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Growth evaluation of rehabilitated mangroves in Indonesia with special emphasis on relationship with soil and hydrological conditions

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Mangrove rehabilitation in Indonesia had been carried out since decades ago in many islands. Growth evaluation of rehabilitated mangrove after planting is essential for a better on-going and plan of rehabilitation managements. In this study, the growth of rehabilitated mangrove stands at four locations of mangrove rehabilitation areas in Indonesia (Riau and Lampung of Sumatera Island, Cilacap of Java Island and Sanur of Bali Islands) were evaluated. The study focused on the assessment of mangrove growth, its relationship with soil and hydrological conditions. Growth indicated by parameters of plant height, stem diameter, crown volume and biomass production was higher in mangrove stands grown in Riau and Lampung of Sumatra Islands than those grown in Cilacap of Java and Sanur of Bali Islands. Soil properties and hydrological condition of each location of rehabilitated mangrove areas might be factors responsible for the discrepancy among the growth of mangrove in Sumatera, Java and Bali. Mangrove soil in Sumatera was more fertile and hydrological site conditions were more suitable for optimal mangrove growth. In a rehabilitated area located at intertidal seaward zones such as in Cilacap of Java, it would be better to be planted salinity tolerant mangrove species of *Avicennia marina* and *Sonneratia alba*, rather than only planted *Rhizhopora apiculata*.

Keywords: Mangrove, rehabilitation, growth, soil- hydrology, Rhizophora

INTRODUCTION

Mangrove rehabilitation programs in Indonesia was started since four decades ago carried out in several areas, such as in Sinjai South Sulawesi, the northern coast of West Java, and in Cilacap of Central Java (Sukarjo and Yamada, 1992). During the period from 2001 to 2005, Indonesian government rehabilitated 19,918 ha of mangrove forest along its vulnerable coastline around the country, as well as restoring 3,973 ha of mangrove forest in tsunami devastated Province of Aceh. During the two years of Coastal Ecosystem Restoration Project in Aceh, the NGO's and Indonesian Government implemented the rehabilitation of 27,075 ha mangrove areas by planting 28,349,350 seedlings (Wibisono and Suryadiputra, 2007). Mangrove Action Project in Indonesia also reported being facilitated hundreds of hectares mangrove restorations in Langkat North Sumatra, Bengkalis Riau, Segara Anakan Central Java; Bunaken North Sulawesi, West Kalimantan and Lampung (Department of Forestry, 2006) Given the enormous effort that has been done, it is important that the growth of rehabilitated mangrove is evaluated. Evaluation of growth quality of rehabilitated mangrove after planting is essential, for a better on-going and plan of mangrove rehabilitation management (Samson and Rollon, 2008). So far, evaluation on the growth after planting and the successful of rehabilitation mangrove program in Indonesia is not being undertaken widely. In general, mangrove rehabilitation programs have had limited success. Mangrove forest cannot be rehabilitated cheaply and rapidly, it is very difficult tasks, and is not easy to have the planted individuals continue to grow successfully. The success rate of mangrove rehabilitation in Indonesia, including in mangrove rehabilitation project in Aceh after the tsunami, was very

Figure 1: Distribution of mangroves in Indonesia (Atmaja and Soerojo.1994.), and locations of the research studies: Riau and Lampung of Sumatera Island, Cilacap of Java Island and Sanur of Bali Island.

Table 1: Areas, spacing, stand density, and managements of four locations of mangrove rehabilitation areas in Indonesia

Locations	Areas	Spacing	Plant age (years)				Mangrove Managements
			4	5	6	13-14	
	Ha	m x m	Plant stands/ha				
Riau	60	2 x 1	8750	8300	15300	-	Community – Local NGO
Lampung	750	2 x 1	-	-	-	18400	Fisherman's community - Lampung University.
Cilacap	114	6 x 1	1780	1800	1850	-	Perhutani of Forestry Dept.
Bali	186	2 x 2	-	-	-	16300	Mangrove Information Center - Forestry Dept.

low, between 15 to 60 % (Wibisono and Suryadiputra. 2006).

Soil characteristics such as texture, pH, salinity, and nutrient availability controlled the growth and occurrence pattern of mangrove forest community (Kusmana and Sabihan, 1991). Because of high salinity and limited nutrient availability in the mangrove soil, the morphological characteristics of mangrove communities are not uniform, and mangrove stands near the sea usually grow dwarf (Medina et al., 2010). The general purpose of this study is to evaluate the growth of rehabilitated mangrove stands, while specific objectives are (1) to compare the growth of rehabilitated mangrove stands grown at different locations of mangrove rehabilitation areas in Indonesia, (2) to assess the variability of soil characteristics and hydrological conditions of mangrove rehabilitation areas in Indonesia, (3) to examine the relationship between growth of rehabilitated mangrove with soil characteristics and hydrological condition.

MATERIALS AND METHOD

Study sites

The study was conducted during the period of July 2007 to June 2009 at four locations of different rehabilitated mangrove ecosystems in Indonesia. Two locations were at east coast of Sumatera island: Sungai Asam, Riau (Lat. 0˚ 36' N to 1˚ 07' S, and Long. 102^{o} 32` to 104$^{o}$ 10`E) and East Lampung (Lat. 3˚ 45' to 6˚ N and Long. 105^{o} 45' to 103^{o} 48` E); one location was at Cilacap, south coast of Java island (Lat. 7˚ 30` – 7^{o} 45` 20 S and Long. 102˚ 4' 30" E) and one location was at Sanur Beach at south coast of Bali island (Lat. 3˚ 45' - 6˚ S; Long. 105$^{o}$ 45'-103$^{o}$ 48` E) (Figure 1). According to Schmidt and Ferguson (1951), Riau areas are located within the climatic type A, where East Lampung, Cilacap Java, and Sanur Bali are covered by B climatic types. The four locations were chosen because only at those locations were found the rehabilitated mangrove stands which the date of planting is known. The age of rehabilitated mangroves stands in Riau was 4, 5, and 6 year olds, while in Lampung and Sanur of Bali was about 13-14 year old. Areas, plan's densities and the management way of each location of rehabilitation were indicated in Table 1.

Measurement of growth and biomass production

Growth of mangrove forest community was observed in 10 mangrove stands at each site, so there were 30 mangrove stands in three sample sites at each location

Table 2: Stem and plant height and stem diameter of different age rehabilitated mangrove Rhizophora apiculata grown at four locations in Indonesia

Locations	Plant age(years)											
	4			5			6			13-14		
	Stem height	Plant height	Stem diameter	Stem height	Plant height	Stem diameter	Stem height	Plant height	Stem diameter	Stem height	Plant height	Stem diameter
Riau	265.4	740.7	4.8	446.2	776.5	4.7	468.9	859.3	5.7	-	-	-
Cilacap	88.5	207.3	3.2	94.1	220.3	3.5	86.0	201.3	2.7	-	-	-
Lampung	-	-	-	-	-	-	-	-	-	336	933	7.8
Bali	-	-	-	-	-	-	-	-	-	237	554	5.5

Table 3: Crowm volume and stand biomass of different age rehabilitated mangrove Rhizophora apiculata grown at four locations in Indonesia

Locations	Plant age (years)							
	4		**5**		**6**		**13-14**	
	Crown volume	**Stand biomass**	**Crown volume**	**Stand biomass**	**Crown volume**	**Stand biomass**	**Crown volume**	**Stand biomass**
Riau	18.25	3.4	7.4	2.7	16.35	5.1	-	-
Cilacap	3.40	0.4	4.3	0.5	2,1	0.3	-	-
Lampung	-	-	-	-	-	-	37.00	9.6
Bali	-	-	-	-	-	-	27.90	6.6

for each age of mangrove forest community. Stem diameter at 30 and 130 cm for stems taller than 40 and 150 cm, respectively, root height, stem height, height to base of crown (CRWNHT), total height (TOTHT), crown length (CRWNL) and width (CRWNW) and stand density were recorded. The product [CRWNHT * CRWNL * CRWNW] provided an index of crown volume (CRWNV). Total biomass of a stand (kg/stand) was determined by alometric method according to Ross Method (Rose, *et.al*. 2001)

Determination soil characteristics and hydrological conditions.

Three sample sites of 10 x 10 m, respectively was 10, 100 and 200 m distance from the river bank were established at each research location to explore soil characteristics, and growth of mangrove forest. Soil sample then was taken up to a depth of 20 cm, collected in labeled polyethylene bags and composed. They were brought to the laboratory for physic-chemical analysis. The analysis was conducted by using various standard soil testing procedures. Particle size distribution was determined by the Bouyoucos hydrometer method. Soil reaction (pH) was measured at 1:1 water suspension, then measured by pH meter. Total nitrogen determined by the Kjeldahl method. Organic carbon was determined by the wet oxidation of Black method. Available phosphorus content was extracted by Bray P1 solution and measured on Spectrophotometer. Sodium and potassium were extracted with 1 N Ammonium acetate solution at pH 7, determined by flamephotometer. Calcium and magnesium were extracted with EDTA solution and determined with Biuret method. Salinity of water was measured in the field by a handrefractometer (ATAGO, Type:S/Mill-E). Site elevation measured with a GPS (GARMIN, Type:76 CSx), information on tidal frequency, site zonation, and previously land used were observed directly and collected from field site managers.

RESULTS AND DISCUSSION

Results

1. Growth of Rehabilitated Mangroves

Growth of Mangrove indicated by parameters of stem height, plant height, stem diameter, crown volume and stand biomass were respectively presented in Table 2, 3, 4, 5, and Table 6. There was a great different in

Table 4: Hydrological characteristics, previously land used, palnted and recommended specis of four locations of mangrove rehabilitation areas in Indonesia

Locations	Tidal Frequency	Elevation (m asl.)	Zonation	Previously the land use	Mangrove Species	
					Planted	Recommended
Riau	Daily, 20 d/month	5,4	Mesozone River bank	Secondary mangrove forest	*R.apiculata*	*R.apiculata* *R.mucronata*
Lampung	Daily 20 d/month	6	Mesozone	Abandoned shrimppond	*R.apiculata*	*R.apiculata* *R.mucronata*
Cilacap	Daily 20 d/month	0-5	Seaward	Abandoned shrimppond	*R.apiculata*	*Avicennia spp.* *Sonneratia alba*
Bali	Daily 20 d/month	0-3	Seaward	Abandoned shrimppond	*R.apiculata*	*Avicennia sp.* *Sonneratia alba.* *R.stylosa*

Table 5: Substrates, texture and salinity of soil at four locations of mangrove rehabilitation areas in Indonesia

Locations	Soil Characteristica						
	Substrates	Particle size %			Texture	Salinity ppt	
		Sand	Silt	Clay			
Riau	Black mud	26.8	29.4	41.5	Clay	20	Moderate
Lampung	Black mud	21.5	18.73	59.77	Clay	12	Low
Cilacap	Saline Mudflat	59.62	14.45	25.93	Sandy clay loam	30	High
Bali	Mudflat	47.48	35.73	16.79	Loam	22	Moderate

Table 6: Soil chemical characteristics of soil at four locations of mangrove rehabilitation areas in Indonesia

Locations	Soil Characteristics									
	pH H_2O (1:1)		C-organic	N-total	C/N	Available P	K	Mg	Ca	CEC
			%			ppm	me/100 g			
Riau	5.70	Slightly Acid	6.60	0.4	16.5	28.1	1.90	1.4	8.80	36.5
Lampung	6.71	Neutral	2.35	0.19	12.4	51.15	1.92	1.11	4.83	25.23
Cilacap	3.70	Very Acid	3.01	0.21	14.3	9.58	0.48	1.9	5.07	15.6
Bali	5.34	Acid	3.83	0.24	15.9	28.05	4.79	0.48	5.35	27.41

growth across mangrove locations. The stem and total plant height in 4,5,6 year old stands were higher in mangrove grown in Riau compared with those in Cilacap, while in 13-14 year old stands, it was higher in mangroves grown in Lampung compared with that grow in Bali. The height of stem and plants of 4, 5, and 6 year old mangrove in Riau was almost four times the height of stem and plant the mangroves grown in Cilacap; while the plant height of 13-14 year old mangrove planted in Bali was only 60% the height of mangrove grown in Lampung. Averaged stem diameter of 4,5, and 6 years old mangrove stands grown in Riau (5.1 cm) were thicker compared with the stem diameter of mangrove stand grown in Cilacap (3.1 cm); while in 13-14 old mangrove stand, mangroves planted in Lampung had a ticker stem diameter (7.8 cm) than that grown in Bali (5.5 cm).

The crown volume was a result of multiplication among width, length and height of plant canopy. It was about 4 times larger in 4, 5, and 6 year old mangrove stands grown in Riau compared with those grown in Cilacap. In 13-14 years old mangrove stand cultivated in Lampung, its crown volume was almost 1,3 times larger than the crown volume of the same age mangrove cultivated in Bali. Stand biomass of 4, 5, and 6 year old mangroves grown in Riau respectively were 3.4; 2.7 and 5.1 kg/stand. It was almost 9 times of the biomass of the same old mangroves grown in Cilacap. Stand biomass

Figure 2: Performance of 4, 5, and 6 year old rehabilitated mangrove in Cilacap of Java (top), and in Riau of Sumatera (botom)

Figure 3: Performance of 14 year old rehabilitated mangrove in Bali (left) , 13 year old in Lampuhng of Sumatera (right)

of 13-14 years old mangrove grown in Lampung (37.0 kg/stand) was 1,5 times larger than the stand biomass of the same age mangrove grown in Bali(27.90 kg/stand).

Plant's performances of 4, 5, and 6 year old mangrove stands in Riau and Cilacap was indicated in Figure 2, while that of 13-14 year old mangrove stands in Lampung and Bali were showed in Figure 3. Stands 4, 5, and 6 year old mangroves in Riau thrive flourishing and their canopies shade each other forming a closed mangrove forest plantations, while those in Cilacap grew languished in the stretch of soft mud. In 13-14 year old rehabilitation mangroves, stands grow in Lampung have established thriving forests while those in Bali developed in to a rarely and not uniform mangrove stand communities.

2. Soil and hydrological condition of mangrove rehabilitation areas.

Soil characteristics at four locations of rehabilitated mangrove areasn were different. Mangrove rehabilitation areas in Riau and Lampung are located in mesozone area along the riverbank of broad estuary, with site elevation of 5-6 m above sea levels, and previously were respectively used as secondary forest and abandoned shrimp ponds, while those in Cilacap and Bali are composed of mudflats with site elevation of 0-5 m above sea level, located in the intertidal seaward zones and previoudly were abandoned shrimp ponds. All locations of rehabilitated areas are influenced by daily tidal inundation with frequencies of 20 days per month (Table 7). Substrate of soil mangrove in Riau and East Lampung of Sumatera Islands dominated by blackmud riches of organic matters with clay textures, while those in Cilacap of Java and Sanur of Bali seem to be sedimentation of mudflats with sandy clay loam and loam textures. Mangrove soil in Riau had high pH, low salinity, and high availability of nutrients, in the contrary mangrove soil in Cilacap had low pH, high salinity, and low availability of nutrients, while the characteristics of mangrove soil in East Lampung and Sanur of Bali were in the range in between the values of mangrove soil in Cilacap and in Riau with a slight variation (Table 8, 9 and 10).

Discussion

Growth of rehabilitated *Rhizophora apiculata* mangrove in Riau and Lampung of Sumatera islands was higher than that in Cilacap of Java and in Sanur of Bali islands. Soil and hydrological conditions as well as natural zonation of each rehabilitated sites were also different. At four location of rehabilitation areas, only a monospecies of *Rhizophora apiculata* was planted. Although *Rhizophora apiculata* was the most popular and commercial mangrove species for rehabilitation in Indonesia and throughout Asia countries (Salmo, et al., 2007), it has limited and distinct niche in the intertidal zones (Wibisono and Suryadiputra, 2006, Brown and Yuniarti 2007). Therefore, the current management of replanting only monospecies *Rhizophora apiculata* at different mangrove rehabilitation areas should be reveiwed.

Soil characteristics and hydrological conditions of mangrove rehabilitation area in Riau and Lampung might meet the ecological requirements for the optimal growth of *Rhizopora apiculata*, while those in Cilacap and Bali might have some physical and chemical and hydrological constraints which hampered the optimal mangrove growth. Mangrove species of *R.apiculata* might be not very appropriate to be planted in Cilacap and Bali mangrove soils, which locates in intertidal zone close to the sea, composed of sandy mudflat, and had low pH, high salinity and low nutrient availability.

Soil ecological condition required for optimum growth of *Rhizopora apiculata* was zone area that has less sedimentation and short inundation and less ecxposure to wind and waves (Thampanya *et al* 2002), the mudfat area adjacent to large river and riverine fringes at mouth of rivers (Duarte *et al* 1998), in a lagoon of no wave action (Maxwell, 2008), and at soils with low salinity and high pH and silt texture (Ahmed et al., 2007). The area of extensive mudflat extending far seaward with little or no gradient at low intertidal zone seafront such as in Cilacap and Bali are usually high risk site for the successful planting of mangrove species notably Rhizophora species (Clough, 2008). Samson and Rollon (2008), reported that individual *Rhizophora* spp surviving at seafront of the low tidal zones would barely attain 3 m height during the firts 10 years, where the corresponding vertical growth of *Rhizophora* at high intertidal zones would be 2-3 times as much. In this study, growth of 4, 5, and 6 year old *Rhizophora apiculata* in Cilacap, indicated by averaged stand biomass production, was rather similar, about 10.73 % of *Rhizophora apiculata* growth in Riau; while growth of 13 old *Rhizophora* mangrove in Bali was 68.75% of *Rhizophora* mangrove growth in Lampung.

Areas of mangrove rehabilitatation in Cilacap and Bali might be more suitable to be planted with other true mangrove species such as *Avicenia marina and Soneratioa alba*. The site areas prefered for the establishment of *Avicenia* spp. and *Sonneratia* spp are zone areas of front liner, seaward areas that outfacing edge, fully exposed to daily high tides, waves and winds (Katiresan 2002; Giesen et al. 2006; Primavera, 2006; Langat and Kairo, 2008). Each species of mangrove thrives at different substrates, *Avecinnea* spp. and *Sonneratia* spp. thrive at lower substrates potentially subject to abrupt sedimentation, composed of sandy muddy substrate with sandy loam soil texture (Duarte et al. 1998; Nakamura 2000; Onrizal, 2002; Tampanya, *et al* 2003; Primavera, 2006), in which *Avicennia* sp grow on softer and and muddier areas with the high value of silt, while *Sonneratia* sp grow on sandier and stable areas (Mastaller, 1997; Winarno and Setyawan, 200; Melana *et al*.,2003). *Avicennia marina* and *Sonneratia alba* are pioneer species that are tolerant to extremely saline (Mastaller 1997; Ahmed et al. 2007; Maxwell, 2008). Therefore, it would be proper to *select Avicennia sp* and *Sonneratia* alba species to planted on sites having high salinity at front liner full sea water (Onrizal, 2002; Katiresan 2002; Wibisono and Suryadiputra, 2006).

Early colonizing species may encounter an abrupt high sedimentation, strong water currents as well as prolonged submergences, necessitating a rapid development of the root system and stem elongation. Species that colonize the outer edge of mangrove forest such as *Avicennia marina* and *Sonneratia alba* are able to remain firmly rooted as seedling when they are regularly inundate by high tides (Thampanya et al. 2000). Mangrove species that first establish mangrove forest almost often posses a major system of aerial roots, called pneumathophores which are slender cone, stand up in the line on the cable roots spreading horizontally in every directions in the soil, the cable root variables from to 1 m to over 20 cm depending on the tree size and age. Such roots not only help to anchor the plant and keep it raised out of water but also create a tangel of crossed and looping roots. Within that tangle of roots collect sediment including organic matters from decaying plant organs (Nakamura, 2000; Melana et al. 2000, Thampanya et al. 2002).

Planting selection only mangrove species of *Rhizophora apiculata* at four locations of mangrove rehabilitation in Riau and Lampung of Sumatera island and in Cilacap of Jawa and Sanur of Bali was probably not recommended. Unsuitable choice of mangrove species by planting only Rizhophora sp in all locations without regard to the specific-site natural mangrove zonation, is the factor most frequently reported causes of failure of post tsunami mangrove rehabilitation projects in many Asia countries (Salmo et al., 2007; Soegiarto, 2008; Samson and Rollon, 2008; Onrizal and Mansor, 2010). In species selection for mangrove rehabilitation, as much as possible, mangrove restoration should involve mixed species planting, or at least species other than the Rhizophora sould be included (Macintosh and Ashton 2002). A plantation approach does not restore a viable, biodiverse ecosystem, but instead creates a monoculture which creates a homogeneity, and is not good for ecological balances. There is a better way than promoting monocultures of such a multi-species ecosystem- especially in Asia, where there may well be 20-30 varieties of mangroves found in a single area. For this reason, in order to enrich mangrove species biodiversity , it is proposed to mix crops of many mangrove species such as *Avicennia* spp, *Sonneratia* spp., *Ceriops* spp. *Bruguiera* spp. ; *Aegiceras* spp., *Nypa fruticans* on the site which suitable each particular species,. (Wibisono and Suryadiputra, 2006 Brown and Yuniarti, 2006; Maxwell (2008).

Rehabilitation of various mangrove species, other than the widely researched species of the genus Rizhophora, was especially difficult, because planting guidelines were implete (Elster, 2009). The guidelines about Mangrove Rehabilitation in Indonesia issued by Perum Perhutani (1995) and the Regulation of Forest Minister (2004), mentioned only about plantation's techniques and the suitability of *Rizophora apiculata* for mangrove rehabilitation, and did not clearly describe the important of taking consideration the hyrological site conditions as well as suggestion to select other mangrove species of mangrove such as *Avicennia* spp., *Sonneratia* spp. *Bruguiera* spp and *Ceriop* spp on the site which suitable each particular species.

One of many problems responsible for the failure of after the tsunami mangrove rehabilitation in Indonesia is lack of resources for monitoring the survival and growth and caring of mangrove after planting (Wibisono and Suryadiputra, 2006; Brown and Yuniarti, 2006; Soegiarto, 2008; Onrizal and Mansor, 2010). Rehabilitation will succeed only when people get sustainable benefits from the rehabilitated systems. Community livelihoods are significantly linked to the mangrove ecosystem. However, most mangrove rehabilitation program are concervative oriented, aimed promarly at land concervation and are not necessarily linked with livelihood option for local people (Kanagaratnam, et al. 2006), There is a need of an integrated strategy for rehabilitation of degraded ecosystems together with conservation such that rehabilitation that improves livelihoods of local communities (Tabuchi, 2003). Therefore the rehabillitation program should involved and work together with the local community in order to ensure the restored areas are adequately protected in the longterm (Macinthos and Ashton 2002). Eviedence in this study indicated that growth of rehabilitatted mangrove in Riau and Lampung were better than in Cilacap and Bali, because the management of rehabililtation programs in Riau and Lampung involved local community's participation, while mangrove rehabilitation programs in Cilacap and Bali probably did not involve the local community. The rehabililation program in Riau was under the initiative of Local NGOs and communities, while in Lampung was conducted by local private fisherman's group worked together and under suvervised of Lampung University. Rehabilitation program in Cilacap was undertaken by 'Perhutani', a government forestry enterprise raised mangrove plantations, and rehabilitition in Bali was under managements of Forestry Department sponsored by JICA Japan(Table 1).

The facts of this study indicated that characteristics of soil and hyrological conditions became the primary factor controlling the growth of mangroves at four location of mangrove rehabilitation in Indonesia. This findings may emphasize the important of properly assesing and investigating the specific site condition and coastal ecosystems of prospective site before deciding whether to use it for rehabilitation. Unfortunately, much of mangrove restoration that had been carried out to date had been conducted without adequate site assesment (Lewis III, 2005). The majority of mangrove restoration projects in Indonesia have experienced high or even complete mortality. Adherence to "blind" planting methods, without regard to the hydrological and ecological needs of various mangrove species, has led to repeated failure (Lewis III, 2007; Brown,B. and W.Yuniarti. 2006).

The fact that characteristics of soil ecological condition became the primary factor controlling the growth of replanted mangroves, emphasizes the important of considering ecological aspects of mangrove soil to be rehabilitated. Sound management of mangrove rehabilitation program should consider the site-specific requirement management (Matsui *et al,* 2008). The study showed the evidence that each site of mangrove rehabilitation areas in Indonesia had a specific soil and hydrological condition. In general, soil and hydrological characteristic of Riau was almost same as with Lampung; while ecological characteristic of Cilacap was rather similar with that of Sanur Bali. If these ecological characteristics were taking into consideration in determining suitable mangrove species at each location, the mangrove species planted should be different, but in fact at four locations was planted the same mangrove species of *Rizhophora apiculata*.

Many attempts to rehabilitate mangroves fail completely, as they are poorly planned and managed. Planting the wrong species in the wrong place is one of the main reasons for much failure in Mangrove rehabilitation (Lewis, 2005). It would dangerous to apply a single management option to all mangroves region. Broad supplementary objectives may be initially set and these may subsequently be refined specifically for each regions or country (Saenger, 1999). As large tracts of destroyed mangrove areas located in various islands in Indonesia have different soil ecological characteristics, then developed management program of mangrove rehabilitation for each region in Indonesia should be developed specifically according to their soil ecological characteristics. Kathiresan (2002) proposed that species selection is the most important needed for successful restoration of mangrove plantation. He recommends the mangrove's adaptability to chemical environment, to the soil composition, and to the sea salinity as criteria for species selection of mangrove species for rehabilitation. True mangrove species have different tolerance and adaptability to some ecological factors including to salinity and soil characteristics conditions. (Kathiresan, 2002; Jayatissa and Wikramasinghe, 2006).

CONCLUSION

Growth of rehabilitated mangroves depends on the suitability between planted mangrove species with soil characteristics and hydrological conditions of the rehabilitated areas. Therefore (1) it is important of taking into consideration the ecological aspects of mangrove soil to be rehabilitated and selecting species of mangrove suitable for the selected sites; (2) in species selection for mangrove rehabilitation, as much as possible, should involve mixed species planting of many mangrove species.

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