Mangrove's structural complexity and disturbances

A case study of the Berau Delta, East Kalimantan, Indonesia!

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要旨：今日、マングローブ林の多くが人為的あるいは自然的影響による問題に直面している。この研究では、マングローブ林の根の構造および樹形特性と、これら影響要因・因子との関連性について調査した。その結果、自然的要因から離れた位置に生育しているマングローブ林ほど樹高成長の増加と本数密度の減少がみられた。一方、根の分岐の度合いは自然的要因と相関関係にあり、人為的要因から離れているほどマングローブの根の直径は大きくなっていた。この結果は、マングローブ林の樹高分布や根の状態を調査することにより、その林が受けている影響を知ることも可能であるということを示している。

Abstract Continuous development is threatening the coastal environment and common types of disturbances faced by mangrove forest are natural and anthropogenic disturbances. These disturbances lead to a decline of the mangroves forest area, lessening its role as land stabilizer from costal damages, and its functions in providing fisheries habitat, shelter and food for marine organisms. Rhizophora's prop roots not only provide anchorage to the tree, but can also serve as an indicator for mangrove disturbances. In this study, mangrove roots structure and tree characteristics were studied to investigate which variables are related to disturbance factor. The influence of the distance to natural disturbances (open water) and anthropogenic disturbances (e.g. villages) on the changes in these trees and roots characteristics were measured. A significant increase in tree height and a decrease in tree density were found when mangroves were further located from natural disturbance. In addition, the roots branching order was correlated with the distance to natural disturbances, whilst root diameter increased in relation to the distance to anthropogenic disturbances. The result of this study reveals the potential use of tree and root complexity as an indicator related to disturbance factors in the mangrove forest.

Keywords: *mangrove forest, Berau Delta, disturbances, tree structure and root complexity*

1. INTRODUCTION

The Berau Delta is characterized by a high botanical density (Bodegom et al., 1999) where various mangrove and non-mangrove species can be found in this area. Mangroves resources are utilized by the villagers, especially fisherman for fishing stakes, firewood, housing material and the delta area is use for human settlements and brackish fish ponds for fish farming. The great ecological and economical potential offered by mangrove forest is unfortunately in a serious decline as the impact of several disturbances. The declination was due to two major types of disruptions: natural and anthropogenic (man-made) disturbances (Jason Broshear, 2005). Most researches have been carried out on the botany and ecology of mangrove, but less is known about the interactions with the environment. For this reason, this study was carried out to investigate the relationship between mangrove disturbances (both man-made and natural) with tree structural and root complexity. Holdridge (1976) had described complexity by high number of species, stem density, basal area and height of trees while Brooks and Bell (2005) added the below-water measurement (e.g., roots) in explaining the complexity of mangrove forest. In this study both above and below-water parameters were used to check its relation with the distance to the disturbance factors.

2. MATERIALS AND METHODS

Study area: The study was carried out at the Berau Delta, East Kalimantan, Indonesia (Figure1). The area about 227,138 ha is located between 1° 00' 00" to 2° 33' 00"N and 117° 00'00" to 119° 00' 00"E. The tropical season was influenced by West monsoon from November to April and East monsoon from May until October with average temperature up to 31°C and average rainfall of 298mm per month.

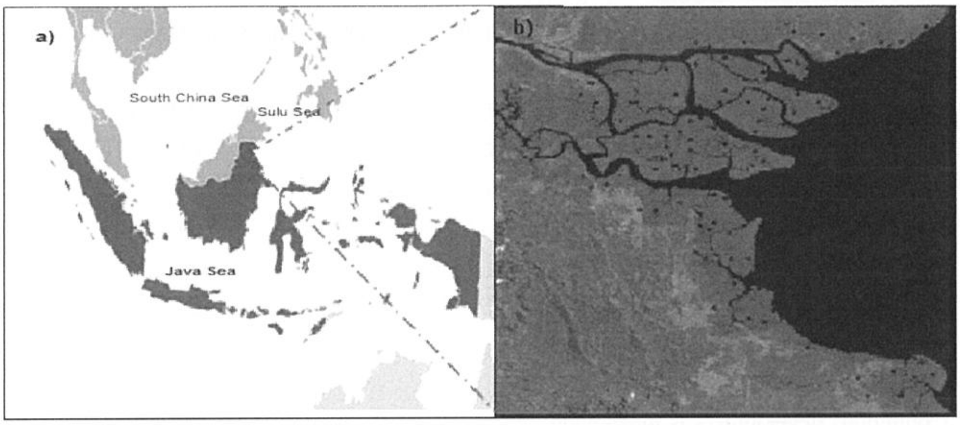

Figure1: a) Indonesia map and b) Location of study area (Berau Delta, East Kalimantan) with black dots indicating the study sites

Tree composition: Fifty sampling points were chosen through a random selection based on a gridded map. In each point a 20x20m plot was setup and information on mangrove stands (species, tree height, diameter at breast height (dbh), geographical coordinates, percentage of crown cover in the plot, number of seedlings and saplings) were recorded. An electronic laser distance meter was used to measure the tree height in meter (m). Tree dbh was measured using diameter tape and the geographical position of the central point of each plot was recorded using a hand-held GPS Garmin 60CX 12-channel receiver.

Root composition: In each 20x20m plot setup for quantifying the tree composition, another five $1m^3$ collapsible quadrants made of PVC pipe were set up to determine the root density (Figure 2). In these small plots, root composition (root length, root diameter and branching order) were measured. Prop roots branching pattern were recorded with a first branching order is the first root sprouts from the main tree trunk and when the new roots branching off from the first root, it was recorded as the second order etc. These root composition data were used to obtain the density and structural complexity of each plot.

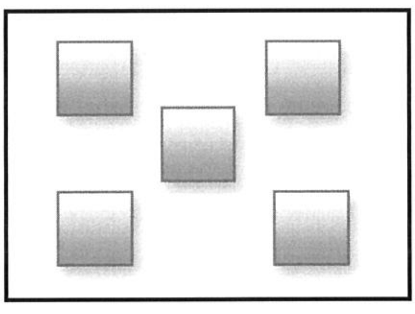

Figure 2:
A 20x20m plot (big square) was setup in each sampling point. Within the big plot, tree composition was measured. In five small subplot of 1x1m (small square) data of roots composition was recorded.

Besides field work, image analysis of Landsat TM, image of 2004 was carried out using ERDAS software. Measurement of the distance to nearest village and open water (big channel) were determined using this tool.

Statistical analysis: Distance to a disturbance sources were tested in relation to tree characteristics, tree cover and root characteristics. All variables were first tested using Spearman's rho (rs). Then a regression analysis was done to check positive or negative relation between variable with a disturbance factors. Additionally, a multivariate analysis was carried out to identify species distribution and structure of the data.

3. RESULT

Rhizophora apiculata was found as a dominant species with an average tree height and dbh of 13.9m and 17.6cm respectively. Table 1 summarized the result of tree and root structure of surveyed plots.

Table 1: Summarizing table of correlation results between distances to disturbances and various dependent variables, using Spearman's rho, in the Berau Delta mangrove area.

	Distance to natural disturbance (water)			Distance to anthropogenic disturbance (village)		
Tree characteristics	rs	p	n	rs	p	n
Tree density(N/0.04ha)	-0.43	0.007	38	-0.14	n.s	38
Tree height(m)*	0.35	0.03	38	0.22	n.s	38
Tree diameter(cm)	0.25	n.s	38	0.1	n.s	38
Tree cover and density						
Species number(N)	0.06	n.s	50	-0.12	n.s	50
Crown cover(%)	0.26	0.07	50	0.02	n.s	50
Saplings number(N/0.04ha)	-0.19	n.s	50	-0.15	n.s	50
Seedlings number(N/0.04ha)	-0.46	n.s	50	0.89	n.s	50
Root characteristics						
Root density(m^2)	-0.14	n.s	32	0.23	n.s	32
Root length(cm/m^2)	-0.04	n.s	32	-0.21	n.s	32
Root diameter(cm/m^2)*	-0.05	n.s	32	-0.43	0.01	32
Branching pattern(N)	0.51	0.008	25	0.12	n.s	25

* tree height regression ($r=0.44$, $R^2=0.19$, $df=37$, $p<0.01$)

* root diameter regression ($r=0.38$, $R^2=0.15$, $df=3$, $p<0.01$)

Based on the result, only tree height and density, root diameter and branching pattern had significant relationship to disturbances. A multiple regression analyses using the Enter method was also carried out, unfortunately combination of both disturbance factors did not show any significant relationship to each variables tested.

4. DISCUSSION

An increase in tree height and a decrease in tree density were found when mangroves were further from natural disturbance. Further from the main water sources e.g., sea or big river, different mangrove species composition were found due to the different salinity and inundation factors (Chapman, 1975). For example, in Apar Nature Park, Kalimantan, the average tree height of seaward is lower than at landward edge. The height of *Avicennia* sp. which is more tolerant to salinity in the seaward area was found at 30m while *Rhizophora* sp. was found at 10m higher (Sukardjo, 1994). Wave and currents can directly or indirectly change the structural characteristic and functions of mangrove ecosystem and high and low tidal range also could affect the root system of mangrove. Prop roots of *Rhizophora* sp. with a wide tidal range will extend far above the soil surface while with the narrow tidal range of water the roots were significantly found to have lower roots. At the wave exposed sites, micro nutrient and organic matter probably accumulated in the soil, increasing the productivity (Carter et al., 1973) and therefore increased the standing biomass (Alongi et al., 2000). This suggests that at the seaward margin we would find a greater tree density compared to the wave sheltered area which contained less nutrients sedimentation. Besides having a greater tree density, the trees in this area were found lower in height. This was caused by natural disturbance like wave action and tropical storm that attack and had limited the development of the tree (Egler, 1952). Therefore we would expect trees that were exposed to disturbances are generally smaller in diameter and height compare to the sheltered area which has lower disturbance effects.

The root branching pattern influence the distance to natural disturbance. Referring to Brown and Lugo (1982) the physical complexity decreased because of wave interruption which this factor could slower the development and growth of the roots. Hence the prop roots are found difficult to anchor in the sandy and muddy area near seaward. As a result, more complex root structure was found further away from natural disturbance. The presence of crab and predator near the seaward area are another factor of unsuccessful growth of the roots hence decreases the root complexity.

Salinity is one of the factors that caused the pencil-like roots of *Avicennia* sp. and *Sonneratia* sp. could accommodating the seaward area and this type of roots are relatively smaller in sizes compared to the prop root of *Rhizophora* sp. and plank root of *Xylocarpus* sp. Besides that, from my personal observations, bigger roots were found 20 to 50m from villages in Berau delta. As the fisherman village located near the water, it was exposed to the sea wind and tidal inundation. The vegetation barrier offered by mangrove helps to shelter the community from tsunamis and wave action where usually in this area bigger trees with strong roots are found.

In conclusion, this study revealed the significant influence of the distance to disturbances on the changes in tree and root characteristics. However, the method could be improve by including environmental factors e.g., salinity, altitude, rainfall to yield better explanation of complexity.

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