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Dynamic Linkages of Mangrove *Rhizophora Mucronata* and its Environment Parameters in Semarang and Demak Coastal Area

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Introduction

Coastal area including mangrove ecosystem are the most dynamic area compared to marine and land ecosystem. Mangrove vegetations lived in unique habitat where marine and land activities were met and create a highly dynamic condition. The condition of the habitat changed by the effect of marine and land dynamic. According to [1], intertidal environment including hydrological and geomorphological condition define the structural variation of mangrove ecosystem.Inundation by salt water is the main character of mangrove ecosystem [2].

Mangrove ecosystems are under great pressure of population and development activities [3]. A research conducted by [4] noted that human activities including urban expansion, landuse conversion was the main cause of mangrove decline. While [5] mentioned that sea level rise also caused mangrove decrease. Sea level rise caused sediment elevation to be lowered. Hence, inundated area of mangrove ecosystem increased which caused disturbance on mangrove vegetations.

Variability of mangrove ecosystem is defined by water mass dynamic from marine and land. According to [6], hydrographic, nutrient distribution and water biomass of mangrove ecosystem were influenced by freshwater input from rivers and marine water input from wave and tide. Hence, the distribution of salinity and nutrient are dynamically change.

The growth of mangrove vegetation such as *Rhizophora mucronata* is affected by the condition of environment parameters. The condition of environment variables simultaneously effect the growth rate of the vegetation as well as its reproduction. According to [7], the habitat of *R. mucronata* were characterized with low soil salinity, silt and pH value. *Rhizophora mucronata* is salinity tolerance species though its less tolerance than *Avicennia marina*[8]. A research conducted by [9] considered that the growth of *Rhizophora mucronata* was limited as the seawater concentration raised above 50%.

According to [10], there were correlation between mangrove species richness and ecosystem function. Variation in the stages of plants effects manifest themselves.The growth of mangrove vegetation differs among ages. According to [11], growth of young stages mangrove inhibition were observed within 2 m circular distance, while old stages (after 20 years) inhibitin were observed within 3 m circular distance. It showed that mangrove growth would increase competition among vegetations. Hence, mangrove abundance would dynamically change as well as the community structure.

Unfortunately, the condition of coastal environment is dynamically change. Marine and land dynamic are the main factors affecting the change of coastal environment. As well as the marine and land dynamic, the mangrove vegetation itself are growing which lead to the change on the condition of the ecosystem. Hence, physical, chemical and biological parameters change by time. This caused to inter ecosystem dynamic. A research conducted by [12] showed that the decrease of sediment pH would decrease the growth of *R. mucronata*.

Further effect of mangrove growth is colonization provided from reproduction processes [13]. Most mangrove mortality was caused by environment stresses. In some regions, mangrove recruitment do not suffice to balance the mortality rate [14]. According to [15], reproduction of mangrove were generated from mangrove tree.

According to [2], to understand the response of mangrove ecosystem, further concern on the environment condition within mangrove ecosystem is needed. Dynamic model estimating further development of mangrove ecosystem could be arranged by considering dynamic reciprocal relation of mangrove structure and environment variables. This research aimed to observe and build the simultaneus and continuous dynamic relation of mangrove structure and environment variables.

Materials and Method

This research was conducted in Semarang and Demak coastal area where mangrove ecosystem existed. Both locations had the same sediment characteristics since both locations are in the same sediment cell. The observation was conducted in 2009, including 8 observation stations and 24 observation transects. Observation was conducted to mangrove structure and environment parameters.

Observation of mangrove structure was including mangrove specieses, abundance and basal area of each mangrove stages (tree, sapling and seedling). Observation was differed by mangrove stages, where tree stage utilized 10 x 10 m^2 of transect size, while sapling stage utilized 5 x 5 m^2 of transect size and 1 x 1 m^2 of transect size for seedling stage. Transects for lower mangrove stages of mangrove was placed within the transects of higher mangrove stages. While observation of environment parameters was conducted within the transect as well.

Environment parameters including physical (soil texture, TSS, temperature) and chemical (salinity, dissolved oxygen, pH, concentration of organic matters, sediment N & P concentration, dissolved N, P & K concentration). While biological parameters including abundance, relative abundance, dominance, relative dominance, importance index of vegetation, heterogeneity index and evenness index of mangrove vegetations.

To analyze the development of mangrove structure, a model was developed. To understand the dynamic reciprocal relation of mangrove structure and environment parameters, the effect of each mangrove structure to environment parameters vice versa should be understood. Regression analysis correlating mangrove structure and environmnet parameters was conducted as initial analysis and to provide the basic numeric relation of reciprocal model. The analysis including linear, logarithmic and polynomial regression models were conducted to achieve the best model fit.

The result of regression analysis was filtered to provide a suitable model. Filtering was conducted through determination index and / or probability index. Corelation between each mangrove structure and environmnet parameters which have determination index $\geq$ 50% or probability index $\leq$ 0,1 was utilized for model development. Model development was conducted with Powersim Studio 2005.

Result

The result showed significant vice versa relations of mangrove structure of *Rhizophora mucronata* and environment parameters. The effect of the environment parameters including to the growth rate and mortality rate of *Rhizophora mucronata* seedling and sapling and reproduction rate of *Rhizophora mucronata* tree. The effect of environment parameters on the growth rate of *Rhizophora mucronata* sapling and seedling achieved from regression analysis are shown in Table 1 and Table 2.
Table 1 showed that growth rate of *Rhizophora mucronata* sapling was effected by temperature, pH, organic matter, soil N, silt and clay. While growth rate of *Rhizophora mucronata* seedling was effected by temperature, organic matter, soil N and soil P. Based on the regression result showed in Table 1 and Table 2, a model was developed to the linked variables as shown in Figure 1.

The environment parameters also effect the reproduction rate of *Rhizophora mucronata* tree. The regression analysis result is shown in Table 3. The growth rate of *Rhizophora mucronata* was effected by salinity, DO, organic matter, soil P, dissolved N and dissolved K. Figure 2 showed the linkage model of environment parameters and reproduction rate of *Rhizophora mucronata*.

Instead of effecting the growth rate of sapling and seedling, and reproduction rate of tree, environment parameters also effect the mortality rate of sapling and seedling of *Rhizophora mucronata* as well. The effect of environment parameters to mortality of *Rhizophora mucronata* sapling and seedling was achieved from regression analysis as shown in Table 4 and Table 5.

Table 4 showed that mortality rate of *Rhizophora mucronata* sapling was effected by temperature, soil N, dissolved N and silt. While mortality rate of *Rhizophora mucronata* seedling was effected by temperature, salinity, pH, DO, organic matter, soil N, soil P, dissolved N and dissolved K. Linkage model of environment parameters and mortality rate of *Rhizophora mucronata* sapling and seedling is shown in Figure 3.

Vice versa relation of environment parameters and mangrove structure of *Rhizophora mucronata* was shown by the effect of *Rhizophora mucronata* abundance to the environment parameters dynamic. Table 6-Table 8 showed the effect of mangrove abundance of *Rhizophora mucronata* tree, sapling and seedling to the environment parameters.

Table 6 showed that tree abundance of *Rhizophora mucronata* effected the environment parameters such as TSS, salinity, organic matter, soil P, dissolved N, dissolved K and clay.

Table 7 showed the effect of *Rhizophora mucronata* sapling abundance on the environment parameters including temperature, TSS and pH.

Table 8 showed the effect of *Rhizophora mucronata* seedling on the environment parameters including DO, soil P, dissolved N and dissolved K.

Instead of mangrove abundance, environment parameters within mangrove ecosystem was also effected by mangrove mortality, including sapling and seedling mortality. The effect of mangrove mortality of *Rhizophora mucronata* sapling and seedling is shown in Table 9 and Table 10.

Table 9 showed that environment parameters effected by sapling mortality of *Rhizophora mucronata* sapling was including temperature, TSS, salinity, BO, soil N, soil P, dissolved N, sand and silt.

Table 10 showed the effect of *Rhizophora mucronata* seedling mortality on the environment parameters including to organic matter, soil P, dissolved N and dissolved K. Mangrove abundance and mortality simultaneously effect the dynamic of environment parameters. Dynamic model was developed to show the link of mangrove structure and the environment parameters as shown in Figure 4.

Instead of being effected by environment parameters, mangrove abundance was also limited by its own abundance and basal area. Mangrove abundance and its limitation effect dynamic model is shown in Figure 5.

Table 1: Effect of Environment Parameters on the Growth Rate of *Rhizophora mucronata* Sapling

No.	Effecting Parameter	Equation	P	R^2
1.	Temperature	$Y = 28{,}879-2{,}012\ X + 0{,}035\ X^2$	0,108	0,671
2.	pH	$Y = 47{,}419-14{,}681\ X + 1{,}136\ X^2$	0,052	0,773
3.	Organic Matter	$Y = 1{,}146-0{,}401.\ln(X)$	0,103	0,443
4.	Soil N	$Y = 0{,}701-3{,}881\ X + 5{,}222\ X^2$	0,002	0,961
5.	Silt	$Y = 0{,}223-0{,}048.\ln(X)$	0,07	0,514

Table 2: Effect of Environment Parameters on the Growth Rate of *Rhizophora mucronata* Seedling

No.	Effecting Parameter	Equation	P	R^2
1.	Temperature	$Y = 0{,}823-0{,}241.\ln(X)$	0,292	0,351
2.	Organic Matter	$Y = -1{,}040 + 0{,}138X-4{,}406e^{-3}\ X^2$	0,503	0,497
3.	Soil N	$Y = -0{,}034-0{,}051.\ln(X)$	0,293	0,351
4.	Soil P	$Y = 7{,}853e^{-3}-2{,}438e^{-4}\ X + 1{,}605e^{-6}\ X^2$	0,195	0,805

Table 3: Effect of Environment Parameters on the Reproduction Rate of *Rhizophora mucronata*

No.	Effecting Parameter	Equation	P	R^2
1.	Salinity	$Y = 172{,}572-50{,}718.\ln(X)$	0,179	0,505
2.	DO	$Y =-7{,}153 + 4{,}601\ X-0{,}534\ X^2$	0,365	0,635
3.	Organic Matter	$Y = 73{,}668-9{,}590\ X + 0{,}312\ X^2$	0,100	0,900
4.	Soil P	$Y = 0{,}458 + 2{,}270e^{-2}\ X-9{,}409e^{-5}\ X^2$	0,592	0,408
5.	Dissolved N	$Y = 5{,}716-3{,}682\ X + 0{,}582\ X^2$	0,408	0,592
6.	Dissolved K	$Y = 2{,}182-8{,}668e^{-3}\ X + 7{,}143e^{-6}\ X^2$	0,049	0,951

Table 4: Effect of Environment Parameters on the Mortality Rate of *Rhizophora mucronata* Sapling

No.	Effecting Parameter	Equation	P	R^2
1.	Temperature	$Y = 50{,}740-3{,}457\ X + 0{,}059\ X^2$	0,079	0,719
2.	Soil N	$Y = 1{,}652-7{,}137\ X + 7{,}952\ X^2$	0,169	0,589
3.	Dissolved N	$Y =-0{,}216 + 0{,}387\ X-0{,}082\ X^2$	0,1	0,684

Table 5: Effect of Environment Parameters on the Mortality Rate of *Rhizophora mucronata* Seedling

No.	Effecting Parameter	Equation	P	R^2
1.	Temperature	$Y =-15{,}178 + 4{,}629.\ln(X)$	0,115	0,618
2.	Salinity	$Y = 69{,}067-20{,}331.\ln(X)$	0,028	0,844
3.	pH	$Y =-19{,}095 + 10{,}295.\ln(X)$	0,262	0,388
4.	DO	$Y =-2{,}404 + 1{,}432\ X-0{,}156\ X^2$	0,133	0,867
5.	Organic Matter	$Y = 5{,}048-1{,}742.\ln(X)$	0,197	0,477
6.	Soil N	$Y = 1{,}307 + 0{,}977.\ln(X)$	0,123	0,602
7.	Soil P	$Y = 0{,}511 + 8{,}960e^{-4}\ X-1{,}127e^{-5}\ X^2$	0,598	0,402
8.	Dissolved N	$Y = 2{,}218-1{,}652\ X + 0{,}293\ X^2$	0,201	0,799
9.	Dissolved K	$Y = 5{,}805e^{-2} + 6{,}289e^{-4}\ X$	0,061	0,742

Table 6: Effect of *Rhizophora mucronata* Tree Abundance on the Environment Parameters

No.	Effected Parameter	Equation	P	R^2
1.	TSS	$Y = 463{,}465 + 0{,}065X$	0,072	0,2
2.	Salinity	$Y = 20{,}890 + 1{,}010.\ln(X)$	0,108	0,163
3.	Organic Matter	$Y = 31{,}935-2{,}280.\ln(X)$	0,011	0,357
4.	Soil P	$Y = 290{,}300-0{,}057\ X$	0,085	0,185
5.	Dissolved N	$Y = 4{,}012-5{,}817e^{-4}\ X$	0,079	0,192
6.	Dissolved K	$Y = 459{,}828-0{,}269\ X + 9{,}093e^{-5}\ X^2$	0,001	0,642

Table 7: Effect of *Rhizophora mucronata* Sapling Abundance on the Environment Parameters

No.	Effected Parameter	Equation	P	R^2
1.	Temperature	$Y = 29{,}996\text{-}1{,}430e^{-4}.\ln(X)$	0,039	0,288
2.	TSS	$Y = 696{,}263\text{-}2{,}676e^{-2}\ X + 2{,}316e^{-6}\ X^2$	0,016	0,5
3.	pH	$Y = 5{,}437 + 0{,}125.\ln(X)$	0,088	0,207

Table 8: Effect of *Rhizophora mucronata* Seedling Abundance on the Environment Parameters

No.	Effected Parameter	Equation	P	R^2
1.	DO	$Y = 2{,}517 + 7{,}940e^{-6}\ X$	0,078	0,22
2.	Soil P	$Y = 667{,}971\text{-}49{,}474.\ln(X)$	0,068	0,234
3.	Dissolved N	$Y = 2{,}736\text{-}9{,}809e^{-9}\ X + 1{,}364e^{-11}\ X^2$	0,084	0,338
4.	Dissolved K	$Y = 216{,}176 + 5{,}889e^{-3}\ X\text{-}7{,}608e^{-9}\ X^2$	0,003	0,618

Table 9: Effect of *Rhizophora mucronata* Sapling Mortality on the Environment Parameters

No.	Effected Parameter	Equation	P	R^2
1.	Temperature	$Y = 30{,}336\text{-}1{,}986e^{-3}\ X + 2{,}369e^{-7}\ X^2$	0,009	0,607
2.	TSS	$Y = 688{,}266\text{-}4{,}664e^{-2}\ X + 2{,}153e^{-5}\ X^2$	0,009	0,607
3.	Salinity	$Y = 28{,}611 + 0{,}133.\ln(X)$	0,093	0,235
4.	Organic Matter	$Y = 13{,}187 + 3{,}056e^{-3}\ X\text{-}4{,}306e^{-7}\ X^2$	0,099	0,371
5.	Soil N	$Y = 0{,}583\text{-}0{,}034.\ln(X)$	0,05	0,306
6.	Soil P	$Y = \text{-}81{,}472 + 30{,}761.\ln(X)$	0,002	0,612
7.	Dissolved N	$Y = 3{,}089\text{-}0{,}227.\ln(X)$	0,05	0,306

Table 10: Effect of *Rhizophora mucronata* Seedling Mortality on the Environment Parameters

No.	Effected Parameter	Equation	P	R^2
1.	Organic Matter	$Y = 15{,}165\text{-}2{,}706e^{-5}\ X + 4{,}930e^{-11}\ X^2$	0,092	0,411
2.	Soil P	$Y = 423{,}947\text{-}33{,}028.\ln(X)$	0,046	0,342
3.	Dissolved N	$Y = 2{,}389\text{-}1{,}015e^{-5}X + 1{,}679e^{-11}\ X^2$	0,14	0,354
4.	Dissolved K	$Y = 244{,}130 + 1{,}005e^{-2}\ X\text{-}1{,}849e^{-8}\ X^2$	0,002	0,739

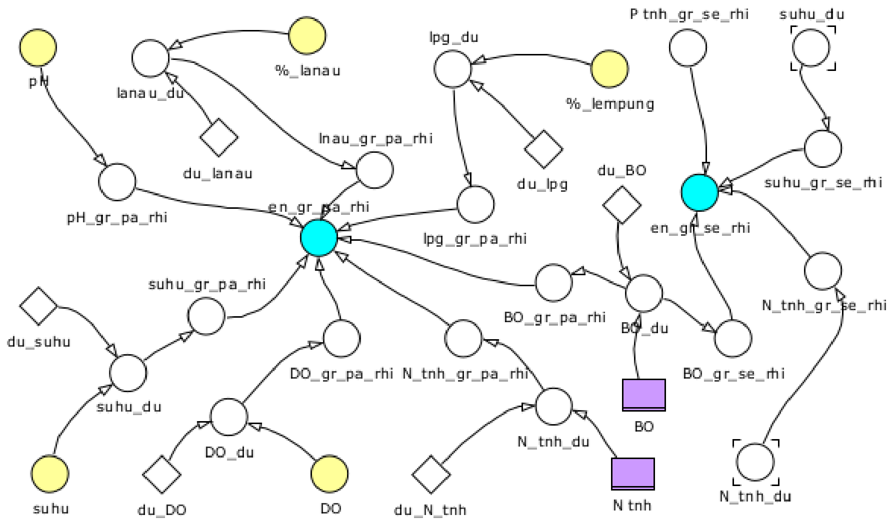

Figure 1: Dynamic Effect of Environment Parameters on the Growth Rate of Mangrove *Rhizophora mucronata*

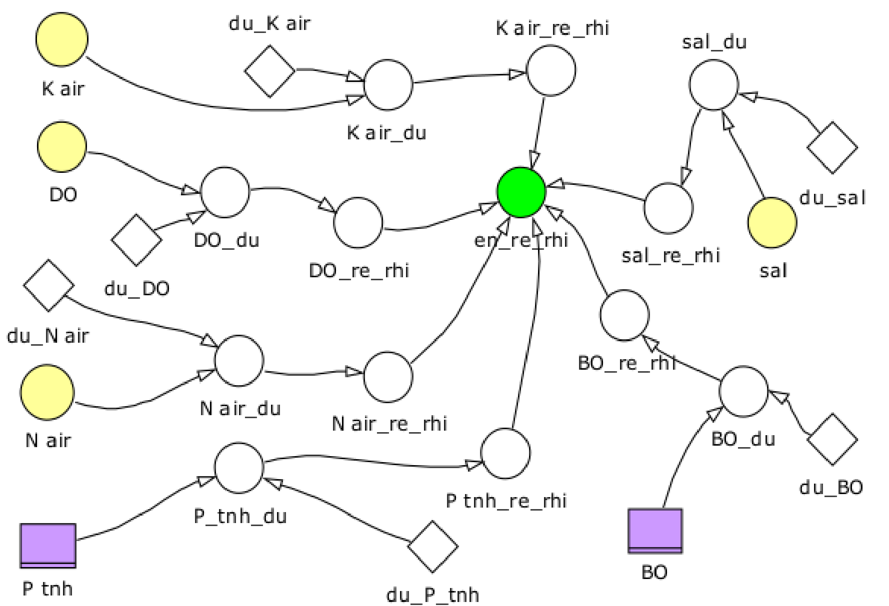

Figure 2: Dynamic Effect of Environment Parameters on the Reproduction Rate of Mangrove *Rhizophora mucronata*

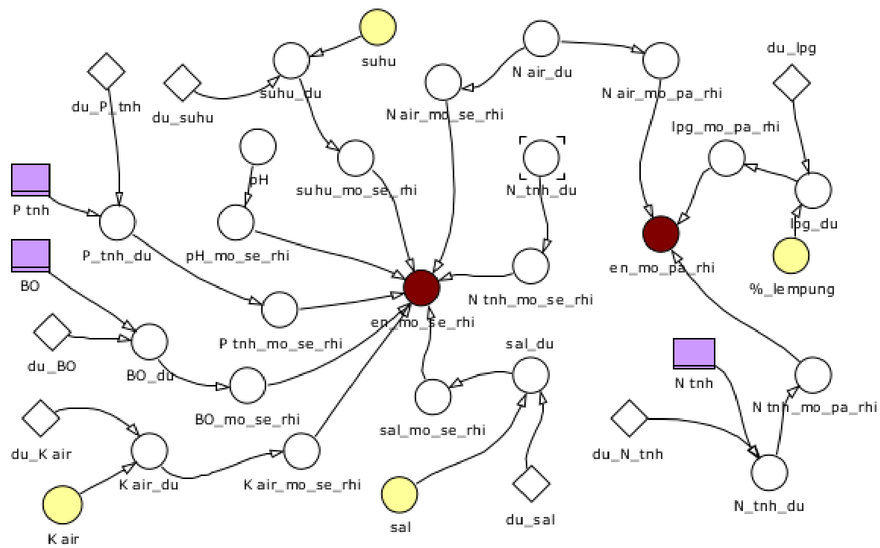

Figure 3: Dynamic Effect of Environment Parameters on the Mortality Rate of Mangrove *Rhizophora mucronata*

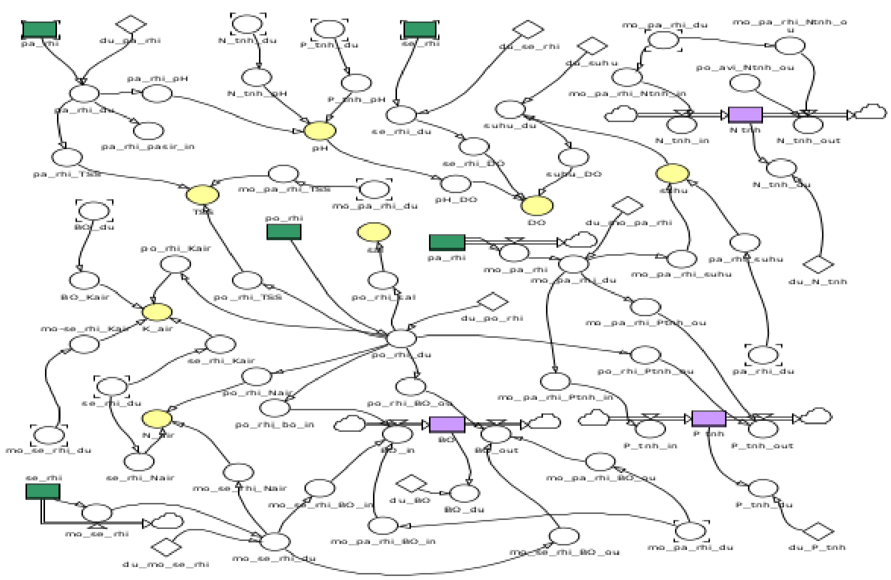

Figure 4: Dynamic Effect of Mangrove *Rhizophora mucronata* Structure on the Environment Parameters

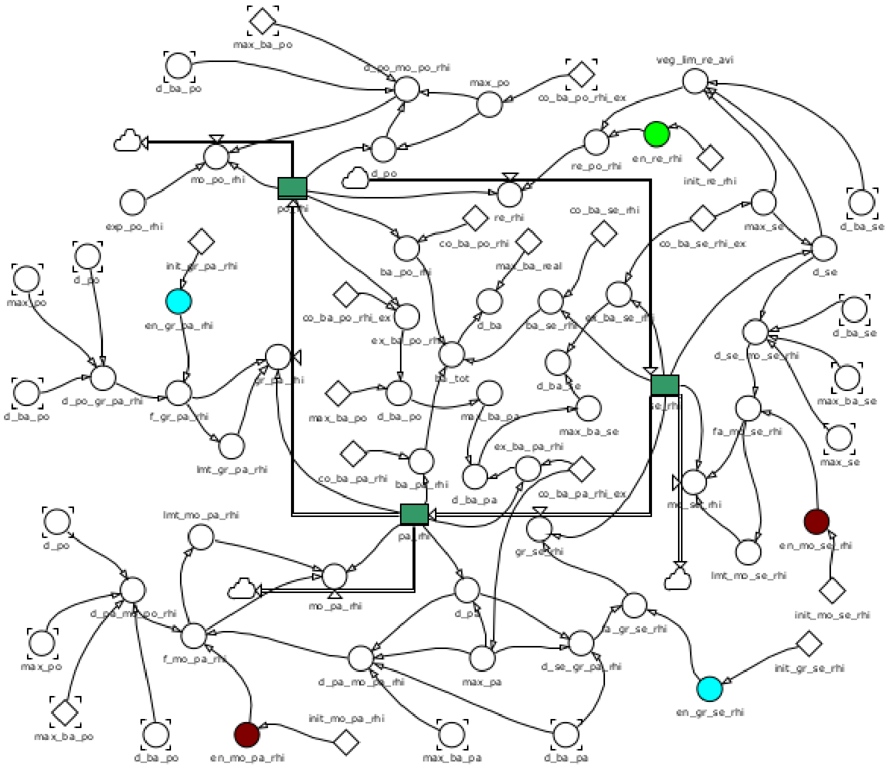

Figure 5: Dynamic Model of Mangrove Structure of *Rhizophora mucronata*

Discussion

The result above showed the dynamic vice versa effect of mangrove structure of *Rhizophora mucronata* and environment parameters. Growth of *Rhizophora mucronata* at sapling and seedling stages are significantly effected by temperature, organic matter and soil N. Higher temperature provide better growth rate on sapling growth rate, while on seedling growth rate it provide inhibition. According to [16], high temperature lead to photo inhibition and heat temperature damage of photosynthetic organ.

The effect of organic matter to the growth rate of mangrove sapling and seedling was negative, which means that the growth rate of mangrove sapling and seedling would be decreased as the organic matter concentration raised. According to [17], accumulation of organic matter in mangrove ecosystem caused to the increase of soil volume and sediment elevation. Hence, the function of mangrove root is limited.

The abundance of soil N concentration was the effect of high decomposition rate of organic matter in mangrove ecosystem. Soil N is the source of nutrient for mangrove vegetations where the abundance of soil N support growth rate of mangrove vegetation [18]. Even though the N is one of nutrient which is needed by mangrove vegetation, concentration of N can also be a limiting factor for mangrove growth rate. As well as soil N, growth rate of mangrove seedling was also effected by soil P. Both are essential nutrients for mangrove growth, especially at seedling stages.

Soil structure had significant effect on growth rate of mangrove sapling. According to [7], soil structure define the distribution pattern of mangrove species. It means that the growth of mangrove species is effected by soil structure. Sediment composition including sand, silt and clay devine the soil structure. Among the three sediment fraction, silt and clay have significant effect on the growth rate of *Rhizophora mucronata*. Both fraction has negative effect on the growth rate, which means that more composition of both fraction would lead to decrease of growth rate.

The reproduction rate of *Rhizophora mucronata* was significantly effected by salinity, DO, organic matter, soil P, dissolved N and dissolved K. Salinity is the most important parameter for mangrove. Mangrove had been well known to be tollerant to salinity stress. According to [15], *Avicennia marina* and *Rhizophora mucronata* were mangrove specieses with better salinity tollerance than any other specieses.

Nutrient has essential value in mangrove reproduction. Mangrove seed require adequate nutrient to support its survival and growth. A research conducted by [19] noted that seedling survival and growth was effected by light, nutrient, sulfide and elevation. Even though nutrient availability become a limiting factor of mangrove reproduction, mangrove vegetation has adaptation pattern as its response to nutrient limit [20].

Mortality rate of mangrove sapling and seedling was effected by temperature, soil N, dissolved N. According to [21], temperature varies greatly within the forest. Mangrove ecosystem may encounter high or low temperature. High temperature in the mangrove ecosystem tend to increase mortality rate of mangrove vegetaion. This should be a major thread to mangrove ecosystem since the atmosphere had encounter global warming which lead to the increase of temperature raising in the atmosphere.

Soil nutrient showed positive effect on mangrove mortality at sapling and seedling stages. This means that nutrient enrichment lead to higher mortality rate of mangrove. According to [22] mortality of mangrove by nutrient enrichment occured on addition of N fertilizer while the rainfall was low. This lead to lower productivity and enhance mortality of mangrove. This match with the result of the research which mortality rate increased by soil N enrichment.

The effect of salinity on the mortality rate of mangrove seedling showed negative value which means the increasing salinity would lower the mortality rate of *Rhizophora mucronata* seedling. According to [23], *Rhizophora mucronata* responded high salinity stress by decreasing stomatal conductance rate. According to [24], *Rhizophora mucronata* is mangrove species with high salinity tollerance instead of *Avicennia marina*.

Effect of mangrove abundance including to temperature, TSS, salinity, pH, DO, organic matter, soil P, dissolved N, dissolved K and clay. Mangrove abundance increase the absorbtion of ambient temperature which lead to temperature decrease [25]. TSS increase as the increase of mangrove abundance since mangrove root system create barrier for water current. Hence, water flowed slower and TSS concentration increase [26].

The increase of pH was caused by decomposition rate of mangrove litters [27], hence organic acid was produced and define the pH. As the abundance of mangrove increase, photosynthetic processes increased as well and produce more oxygen [28].

Effect of mangrove abundance to nutrient balance was caused by mangrove productivity resulted from litter decomposition. But, in certain case, mangrove also utilize nutrient for its growth. A research conducted by [29] showed that the dynamic of soil P concentration significantly affected by litter production and absorbtion by mangrove vegetation.

Instead of mangrove abundance, mangrove mortality also had significant effect on the environment parameters. Environment parameters affected by mangrove mortality, including sapling and seedling stages were: temperature, TSS, salinity, BO, soil N, soil P, dissolved N, dissolved K. Those parameters were affected since there were changes in mangrove abundance.

The dynamic linkage model resulted from this research should provide information concerning further development of mangrove ecosystem. Such research concerning ecosystem dynamic within mangrove forest had been conducted in several research such as [30] and [31]. A research conducted by [30], showed the ecological interaction model in the mangrove estuaries related to global warming effect such as sea level rise and reduced freshwater flow. While [31] showed the dynamic interaction of sedimentation and mangrove seedling. A research conducted by [14] showed dynamic development of mangrove seedling in certain abundance. According to [11], the competition within mangrove ecosystem by mangrove development.

Further information is needed to study the potential development and stress of mangrove ecosystem. This study provide early information concerning dynamic lingkage model of *Rhizophora mucronata* development in Semarang and Demak area. Further studies are needed to understand the environment and mangrove dynamic response to related development of mangrove ecosystem.

Conclusion

Mangrove ecosystem in Semarang and Demak is dynamically linked and has vice versa effect which lead to dynamic development of mangrove growth and environment parameters. Instead of the effect of environment parameters, mangrove development was also effected by abundance limit which lead to inhibition of growth rate. Increasing abundance created competition among vegetations.

References

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GENERAL COMMENTS

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