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DIRECTIVES FOR MANGROVE FOREST AND COASTAL FOREST REHABILITATION IN EARTHQUAKE AND TSUNAMI DISASTER AREA IN THE PROVINCES OF NANGGROE ACEH DARUSSALAM AND SUMATERA UTARA (NIAS ISLAND), INDONESIA

(*Arahan Rehabilitasi Hutan Mangrove dan Hutan Pantai di Wilayah Bencana Gempa Bumi dan Tsunami Nanggroe Aceh Darussalam Dan Sumatera Utara (Pulau Nias) Indonesia*)

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ABSTRACT

Peristiwa gempa bumi dan tsunami yang melanda Nanggroe Aceh Darussalam (NAD) dan Pulau Nias Sumatera Utara pada bulan Desember 2004 telah mengakibatkan rusaknya sebagian besar hutan mangrove dan hutan pantai di kedua wilayah tersebut. Berhubung kedua tipe hutan tersebut sangat penting untuk menopang kelangsungan hidup penduduk pantai, maka penelitian ini dilakukan untuk mendapatkan arahan rehabilitasi hutan mangrove dan pantai yang rusak akibat tsunami di NAD dan Pulau Nias. Hasil penelitian menunjukkan bahwa wilayah pantai yang tanahnya berupa tanah mineral yang bukan lumpur dengan salinitas yang tinggi (di atas 10 $^{0}/_{00}$) seyogyanya ditanami oleh jenis mangrove eklusif (Rhizophora stylosa, R. apiculata, Sonneratia alba, Ceriops tagal dan Aegeciros floridum) dan mangrove asosiat (Osbornea octodonta dan Scyphiphora sp.), tanah bukan lumpur dengan salinitas rendah oleh berbagai jenis pohon hutan pantai (Casuarina equisetifolia, dan lain-lain), tanah lumpur bersalinitas tinggi oleh Avicenia spp. dan R. Mucronata; dan tanah gambut seyogyanya ditanami oleh Bruguiera gymnorrizha. Adapun lebar jalur hijau vegetasi yang disarankan adalah minimal 225 m untuk wilayah NAD dan 211 m untuk wilayah pulau Nias. Untuk merealisasikan kegiatan rehabilitasi vegetasi pantai yang bersifat multi-tahun di NAD dan Nias maka kegiatan rehabilitasi tersebut harus ditempatkan dalam rangka pembangunan daerah

Kata kunci : hutan mangrove, hutan pantai, jalur hijau, mangrove asosiat, mangrove eksklusif

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INTRODUCTION

Mangrove forests and coastal forests are renewable resources that provide environmental protection and play an important role for supplying goods and services for human survival and improvement of people's welfare, particularly that of coastal inhabitants, through utilization of wood and non wood forest products, including the utilization of environmental services. Therefore, mangrove forests should be properly managed so that its benefit could be maximally and sustainably utilized.

Occurence of tsunami in the province of Nanggroe Aceh Darussalam (NAD) and North Sumatra (Nias island) on 26 December 2004, had caused considerable damage on most mangrove and coastal forests in coastal areas of the two porvinces. This phenomenon had caused reduction, and even loss of benefit and roles of the two forest ecosystem. The implication of this phenomenon is that inhabitants of the two provinces had lost one of the resources that had significantly support their livelihood. Therefore, mangrove and coastal forests in the two provinces, should be rehabilitated to recover, maintain and improve the forest functions, so that their carrying capacity, productivity and their role as life supporting system, are maintained. Beside that, according to results of research by Mazda and Wolanski (1997) and Mazda and Magi (1997) , it had been proven that mangrove vegetation, particularly its rooting system could suppress wave energy by reducing the height of waves when they pass through the forests.

This study is intended to provide directives for implementing the rehabilitation of forest and land with mangrove and coastal forest tree species, in earthquake and tsunami disaster area in the provinces of NAD and North Sumatra (Nias island). The objective of this study are as follows: (a) Inventory the characteristics of soils, oceanography, socioeconomic condition of the community, species composisition and vegetation structure in the regions of NAD province and Nias island that had potential to be planted with mangrove and coastal forest tree species; and (b). Studying land suitability in the study area for several mangrove and coastal forest tree species and other alternative land uses in locations outside forest area

METHODS

According to study on *land system* map of Sumatera island, published by Bakosurtanal in year 1988, in the province of Nanggroe Aceh Darussalam (NAD) and Nias island, there are three kinds of *land system* that had potential to be grown with mangrove forest and coastal forest, namely (a) KHY (kahayan); (b) KJP (kajapah) and (c) PTG (puting). For obtaining information on *land-use cover*, existence of mangrove/coastal forests, position/location, area sizes, and severity of forest damage in each *land system* (KHY,KJP and PTG), overlay process was conducted between *land system* digital map and *land-use* digital map (landsat TM digital imagery) in the study area. Classification of land coverage was conducted by using method of *unsupervised classification* or *supervised classification* with method of *Maximum Likelihood Classification* (MLC).

Main material used in this study were *Landsat TM* imagery (year 2004 coverage) for the whole observation area, Map of Consensus Forest land Use (TGHK) (scale 1 : 250.000, year 1999), Map of *Land System* and *Land Suitability* (scale 1 : 250.000, year1988), Topographic map (scale 1 : 250.000 year 1988), and Administration map (scale1 : 250.000, year 2004). Main equipments used in the digital analysis were computer (PC or *work station*) together with its accessories, software *Erdas, Arcinfo,* and *Arc View* for image processing. Data and information collected in this study were (1). Condition of vegetation, that comprise: plant species, number of individuals, diameter and height of tree; (2). Soil condition, that comprise physical and chemical properties of soil; (3). Water quality, that comprise physical, chemical and biological properties; (4). Oceanographic condition, that comprise bathymetry, wind, tide, sea current, and texture of marine sediment ; and (5). Community socioeconomic condition, that comprise characters of demography, infrastructure, perception and expectation (hope) of the people toward forest rehabilitation, and knowledge and skill of the people in rehabilitation of mangrove and coastal forest.

For learning the condition of vegetation and soil in target sites, training area was established in each land use cover, in each land system in the coastal area of western part of NAD, eastern coast of NAD, and coastal areas of Nias island, North Sumatra. On the other hand, for learning the condition and quality of water and oceanography, samples were taken in Meulaboh (3 stations), Banda aceh (3 stations) and Nias island (3 stations). For obtaining information on the perception and hope of the people toward the study on mangrove forest and coastal forest rehabilitation, direct interview with the people was conducted in the study area with method of *purposive sampling.*

Vegetation analysis was conducted by using Cox method (1967), while tidal type was determined quantitatively by using *Formzahl* number, which can be expressed mathematically by the following formula:

$$F = \frac{O_1 + K_1}{M_2 + S_2}$$

where:

F = *Formzahl* number

O_1 = amplitude of main single ebb and tide component, due to lunar gravitation,

K_1 = amplitude of main single ebb and tide component, due to lunar and solar gravitation,

M_2 = amplitude of main multiple ebb and tide component, due to lunar gravitation, and

S_2 = amplitude of main multiple ebb and tide component, due to solar gravitation

Data on physical and chemical properties of soils were studied in terms of their suitability for, or ecological preference of mangrove and coastal forest tree species, so that land suitability for each tree species was obtained. Data on population social economy were analyzed descriptively and quantitatively for obtaining characters of demography, infrastructure, perception, expectation/hope, knowledge and skill of the people in forest rehabilitation.

RESULTS AND DISCUSSIONS

Vegetation

Mangrove vegetation in east coast of NAD

Mangrove forests in *land system* PTG in east coast of Nanggroe Aceh Darussalam (NAD) had been converted into fish ponds. Species *R. mucronata* is the most dominant species at tree and seedling stage with Importance Value Index (IVI) of 170,0% and 71.9 % respectively. Species *R.stylosa* and *R. mucronata* are the dominant and codominant species at sapling stage with IVI of the two species as large as 71,6% and 68,9% consecutively. At seedling stage, species *R. mucronata* and *R. stylosa* were the dominant and codominant with IVI as large as 71,9% and 31,4% consecutively. Complete information on IVI of mangrove species at all growth stages is presented in Table 1.

Table 1. List of plant species identified in east coast of NAD

Land system	Growth stage	Vegetation	D (ind/ha)	RD (%)	F (%)	RF (%)	IVI (%)
PTG	Mangrove seedlings	*Rhizophora mucronata*	800	35.8	8.7	36.1	71.9
		Rhizophora stylosa	392	17.5	3.3	13.9	31.4
		Avicennia marina	367	16.4	3.3	13.9	30.3
		Nypa fruticans	283	12.7	3.7	15.3	28
		Rhizophora apiculata	142	6.3	2	8.3	14.7
		Derris trifoliata	83	3.7	0.7	2.8	6.5
		Derris trifoliata	83	3.7	0.7	2.8	6.5
		Sonneratia alba	17	0.7	0.3	1.4	2.1
	Mangrove sapling	*R. stylosa*	109	45	4.3	26.5	71.6
		R. mucronata	77	31.8	6	37	68.9
		Avicennia marina	24	9.9	1.7	10.5	20.4
		Xylocarpus granatum	11	4.5	2.3	14.2	18.7
		Rhizophora apiculata	11	4.5	1.3	8	12.6
		Thespesia populnea	7	2.9	0.3	1.9	4.7
		Excoecaria agallocha	3	1.2	0.3	1.9	3.1
	Mangrove tree	*Rhizophora mucronata*	32	64	11	56.9	170
		Avicennia marina	9	18	3.7	19	69.4
		Rhizophora stylosa	3	6	2.3	12.1	20.8
		Rhizophora apiculata	2	4	0.3	1.7	11.5
		Sonneratia alba	1	2	0.7	3.4	7.9
		Xylocarpus granatum	1	2	0.3	1.7	7.6
		Avicennia officinalis	1	2	0.7	3.4	6.8
		Casuarina equisetifolia	1	2	0.3	1.7	5.9
	Coastal trees	*C. equisetifolia* *)	Rare				
KHY		*Nypa fruticans* *)	Abundant				
		*Acrosticum aureum**)	Abundant				
		Oncosperma sp *)	Abundant				
		Metroxlylon sp *)	Abundant				
		*A. aureum**)	Rare				

*Notes : *) = only estimates because the sites could not be accessed, D = densitas, RD = relative density, F = frequency, RF = relative frequency, IVI = Importance Value Index*

Mangrove Vegetation in western coast of NAD

Mangrove vegetation in land system PTG in western coast of NAD is generally in damaged condition. Field observation showed that vegetation that dominated this area was *Nypa fruticans* (Table 2), while *Rhizophora mucronata* grew sporadically and comprised 4 up to 6 trees with diameter around 11 cm and height around 3.5 m. On the other hand, in land system KHY, the following species were identified: meranti, bangka (Aceh language), jerok (Aceh language), bubreh (Aceh language), tampu (Aceh language), siklat (nyamplung), simasam, pedarah, ubo, merbau, medang, and gmelina.

Table 2. Plant species identified in western coast of NAD

No	Landsystem	Growth stage	Plant species	Condition
1	PTG	Mangrove tree	*Nypa fruticans*.	Dominant
			Rhizophora mucronata	Rare
			Sonneratia sp	Rare
			Metroxylon sp.	Rare
		Coastal tree	*Aleurites moluccana*	Dead
			Aren	Dead
			Arenga pinata	Dead
			Jambu Botol	Dead
			Kedondong	Dead
			Kuini	Dead
			Mangga	Dead
			Pala	Daed
			Casuarina equisetifolia	Alive
			Cocos nucifera	Alive
			Ficus sp.	Alive
			Hibiscus tiliaceus	Alive
			Manilkara sp.	Alive
			Belimbing wuluh	Dead/Alive
			Sukun	Dead/Alive
			Terminalia catappa	Dead/Alive
2	KHY	Tree	*Havea braziliensis*	Alive
			Cyperus rotundus	Alive

Mangrove vegetation in Nias island

Mangrove vegetation at land system KJP in Nias, is categorized as dense mangrove forest, as can be seen in the very high density of individual plants, namely 24.100 ind/ha for seedling stage and 20.632 ind/ha for sapling stage. Beside that, this mnagrove forest had thickness of more than 300 m from coast line toward inland, and was dominated by regeneration saplings of *Rhizophora apiculata* species.

In seedling and sapling stage, *R.* ap*iculata* was scattered in the whole sample plot, or regularly scattered. In areas which border with dry land that are rarely inundated by high ocean tide, other species were found, such as *Hibiscus tiliaceus, Casuarina equisetifolia, Vitev ovata*, and coconut (*Cocos nucifera*).

In landsystem KHY and PTG, seedling and sapling stage of *Rhizophora apiculata is* the species most commonly found, beside also other species such as *Ceriops tagal, Xylocarpus moluccensis, Scympiphora hydrophyllacea, Lumnitzera littorea, Aegiceras corniculatum* and *Nypa frutican.*

Table 3. Plant species identified in Nias island.

Land-system	Growth stage	Vegetation	**Density (ind/ha)**	**Relative Density (%)**	**Frequency (%)**	**Relative Frequency (%)**	**IVI (%)**
KJP	Seedling	*R. apiculata*	19.156	92.8	100	44.4	137.3
		C. tagal	844	4.09	77	34.2	38.3
		B. sexangula	632	3.06	48	21.3	24.4
		Total	20.632	100	225	100	200
	Sapling	*R. apiculata*	18.500	76.8	100	50.8	127.5
		C. tagal	2.425	10.1	40	20.3	30.4
		B. sexangula	2.200	9.1	38	19.3	28.4
		X. granatum	975	4.0	19	9.6	13.7
		Total	24.100	100	197	100	200
	Tree	*R. apiculata*	38	80.9	30	76.9	228.9
		B. sexangula	9	19.1	9	23.1	71.1
		Total	47	100	39	100	300
PTG	Seedling	*C. tagal*	Abundant				
		X. granatum	Abundant				
	Sapling	*R. apiculata.*	Abundant				
		C. tagal	Rare				
		X. granatum	Rare				
	Tree	*Metroxylon sagu.*	Rare				
		Nypa fruticans.	Rare				
		C. nucifera	Rare				
KHY	Seedling	*R. apiculata*	Abundant				
		S. caseolaris	Rare				
	Sapling	*R. apiculata.*	Abundant				
		E. agallocha	Rare				
		S. caseolaris	Rare				
		N. fruticans	Rare				

*Notes : *⁾ = Estimates only because the sites are not accessible*

Soil physical and chemical properties

Ecologically, mangrove and coastal forests in the NAD and Nias island territory, grow in three kinds of land system, namely PTG (puting), KHY (kahayan) and KJP (kajapah) whose detailed information could be seen in Table 4.

Table 4. Area sizes of each land system which are potential to be planted with mangrove and coastal forest species in NAD province and Nias island.

No	Landsystem	Area sizes (ha)		
		West coast of NAD	East coast of NAD	Nias island
1	Kajapah (KJP)	0	14.776,69	838,91
2	Kahayan (KHY)	36.874,39	96.274,22	10.634,64
3	Puting (PTG)	86.119,22	14.776,69	2.601,48
Total		122.993,61	142.958,9	14.075,03

Complete information on physical and chemical properties of soils found in NAD and Nias island, could be seen in Table 5. In Banda Aceh and the surrounding areas, alluvial soils in land system PTG had soil texture in topsoil categorized as loam, sand and loamy sand. Soil ripeness at topsoil were categorized as unripe, half ripe and ripe. This layer had acid soil pH, and was slighlty alkaline, and there was no potential for pyrite. Soil salinity was categorized as ranging from very low to very high (0.447 – 7.22 ms/cm). The texture of subsoil were loam and silty loam. Soil ripeness were categorized as unripe, nearly ripe and ripe. There was no pyrite potential; On the other hand, soil pH was categorized as slighly acid, neutral and alkaline (6.32 – 7.92). Salinity was categorized as ranging from very low to very high (0.388–7.75 ms/cm), and total soil N were categorized as very low and very high (0.06 – 2.39%).

Top soil at land system KHY had texture categorized as silty loam with soil ripeness ranging from half ripe to ripe. This layer had pH H_2O categorized as very acid and slightly alkaline (4.12 – 7.61) and did not have pyrite potential. Salinity was categorized as ranging from very low to very high (0.447 – 7.22 ms/cm); Soil total N was very high (2.67 – 5.61%). Sub soil had texture categorized as sand and silty loam; with soil ripeness categorized as ranging from half ripe to ripe. The pH of subsoil was categorized as slightly acid, neutral and slighly alkaline (6.32 – 7.92) and did not have pyrite potential. Salinity ranged from very low to very high (0.388–7.75 ms/cm); Soil total N ranged from very low to very high (0.06 – 2.39%).

In the west part of NAD (Meulaboh), land system PTG had soil texture in the top soil categorized as loam, sand and loamy sand. Soil ripeness at top soil had reached the stages of ripe and nearly ripe. This layer had soil pH categorized as acid, neutral and slightly alkaline; no pyrite potential was found. Soil salinity was categorized as ranging from moderate, high, to very high (2.49 – 9.4 ms/cm). On the other hand, soil N total ranged from low to moderate (0.16 – 0.38%).

The texture of sub soil was loamy sand. Soil ripeness was categorized as ripe, and the pH ranged from acid to neutral (4.97 – 6.71), and it was supposed that there was pyrite potential at depth of 20 – 50 cm. Salinity was categorized as very low and moderate (0.486 – 2.53ms/cm). Soil total N was categorized as moderate (0.28%).

Texture of top soil at land system KHY was sandy loam and silty loam. Texture of sub soil ranged from sandy clay to silty clay loam. Organosol found in land system KHY had ripeness categorized as sapric. This soil had pH H_2O categorized as very acid (3.65 – 3.88) and there was no pyrite potential. On the other hand, soil total N was categorized as very high (48.09 – 48.85%) and high (0.88 – 0.92%).

Table 5. Soil physical and chemical properties in NAD and Nias island.

Land system	**Physical properties**		**Chemical Properties**			
	Texture	Soil ripeness	Salinity	pH(H2O)	Pyrite	Nitrogen
Banda Aceh						
a. PTG	Loam, sand, loamy sand (top soil); loam and silty loam (sub soil)	Unripe, half ripe to ripe (topsoil); unripe, nearly ripe, ripe (subsoil)	Very low to very high (top soil; sub soil)	Acid and slighly alkaline (top soil); slightly acid, neutral , to alkaline (sub soil)	Absent	Very low and very high (sub soil)
b. KHY	Silty loam (top soil); sand and silty loam (sub soil)	Half ripe to ripe (topsoil, subsoil)	Very low to very high (top soil; sub soil)	Very acid and slightly alkaline (top soil); slightly acid, neutral to slightly alkaline (sub soil)	Absent	Very high (top soil) very low and very high (sub soil)
Meulaboh						
a. PTG	Loam, sand, loamy sand (topsoil); loamy sand (sub soil)	Ripe, nearly ripe	Moderate, high, very high (top soil); low to very high (sub soil)	Acid to slightly alkaline (topsoil); acid to neutral (subosil)	Absent (top soil); pyrite (sub soil)	Low to moderate (top soil); moderate, very high (sub soil)
b. KHY	Sandy loam, silty loam (topsoil), sandy clay to silty clay loam (sub soil)	Sapric. (peat)		Very acid	Absent	Very high
Nias						
a. PTG	In the form of sand, loamy sand, loam (top soil); sand, sandy loam, silty loam (sub soil)	Ripe and half ripe	Very low and very high (top soil); Class of very low (sub soil)	Acid, neutral, slightly alkaline to alkaline (top soil); slightly acid, neutral, slighly alkaline and alkaline (sub soil)	Absent	Low to moderate (top soil); class of very low to moderate (sub soil)
b. KHY	Loamy sand (topsoil); sand (subsoil), Loamy sand (topsoil); sand (subsoil)	Ripe	Very low and very high (topsoil); very low (sub soil)	Acid, neutral, slighly alkaline to alkaline (top soil); slightly acid, neutral, slightly alkaline (sub soil)	Pyrite	Low to moderate (top soil); class of very low to moderate (sub soil)
c. KJP	Silt dan loam (top soil, sub soil)	Ripe	Very low and very high (top soil)	Acid, neutral, slighly alkaline, to alkaline (top soil)	Pirit	Low to moderate (top soil)

The top soil of Regosol at land system PTG in Nias island had texture of sand, loamy sand and loam. Soil ripeness at top soil reached the stage of ripe and half ripe. Soil pH was categorized as acid, neutral, slighly alkaline and alkaline (4.53 – 8.83). Soil salinity was categorized as very low and very high (0.557 – 6.92 ms/cm). Soil total N ranged from low to moderate (0.16 – 0.26 %).

Texture of subsoil were sand, sandy loam and silty loam. Soil ripeness was categorized as half ripe and ripe. Soil pH was categorized as slightly acid, neutral, slightly alkaline and alkaline (6.00 – 8.98). Salinity was categorized as very low (0.1611 – 0.197 ms/cm), while soil N total ranged from very low to moderate (0.09 – 0.28 %).

Top soil of the alluvial soils in land system KJP had texture categorized as sand, with ripeness categorized as ripe soil. This layer had soil pH that ranged from acid, neutral, slightly alkaline to alkaline (4.53 – 8.83) and had pyrite potential. Soil salinity was categorized as very low and very high (0.557 – 6.92 ms/cm), while soil N total ranged from low to moderate (0.16 – 0.26%). Texture of subsoils were sand and loam. Soil ripeness was categorized as ripe soil.

Top soil of the alluvial soils in land system KHY had texture categorized as loamy sand, with ripeness categorized as ripe soil. The soil had pH that ranged from acid, neutral, slightly alkaline to alkaline (4.53 – 8.83) and was supposed to have pyrite potential. Soil salinity was categorized as very low and very high (0.557 – 6.92 ms/cm), while soil N total ranged from low to moderate (0.16 – 0.26%). Texture of subsoil was sand and was categorized as ripe soil with soil pH categorized as acid, neutral, slightly alkaline and alkaline (6.00 – 8.98) and was supposed to have pyrite potential at depth of 30 – 50 cm. Salinity was categorized as very low (0.1611 – 0.197 ms/cm) with soil N total ranged from very low to moderate (0.09 – 0.28 %).

Land suitability

Based on information of physical characteristic in the form of soil depth, texture, mineral soil ripeness, decomposition stage of organic soil, soil drainage, water table depth, soil chemical properties (soil pH), salinity, sulfate potential (pyrite), soil organic matter content, and soil fertility, that are related with growth requirements and tolerance of several mangrove and coastal forest species, land suitability as shown in Table 6, was obtained.

In the forest area, land uses were recommended in the form of *green belt*, while in non forest area, alternative land uses could also consider the aspect of land potency and people's aspiration that have productive purposes, as well as conservation purposes, such as conducting the activities of *silvofishery* and *agroforestry*. For Meulaboh region and the surrounding areas, activity of rubber plantation and wetland rice cultivation, could be recommended, while land that had potential of shallow pyrite, is not recommended for activity of wetland rice cultivation, and agroforesty/silvofishery. Reductive activities were also recommended, such as the use of swamp forest land.

Table 6. Land suitability of mangrove and coastal forest species at various kinds of soil

Location	Soil type	Species of plants
1. Banda Aceh	Alluvial/Entisol	*Avicennia marina. A. lanata. A. alba.* dan *Rhizophora mucronata. Ceriops tagal. C. decandra. Scyphiphora hyrophyllacea. Osbornea octodonta.*
	Regosol/Entisol	*Casuarina equisetifolia. Terminalia catappa. Cocos nucifera. Hibiscus tiliaceus. and other coastal forest tree species.*
2. Meulaboh	Organosol/Histosol (KHY)	*Bruguiera gymnorrhiza.*
	Regosol/Entisol (PTG)	*Rhizophora stylosa. R. apiculata. Sonneratia alba. Aigiceras floridum. Phemphis acidula* (cantigo). *Ceriops tagal. C. decandra. Scyphiphora hyrophyllacea. Osbornea octodonta.*
3. Nias	Regosol/Entisol (KJP)	*Rhizophora stylosa. R. apiculata. Sonneratia alba. Aigiceras floridum. Phemphis acidula (cantigo)*
	aluvial/entisol (PTG)	*Rhizophora stylosa. R. apiculata. Sonneratia alba. Aigiceras floridum. Phemphis acidula (cantigo)*
	Regosol/entisol (KHY)	*Casuarina equisetifolia. Terminalia catappa. Cocos nucifera. Hibiscus tiliaceus . and other coastal forest tree species.*
	regosol/entisol (PTG))	*Casuarina equisetifolia. Terminalia catappa. Cocos nucifera. Hibiscus tiliaceus. and other coastal forest tree species.*

Water Caracteristics

Aceh region that was located in the westernmost tip of Sumatera island, was surrounded by waters. In general, marine waters that surround Aceh region are deep ocean waters. Based on water chemical and physical properties (Table 7), it could be suggested that Aceh and Nias region are suitable for brackish water culture (fish pond).

Tidal type of Aceh and Nias waters were categorized as multiple type, although there was also mixed type that had tendency to be multiple. Oceanographic condition of coastal areas of NAD province and Nias island, could be seen in Table 8.

Table 7. Physical, chemical an biological properties of waters in the province of NAD and Nias island.

Parameter	Unit	Nias Islands			West coast of NAD			East coast of NAD		
		St-1	**St-2**	**St-3**	**St-1**	**St-2**	**St-3**	**St-1**	**St-2**	**St-3**
Physics :										
Temperature *)	^{O}C	28	26.7	28	34.7	33.8	33.7	27.3	31	34.7
Transparency *)	cm	70.7	77	43.7	69	68.7	39	59	65	56
Turbidity	NTU	0.2	0.68	3.10	2.00	6.60	2.80	18.00	22.00	41.00
TSS	mg/l	6	6	24	6	34	13	39	41	110
TDS	mg/l	37552	19452	24600	31860	35170	35170	37252	36000	36664
Chemistry :										
Salinity *)	$^{O}/oo$	26.3	24.7	17	22.7	29	22.3	35	32.3	31
pH *)	-	8.5	8	7.5	7.7	8	7	8	8	7.5
Dissolved oxygen*)	mg/l	6.098	2.44	6.098	8.13	7.724	8.13	7.32	8.54	7.72
BOD_5	mg/l	2.88	1.27	1.27	0.8135	1.626	2.439	2.85	4.48	4.47
Ammonia (NH_3+NH_4)	mg/l	0.488	1.803	8.994	2.839	1.484	6.145	2.839	0.687	1.205
Nitrite (NO - N)	mg/l	0.0004	0.0005	0.0024	0.0005	0.0005	0.0016	0.0006	0.0005	0.0005
Nitrate (NO3-N)	mg/l	0.073	0.094	0.146	0.084	0.085	0.113	0.087	0.069	0.069
Phosphate	mg/l	9.091E-5	9.091E-5	2.727E-4	1.364E-4	2.273E-4	3.636E-4	4.545E-4	6.818E-4	5.455E-4
Silicate	mg/l	0.016	0.032	0.029	0.031	0.012	0.059	0.013	0.036	0.011
BIOLOGY :										
Plankton:										
- Phytoplankton	Ind/m^3	13790	2118	4867	79887	25157	110736	38903	61397	48024
- Zooplankton	Ind/m^3	2758	2809	4678	5208	1349	1632	10530	6954	13137
Benthos	Ind/m^3	17	7	-	2	7	4	88	25	8

Notes : St = station

Table 8. Oceanographic condition of waters in the province of NAD and Nias island (North Sumatera)

Region	Oceanographic parameters				
	Slope (%)	Height of wave (m)	Tidal type	Speed of current (cm/second)	Tidal range (cm)
West coast of NAD	2 - 40	0.43-1.43	Multiple type	15-25	173.1
East coast of NAD	4.5 - 16	0.5	Multiple type	9-38	162.9
Nias island	1.62	0.39-0.95	Mixed type which tend to be multiple type	5-15	99.5

People's perception

The collected data showed that people were aware of the benefit of mangrove forest and coastal forest, either for improving their welfare or for safeguarding the environment, so that they agree with program of mangrove forest and coastal forest rehabilitation that should be conducted soon, particularly due to their desire to obtain job and income. However, it could be suggested that program of mangrove forest and coastal forest rehabilitation, should not be conducted on private owned land. Furthermore, people in coastal areas are not willing if their residential areas are moved to other places, because their privately owned land and their livelihood are situated in coastal areas. Beside proposing several plant species to be planted, such as beach casuarina, coconut, mangrove, beach pandanus and ketapang (almond tree), in rehabilitation of mangrove and coastal forest, the people also requested the existence of socialization and cooperation between government and the people before implementataion of land and forest rehabilitation.

There are several important problems faced in the context of mangrove and coastal forest rehabilitation, namely: (1) Inaccuracy of data and information on field condition, unavailability of data. Difficulty in data collection, hindered the planning process of mangrove forest rehabilitation in the province of NAD. (2) Accessibility which is still very poor. Even, several locations are still isolated, and their facilities and infrastructure are still very poor, and this hindered the planning and implementation of mangrove forest rehabiltation. (3) Limited supply of goods and services, increase the prices of such things in the province of NAD, and this will in turn create difficulties in allocating funds for mangrove and coastal forest rehabilitation. (4). Formal institution (government), and community institution, particularly at the field level (sub district and village level) were still paralyzed. (5) Loss and damage of boundary markings of land ownership, had created confusion in the status of land ownership in the disaster area. (6) Desire of most people in the coastal area to return to their original places, or in other words, they are not willing to be relocated in terms of their residence, with the reason that their land ownership and livelihod are located in the coastal areas and ocean.

Discussion

Considering the composition of tree species, types of mangrove communities in NAD and Nias island, are relatively similar with other mangrove forests in Sumatra island, as had been reported by other researchers (Sukardjo et al. 1984; Kusmana 1993). Soil condition in the two regions were similar with soil conditions in other regions of Sumatra, as well as also similar with soil condition in mangrove forests in Tanjung Apar (Sukardjo, unpublished); Muara Angke, Jakarta (Kusmana, 1983); Rambut island (Kartawinata and Waluyo 1997); and Delta Cimanuk, Jawa Barat (Sukardjo, 1983).

Before the strike of tsunami in NAD and Nias, most mangrove forest in the two regions, suffered damage that was considerably heavy due to conversion of mangrove forest land into fish ponds, settlement area, and farm land (particularly mixed garden). This phenomemon was due to : (a) Ecological condition of coastal area of NAD and Nias which is generally suitable for the three forms of land utilization. (b). High price fetched by shrimp commodity in international market (c). Considerable increase of human population in NAD and Nias, (d) Lack of control in town infrastructure development, and (e) Management of forest area that is not optimal due to poor security condition. In this case, illegal conversion of mangrove forest into traditional shrimp ponds, constitute a biggest threat toward mangrove ecosystem in Indonesia. In year 2003, in Indonesia, it was estimated that fish ponds had reached area around 400 000 ha (Ministry of Foresty, 2004), an increase of 50 % from the year1993.

Mangrove and coastal forest vegetation, had been proven to be effective enough in protecting coastal area from tsunami danger. Mangrove vegetation along the coast could affect wave characteristics by reducing wave's height when it pass through vegetation so that wave energy is reduced (Pratikto, et al. 2002), water flow speed is reduced due to friction with forest stand, and water volume is reduced and scattered, so that water that reach inland area is less (MSSRF, 2005 in Anonymous, 2005).

Drag force for tidal water that flow through parts of mangrove forests, such as stilt root, peneumatophores, tree stems, twigs and their leaves, had been explored in depth by Furukawa and Wolanski (1996) and Mazda et al (1992), whose results showed that drag force from mangrove forest toward water flow, occur in any depth from the bottom to the surface of water.

Result of model testing in laboratory by Puslitbang PU (Public Works Research and Development Center) (1996) as quoted by Istiyanto, Utomo and Suranto (2003) showed that alternate arrangement, provided better cushioning effect than row-column arrangement. The test also found reduction of run off by 2 % through 5 % in model which equal to prototype clump that had tree diameter of 50 cm and distance between trees of 2.5 m. For conducting coastal rehabilitation, either in the form of mangrove or coastal forest tree species planting, this result provided a directive for planting pattern and planting spacing.

Research on laboratory model by Thaha (2001) in Onrizal (2003) as quoted also by Istiyanto and Suranto (2003) showed that root and clump density, affected very much the amount of cushioning effect on the wave for the case of sinusoidal wave. Result of model simulation by Istiyanto, Utomo and Suranto (2003) in laboratory, concluded among other things that bakau (*Rhizophora*) clump, reflected, passed and absorbed the tsunami wave energy as manifested in the change of wave height when the wave crept through the clump. Result of study by Pratikto *et. al*. (2002) in Teluk Grajagan, Banyuwangi, showed that existence of mangrove in that region was able to reduce wave by 73.40 % and wave energy change by 19 635.26 Joule, so that existence of mangrove forest could reduce tsunami wave that strike coastal areas.

Onrizal (2005) reported that tsunami did not cause significant damage in areas that had dense mangrove and coastal forest in NAD and Nias, while heavy damage occured in areas that did not have good mangrove and coastal forest. Moawo village and Pasar Lahewa village that were located in northern coast of Nias were examples of areas that were save from tsunami strike. The two areas possessed very dense mangrove forest with density of around 17 000 – 20 700 ind/ha for mangrove plants with diameter > 2 cm and height > 1.5 with width of mangrove between settlement area and coast was 200 m or more. People in the two villages felt sure that their villages were save form tsunami due to protection by mangrove forest, although during the tsunami, their houses were flooded 2 –

3 m high, but with calm water. On the other hand, in areas of Mandrehe and Sirombu in western coast of Nias whose coastal areas had been converted into plantation with planting distances of around 6 x 6 m2 and barren land, the damage was very severe. Very severe damage also occured in coastal areas of NAD that did not have compact mangrove and coastal forest. In general, mangrove area in NAD had been converted into fish ponds. The same condition was also reported by WI-IP (2005).

Result of survey WI-IP (2005) in NAD obtained fact that heavy damage occured in coastal area that did not have dense mangrove and coastal forest. On the other hand, very little damage occured in areas that had dense mangrove and coastal forest. One example was village of Ladang Tuha, south Aceh which was save from tsunami strike due to its possession of coastal forest, dominated by dense casuarina trees.

Based on this research**,** several recommendations that should be considered for ensuring the success of mangrove area rehabilitation in NAD and Nias island after the tsunami event, are as follows:

(1) Width of green belt is 225 m for west coast area of NAD, 211 m for east coast of NAD and 129 m for Nias island.

(2) Tree species of mangrove forest and coastal forest that are ecologically suitable to be planted are as listed in Table 6.

(3). Land that contain pyrite should remain or made as swamp forest.

(4). Land utilizations for enhancing community economy in the study area are in the form of agroforestry, coconut plantation, rubber plantation, silvofishery, and wet land rice field.

(5). Policy that should be adopted and implemented is putting the program of mangrove and coastal forest rehabilitation program within the framework of regional development. For implementing the policy of mangrove and coastal forest rehabilitation in NAD province and Nias island, the strategy that should be used are as follows: (a) Empowering mangrove and coastal ecossystem by folowing the principles of land suitability; and (b) Empowerment of socioeconomic capability of the community by provision of incentives, either directly or indirectly in the activity of mangrove forest and coastal forest rehabilitation.

CONCLUSIONS

In general, west coast of NAD is a suitable habitat for the growth of coastal forest, whereas that of the east coast is suitable for the growth of mangrove forest. Coastal areas of Nias is a suitable habitat, either for mangrove forest or coastal forest. Several mangrove and coastal forest tree species that are suitable for being planted in coastal areas of NAD and Nias island are exclusive mangrove species (*Rhizophora apiculata, Rhizophora stylosa, R. mucronata, Avicennia marina. A. lanata. A. Alba, Sonneratia alba, Ceriops tagal, Bruguiera gymnorrhiza., Aegiceras floridum*, mangrove associates (*Osbornea octodonta, Scyphiphophora* sp) for mangrove forest area; and species *Casuarina equisetifolia, Terminalia catappa,* etc for coastal forest area.

Minimum width of coastal vegetation in the coastal areas are minimally 225 m in the west coast of NAD, 211 m in the east coast of NAD and 129 m in Nias island. For implementing the program of mangrove and coastal forest rehabilitation in NAD and Nias island, the program should be integrated within the framework of regional development in the two areas. Policy strategy that should be adopted are as follows: (1) Tree species to be planted should follow the principles of land suitability, and (2) There should be empowerment of the community by using incentive system in the program of mangrove forest and coastal forest rehabilitation.

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