenness was between 0.21 and 0.24. It indicated the vegetation community was poor and one species were very dominant.

All regeneration stage of trees, shrubs, herbaceous and grasses were killed due to tsunami. This is indicated the understory plants in coastal dry land were limited capacity against salinization due to tsunami flood.

There have been relatively little research conducted on littoral forests in Indonesia, particularly Sumatra. Some of them are Mahmud (1991), Mardiastuti (1992), Imanuddin (1999), Ayat (2002), and Onrizal and Kusmana (2004). All publications were from littoral forest in Rambut Island, Jakarta. According to the publications, littoral forests were important as habitats of water birds and migratory birds. Most of the tree canopies were used as nesting places and other activities of these birds.

Some large trees, such as *Cocos nucifera*, *Casuarina equisetifolia* and *Sterculia foetida* have stood firm against tsunami. The species also thrive well after tsunami, however the capacity to decrease tsunami impact was low probably due to the low density of stands, therefore many gap was present in agroforest and littoral forest. Based on Tanaka (2009), Thuy et al. (2009), the presence of an open gap in a forest could intensify the force of the tsunami by channeling them into the gap. In addition, Tanaka (2009) stated that floating debris from broken trees can also damaging the surrounding buildings and hurting the people.

Casuarina equisetifolia has widest distribution in coastal dry land coast of Northern Sumatra immediately after tsunami disaster. Orwa et al. (2009) informed that *C. equisetifolia* is commonly confined to a narrow strip adjacent to sandy coasts, rarely extending inland to lower hills. This tree was found on sand dunes, in sands alongside estuaries and behind fore-dunes and gentle slopes near the sea. It may be at the leading edge of dune vegetation, subject to salt spray and inundation with seawater at extremely high tides. The species tolerates both calcareous and slightly alkaline soils but is intolerant of prolonged water-logging and may fail on poor sands where the subsoil moisture conditions are unsatisfactory.

Many studies have revealed that these demerits can be overcome with proper planning and management of mangroves and coastal forests, and that coastal vegetation has a significant potential to mitigate damage in constructed areas and save human lives by acting as buffer zones during extreme natural events. However, many coastal vegetation including mangroves and littoral forests were degraded and fragmented by anthropogenic disturbance, making coastal areas increasingly vulnerable to tsunamis and other natural disasters. Tanaka (2009) and Samarakoon et al. (2013) explained that the effectiveness of vegetation also changes with the age and structure of the forest. Subsequently, Tanaka et al. (2011) and Samarakoon et al. (2013) proposed *Pandanus odoratissimus* as the front vegetation layer of *Casuarina equisetifolia* stands to reduce the disadvantages of the open gaps in existing forests in dry land coasts.

According to Tanaka et al. (2011), the effectiveness of coastal dry land vegetation (littoral forests) against tsunami were as follow (1) multiple rows were considered more effective than single or double rows of density of vegetation established, (2) plant species were monoculture less effective than mixed species, (3) low density less effective than high density, (4) front-line species were more effective with complex aerial root structure, (5) multi-layer vegetation structure was more effective than single-layer. In addition, the effectiveness could be more effective with continuous maintenance of coastal vegetation and high community participation.

Some of coastal forests have rich in biodiversity which harbors various species of plants, including as habitat of critically endangered species, such as Sumatran orangutan and Sumatran tiger. Subsequently, undisturbed coastal forests including mangroves, littoral forests and peat swamp forests characterized by dense stands, mixed species and structures play an important role in coastal protection against tsunami. Therefore, the coastal vegetation is needed to conserve the biodiversity and to maintain the production capacity as part of sustainable and longlasting vegetation bioshield. Mansor (2003) stated that local people know more about the plants and animals in their own surroundings. Perhaps the local knowledge especially from the old folks should not be cast aside, and their participation should also be encouraged.

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