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Study of Mangroves Ecosystem Management at Binalatung in Tarakan City of North Kalimantan

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Abstract

The potential of coastal resources in Tarakan, until now there has not been managed optimally. Mangrove ecosystem is one of the potentials, and is currently very high degradation. These conditions will have an impact on sustainable development in the future. Resources management optimally and sustainable will provide benefits to society and regional development. The research aims are to know the existing condition and problems of mangrove ecosystems in Binalatung and then formulate an alternative program of mangrove ecosystems. The method used is existing condition analysis of mangrove ecosystem, and multi criteria decision making analysis.

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The results showed that the condition of mangrove ecosystem is damaged category (16-20 trees/ha). Ecosystem conditions show that value of species relative density (RDi) Avicennia sp (56,25%) and Sonneratia sp (43,75%), value of species relative frequency (RFi) Avicennia sp (50%) and Sonneratia sp (50%), value of species relative covered (RCi) Avicennia sp (51.54%) and Sonneratia sp (48.46%), important value index (INP) Avicennia sp (157,79) and Sonneratia sp (142,21). The results observation and analyze found that is the primary factor of degradation of mangrove ecosystem were sedimentation and freshwater fully. The alternative of mangrove ecosystem management to the future based on MCDM analysis were rehabilitation program and DAS management programs.

Keywords: Management pla; mangrove ecosystems; multi criteria decision making (MCDM).

1. Introduction

The Tarakan City located 117°34' -117°38' east longitude and 3°19' north latitude until 3°20' south latitude, with total area is 657 km^2 consist of land area is 250.80 km^2 and sea area is 406, 53 km^2 and has one or more of coastal ecosystem [1]. Coastal ecosystems in the Tarakan City among others mangrove forest, coral reef, seagrass and sandy beach, which these ecosystems provide natural resources productive both as food sources, mining minerals , energy and communication media and recreational areas or tourism [2].

Vision's long-term development of the Tarakan City in autonomy area is to make it as one little Singapore or second Singapore in Indonesia [3]. This vision is expected to be leveraged factors on development of Indonesia became "the big Singapore" and can be visualized by people of Tarakan City based on geography. Economic development and population growth continues to increase it will have a real effect on mangrove ecosystems. The impact is that if carrying capacity of mangroves can not support these activities, so environmental degradation will be more damaged. The main issue of development currently is environmental damaged. Development has been oriented towards economic growth tends to ignore environmental aspects, to have a negative impact not only on ecological aspect, but also on social and economic aspects of society such as floods, coastal erosion, lower catches of fish and shrimp in offshore, marine pollution, shoreline erosion, salinity intrusion, etc.

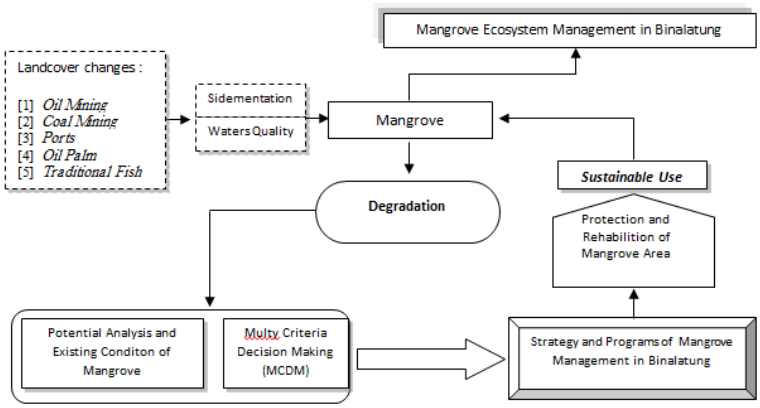

Figure 1: Framework of Problem Approach

The degradation issue of mangrove ecosystem that occurs in northern coastal in Binalatung indicated of land cover changes with triggered sedimentation and water quality [4]. Both of these can directly detain circulation process of sea water and fresh water that is needed by mangrove, so happened dieback. Its simple the conditions presented in Figure 1. The study aims was to know potential existence and problems of mangrove ecosystems in Binalatung, and then to formulate alternative programs of mangrove ecosystem management.

2. Method

2.1. Location

The research was conducted in Binalatung, East Tarakan District, Tarakan City of North Kalimantan. More details as shown below.

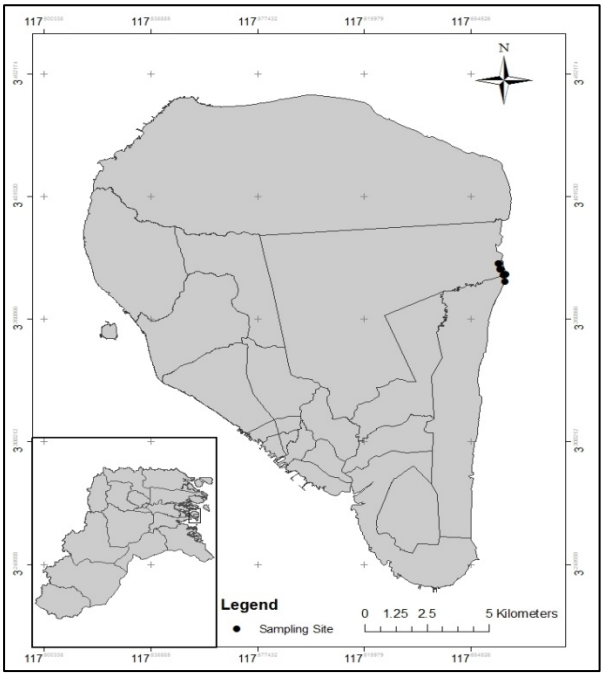

Figure 2: Map of Research Location

2.2. Data Collection Method

The data collection was done by observation, interview, and desk study with two types of data: (1) primary data collection method was done by observation of mangrove ecosystem i.e. Biophysical potential and value of benefits, and direct interviews with local community; and (2) secondary data collection methods was done with literature and other information relating to conditions in Binalatung.

2.3. Data Analysis Method

The data collection was done by observation, interview, and desk study with two types of data: (1) primary data collection method was done by observation of mangrove ecosystem i.e. Biophysical potential and value of benefits, and direct interviews with local community; and (2) secondary data collection methods was done with

literature and other information relating to conditions in Binalatung.

2.3.1. Biophysical Potential Analysis

Biophysical potential Analysis aims to (i) to know the coverage percentage of mangrove, (ii) obtain the important value index (INP values) a species, and then be used to give an overview about the role and influence of vegetation. While calculating of INP Values is used formula as follows [5].

$$INP = RD + RF + RC$$

$$Density\ (D) = \frac{\sum Individual\ of\ a\ Species}{Size\ of\ Sample\ Plot}$$

$$Relative\ Density\ (RD) = \frac{Density\ of\ a\ Species}{Density\ of\ all\ Species} x\ 100\%$$

$$Frequency\ (F) = \frac{\sum plot\ of\ discovery\ species}{\sum all\ plot}$$

$$Relative\ Frequency\ (RF) = \frac{Frequency\ of\ a\ Species}{Frequency\ of\ all\ Species} x\ 100\%$$

$$Covarage\ (C) = \frac{Basal\ Area\ of\ a\ Species}{Size\ of\ Sample\ Plot}$$

$$Relative\ Coverage\ (RC) = \frac{Coverage\ of\ a\ Species}{Coverage\ of\ all\ Species}\ x\ 100\%$$

$$Basal\ Area\ (BA) = \frac{1}{4}\ \pi D^2$$

Basal Area (m^2) and D is Trees Diameter (m)

2.3.2. Multi Criteria Decision Making (MCDM)

Multi Criteria Decision Method (MCDM) used to make a decision based on analysis of criteria [6]. Futher due a method of decision-making to determine the best alternative from a number of alternatives based on certain criteria. Criteria are usually in the form of measures, rules or standards used in decision making.

3. Results

3.1. Potential of Mangrove Ecosystem

The identification results showed that dominant mangrove species are *Avicennia* sp with total ind/transect is 9 trees, and *Sonneratia* sp with total ind/transect is 7 trees. The results showed that average of trees per hectare are 16-20 trees. The conditions show that mangrove in Binalatung is classified damaged based on the Decree of

Environmental Ministry No.201/2004 on standard criteria of mangrove damage [7]. Even though, mangrove in Binalatung is still able to regenerate naturally, as recommended by [8] which is minimum 12 trees/ha. But, the condition of mangrove density is classified as less for tsunami. It is based that the minimum density of mangroves to reduce 50% of a tsunami with height (3m) is 30 trees/ha, with a diameter of a tree is 15cm [9]. This will be particularly important, due location of mangrove ecosystem in Binalatung directly opposite Sulawesi Sea. Measurement of relative density (RDi), relative frequency (RFi), relative coverage (RCi) is also conducted to know the important value index (INP) of mangrove ecosystems in Binalatung contained in Table 1.

Table 1: Values of RDi, RFi, RCi, and INP of Ecosystem Mangrove

Species	Di	RDi	Fi	RFi	Ci	RCi	INP
Avicennia sp	9	56.25	1	50	1.359	51.54	157.79
Sonneratia sp	7	43.75	1	50	1.278	48.46	142.21

The results of the relative density analysis obtained that *Avicennia* sp has density level is higher when compared with *Sonneratia* sp. The density is ratio of the individual amount with size of sample plot [10]. Mangrove density is determined by environmental and human factors. The use of mangrove stems as stake and so on is human impact of mangrove density. While environmental impact is mainly due to growth factors and natural mortality that occurs. The environmental factors can be influenced i.e. Salinity, substrate, temperature, as well as contaminants that can cause death of mangrove. The value of relative density of *Avicennia* sp are caused this species are better able to adapt when compared with *Sonneratia* sp. This condition, could occur due to substrate type (silty loam), as well as coastal topography is dealing directly with the sea, where the influence of oceanographic is very large, such as; tides, waves and currents.

The relative frequency obtained values were the same for both species of mangroves that is 50%. The relative frequency is ratio between the frequency of a species with frequency for all species [10]. The results showed that distribution and existence of a species of mangrove can be found in each transect. Distribution and existence of a species are determined by environmental conditions that sustain to grow optimally. [10] mentions that distribution and existence of mangrove influenced by various environmental factors, such as salinity.

The relative coverage is a dominance description of mangrove species on the area [10]. The analysis showed that relative coverage of *Avicennia* sp is higher when compared with *Sonneratia* sp. It shows that *Avicennia* sp is more dominant than *Sonneratia* sp. The dominance of *Avicennia* sp due to adapting to the environment.

Importance Value Index (INP) is influence description and role of species in mangrove vegetation structure in the area (Figure 2). The analysis showed INP values of *Avicennia* sp is higher (157.79) when compared with *Sonneratia* sp is 142.21. These values indicate that *Avicennia* sp have a higher role than *Sonneratia* sp. The high value of INP of a species is determined by environmental factors, among others; salinity, temperature, substrate and nutrient content. The environmental conditions is well, will support to growth of mangrove [11].

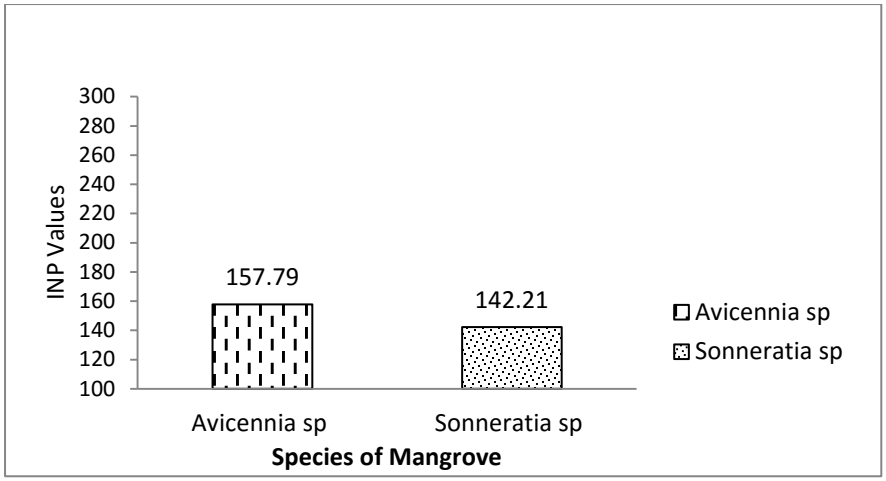

Figure 3: INP Values of Mangrove

The soil texture is a finer degree of soil that occurs because there is a difference in composition and fraction content of sand, silt and clay contained on the soil [12]. The particle size of sand (>0.05 mm), silt (0.002-0.05mm) and clay (<0.002 mm) [13]. The soil texture affects to feature of soil such as; structure, permeability, and porosity. The soil texture in mangrove area is usually composed of accumulated sediment from rivers, beaches or soil erosion from upland. Sediment that accumulates along coastal and in mangrove areas have different characteristics depending on feature of nature, such as sediments from rivers and canals form muddy while coastal sediment is in the form of sand, where sediments are containing organic materials that accumulate continuously [14]. The soil texture is very important for mangrove growth, especially in plants saplings, which root formation is influenced by type of substrate. Here are the analysis results of soil texture of mangrove in Binalatung (Figure 4).

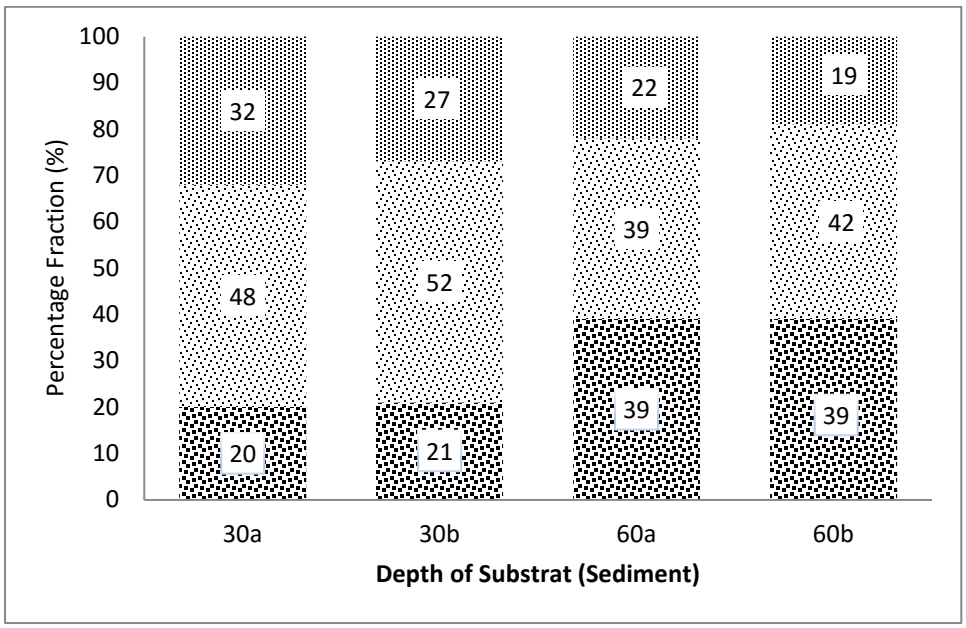

Figure 4: Substrate Type of Mangrove

The analysis results of substrate type to know sediment texture are obtained that generally is silty loam (SIL). The type of soil texture was characterized by sticky soil when held, can be formed a ball, and rolls with shiny surfaces. While other types found in the study site are silty clay loam soil (SiCl). In general, two types of soil texture that describe the smooth-textured soils, which are dominated by clay with a soft and smooth texture that has a smoother surface than coarse textured soils are usually in the form of sand. Smooth-textured soils have the capacity for absorption of nutrients larger than the coarse-textured soil, making it more fertile, due to many contains nutrients and organic material needed by plants. Reference [15] gives an overview of soil dominated a lot of silt would have meso-pores or porous. Further explained that more porous of soil would be more easily roots to penetrate, and very easy of water and air to circulate (drainage and aeration well; water and air are available to the plant), but when very easy it is water to be lost from the soil, and conversely. Therefore, it is great soil reflected from the ideal composition of soil and have not porous, so that soil has texture of silt and clay will have optimum availability of the plants, but in terms of nutrition clay soils better than silt.

Based on texture composition is identified, it can be indicated that mangrove vegetation on the coastal in Binalatung that were dominated by *Avicennia* sp and *Sonneratia* sp species allows occurs because it is based on the substrate type is silty clay. On these substrates often encountered both species. Besides that location directly in front of the sea, so that known as a pioneer vegetation. These results are in line with the stated [14] that the mangrove habitat characteristics generally grow in the intertidal area with silty clay type of substrate.

3.2. Degradation Issue of Mangrove Ecosystem

Based on the results of measurements and observations in field showed that there are two dominant factors that cause dieback of mangrove in Binalatung. Both of these factors are: (1) sedimentation, and (2) waters quality. Sedimentation is based on two factors; 1) longshore current, and 2) run off. While land cover changes are leverage factors occurs sedimentation. The coastal condition of the Tarakan City that located in front of the sea directly, thus causing longshore current be strong . These conditions will have an impact on coastal topography due to the transport of sediment by longshore currents. Sedimentation is determined by currents velocity and particle of sediment transported.

Tarakan City is a small island and oil and gas producers in Indonesia since 1905 until now. Besides oil as an energy source for human needs, exploration and production activities will have an impact on the environment. [16] stated that oil pollution from exploration and production activities, can cause damage to the mangrove. There are two forms of mangrove damage are: (a). If the oil spill in large quantities, generally mangrove trees will occur defoliation on 1-2 months and then death, and (b). If the oil deposits in the sediments are relatively low, so that sub-lethal effect of mangrove, such as; defoliation partially and open canopy, decreased growth rate and changes in species composition. In addition, oil contamination can damage living fauna in sediment and mangrove roots. Residual oil is relatively long occupied (over 10 years), this causes mangrove sediment contaminated by oil requires a relatively long time to be replanted [17].

Land clearing for aquaculture is generally carried out by using heavy equipment such as excavator and bulldozer to construction, especially in areas which has a contour and texture very hard and bumpy ground. While land

clearing using light equipment such as; shovels and hoes is usually used for contoured areas is wetlands and estuary area.

The fish pond construction activity will cause soil particles or substrates being split, that soil fractions are separate so that solid particles frays [18]. The condition causes the separation of fine-particles and coarse particles. Fine particles will then be easy to move and float carried by water and settles on another place to sedimentation. Transport of soil particles is dependent on the size or smooth-coarse, debit of rivers and transports by currents. The fineness of the particles and debit high level and current velocity, so opportunity for sediment transport will be higher. Thus land clearing of fish pond to be one factor supplies to sedimentation in coastal areas. The more land cleared for fish pond, so more high of sediment to be transported.

Beside of fish pond construction activities, sedimentation can also occur from sources other from fish pond activities such as feed residual and excretion (feces of metabolic activity) [19]. Feed residual and feces of organisms that settles in the bottom waters are being rich nutrients, i.e Nitrogen (N) and Phospat (P). But the abundance of organic matter of Nitrogen and Phospat will cause concentration decrease of oxygen in the waters. This happens because the oxygen needed by microorganisms (aerob bacterium) to transform organic matter to be simple compounds. This condition can cause the waters become aerob. Furthermore the process of decomposition happens to also produce gases that are toxic, such as, Ammonia, Nitrite, Carbon Dioxide and Hydrogen Sulfide. The content of these gases in a certain level would be harmful to the cultivation of living organisms, and can cause eutrophication in waters like the bloom (red tide). Furthermore, the organism will die in mass quantities [20].

An abundance of organic matter in the fish pond was influenced by cultivation period and feeding intensity [21]. The cultivation period will increase volume of feed residual in the fish pond, and increase excretion results of metabolic activity of the organism. Feeding with double the amount of biomass products, if the calculated conversion, so only is 10-20%, which can be harvested in the form of biomass, while 90% were discharged into the waters. Thus the abundance of organic matter will cause increased sedimentation in the waters. Furthermore, the sediment will be transported by water replacement process (mixing) [22]. The water volume in the fish pond then flows out to the sea through rivers, which eventually occurs sedimentation process.

The water flow of the rivers will be even greater, as the high rainfall that occurred, and the overflow of water from people settlements [23]. Logging activities in the upstream and residential development in the areas around the river will reduce the extent of catchment area, so the overflow of rainwater and water from people settlements will go straight into the river and increased debit volume of the river. High debit of rivers will transport sediment particles in high volume into the estuary and eventually will be sedimentation. The sand mining activities and clearing forests for fish pond around watersheds, will be a trigger of sedimentation on a large scale. Structure conversion of soil and sand become particles which easily separated will be transported by run off to the estuary. These conditions will cause to erosion and sedimentation in estuaries. The describe of the condition of rainfall, tides and currents surface as follows.

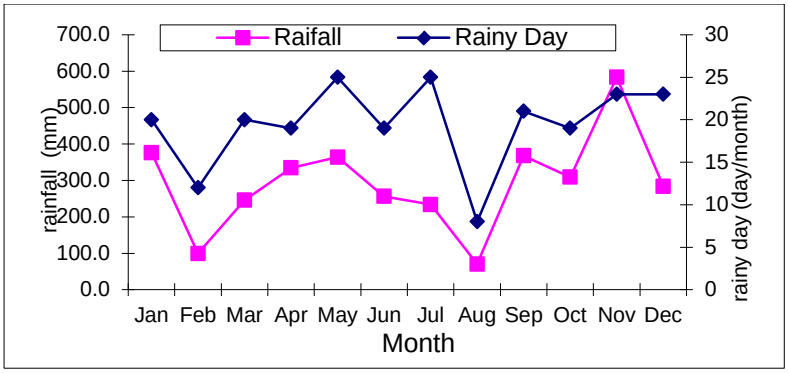

Figure 5: Annual rainfall

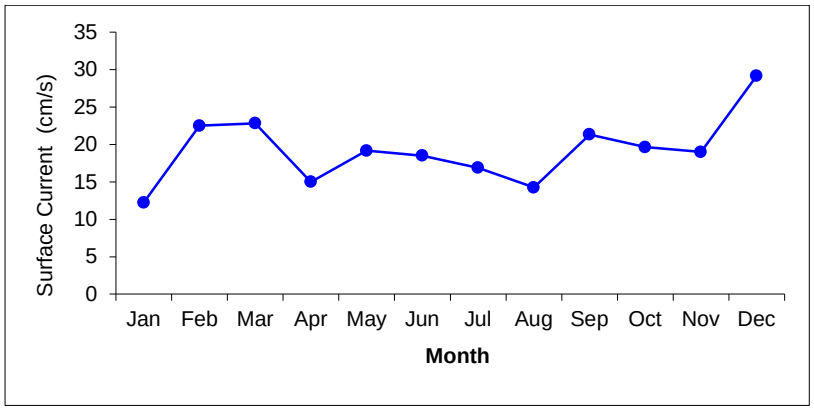

Figure 6: Annual surface current

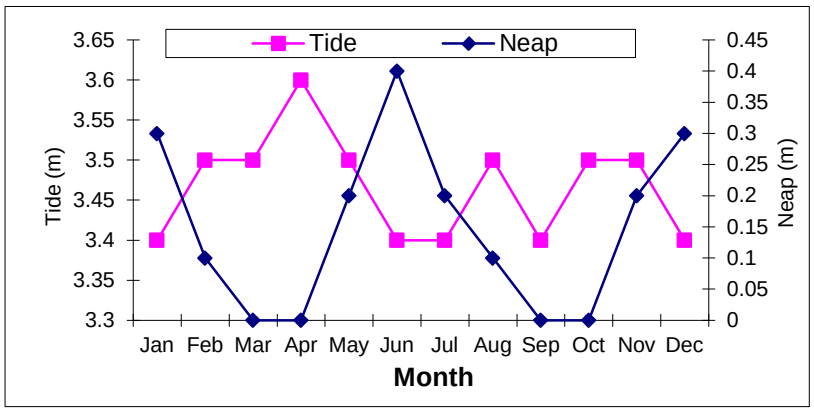

Figure 7: Annual tidal

Water quality is a main factor for survival of aquatic organism [24]. Water quality can be measured either from physical parameters, organic-inorganic chemistry, microbiology and radioactive. In relation with sedimentation in Binalatung some parameters of water quality are indicators, among others: volume of nitrates, phosphates, ammonia, dissolved oxygen, hydrogen sulfide, turbidity (TDS) and total suspended solids (TSS). The results of measurements of water quality parameters in the field (river) in Binalatung, in more detail is presented in Table 2.

Table 2: Parameters of Coastal Waters

Location	Environmental Parameters						
	Nitrate (mg/l)	Phospat (mg/l)	Ammonia (mg/l)	DO (mg/l)	H_2S (mg/l)	Turbidity (NTU)	TSS (mg/l)
Misaya	0.009*	0.908*	0.091	5.3	1.6*	13*	44*
Sungai Maya	0.022*	0.553*	0.144	5.2	1.2*	25*	40*
Beringin	0.058*	0.657*	0.031	5.4	0.8*	57*	70*
Pulau Sadau (A)	0.058*	0.826*	0.084	5.7	0.8*	14*	64*
Pulau Sadau (B)	0.054*	0.741*	0.037	4.1*	0.8*	15*	60*
ASDP	-	0.385*	0.071	5.8	2.4*	47*	74*
Tj.Binalatung	0.013*	0.929*	0.104	6.4	1.6*	62*	72*
Tanjung Batu	-	0.553*	0.157	7.2	0.8*	1	12
Selayung	0.030*	0.783*	0.117	6.0	0.4*	7*	44*
Pantai Amal	0.035*	170.286*	0.104	6.5	0.2*	32*	78*
Tj.Harapan	0.102*	0.218*	0.051	5.9	0.1*	16*	52*
Tanjung Pasir	0.094*	0.427*	0.064	4.4*	0.4*	8*	78*

Source: MCRMP of Tarakan City

*Notice: *Quality standard of Nitrate:0.008, Phospat:0.015, Ammonia:0.3, DO:>5, H_2S:0,01 Turbidity: <5 NTU (Aquatic Organism), TSS: 20 mg/lt (Mangrove)*

The high concentration of nitrate and phosphate in all locations and measurements are showed high people activity on land and surrounding waters. The highest nitrate concentration was found at Tanjung Harapan is 0.102 mg/l. The concentration is below the quality standard (0.008 mg/l). While highest phosphate concentration was found at Pantai Amal is 170.286 mg/l and classified is very high or exceed of quality standard (0,015 mg/l). The high nitrate and phosphate parameters at both these locations are caused by high people activity. The both of these locations are densely populated areas as well as a tourist area. The concentration of nitrate and phosphate in the water can be sourced from organic materials or food residual and sourced from feces. The high activity of people, will supply the nitrate and phosphate in the water is also high. The people activity, i.e. Aquaculture, agriculture, plantation and tourism activities. An abundance of organic material will cause blooming in the water [21]. Blooming will cause the waters become a drop of oxygen, so oxygen in water is limited. Beside that abundance of phytoplankton will be toxic and cause death in some kind of aquatic organisms. The abundance of phytoplankton will cause to an abundance of organic matter back into the waters and the waters become turbid due to the fine sediment particles that source of organic materials. The process of decomposition and conversion of organic materials into simple compounds by bacterium will bring out gases are toxic such as; Ammonia, Nitrite, Carbon Dioxide and Hydrogen Sulfide (H_2S). Concentration of gases in a certain amount would endanger lives of aquatic organisms. An abundance of organic matter and blooming, further cause mass mortality of species [21]. Mortality of organisms and phytoplankton will supply sediment in the water. The sediment are fine sediment particles derived from organisms. A high turbidity caused by the high

particles of sediment in the water, whether sourced from organic and inorganic materials. Based on measurements results of turbidity at several locations in Binalatung was showed that turbidity levels were highest at Tanjung Binalatung is 62 NTU, while highest concentration of TSS were found at Tanjung Pasir and at Tanjung Harapan are 78 mg/l. The high level of turbidity concentration at Tanjung Binalatung, caused by of people activity density at the site. Tanjung Binalatung is a residential area and fishing base (port) of vessels. People activity density, will cause to shifting structure of soil. The shifting will separate fine particles and coarse in the water and eventually transported by currents and waves to other side.

3.3. Mangrove Ecosystem Management Programs

Mangrove ecosystem management in Binalatung currently more concerned with the ecological criteria and socioeconomic conditions than institutional criteria. Analysis results of priority for management of mangrove are showed that rehabilitation value is 0.539 and value of improvements watershed is 0.394. The value of decision indicates that the first priority to be proposed is the rehabilitation of the region and second priority is improving role of the watershed (DAS). Each of management priorities contains values of criteria. So efforts in conducting management strategies should be based on considerations that are in criteria. In detail, this assessment is shown in Figure 8 and Figure 9.

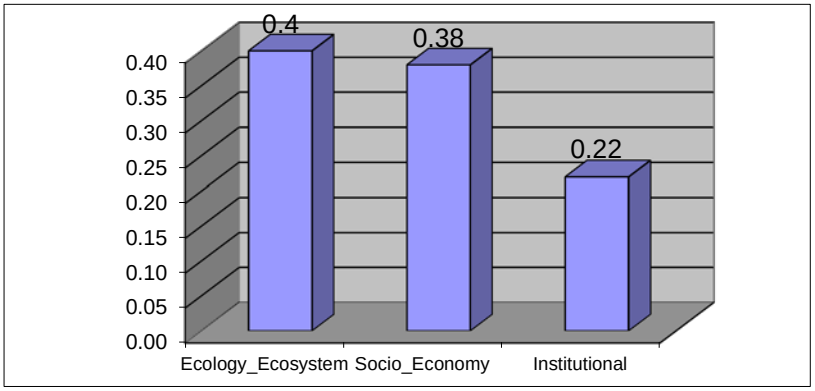

Figure 8: Comparison chart of management criteria

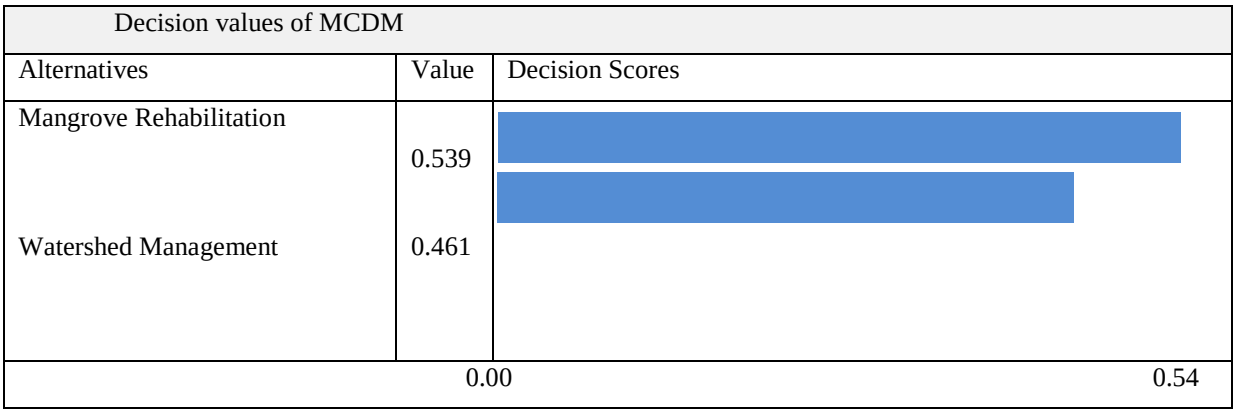

Figure 9: Decision values of MCDM

3.4. Recommendation of Sidementation Control

Based on ecological, socioeconomic and institutional criteria, so that alternative of a management program and the kinds of practices to sedimentation control of mangrove ecosystem are consist of: (1) Mangrove rehabilitation i.e. (a) replanting of mangrove seedling of species; *Avicennia* sp, *Sonneratia* sp and *Rhizophora* sp; (b) the construction of mangrove cultivation in Binalatung with managed by the local community; (c) the construction of the wave barrier (APO); (d) Construction of breakwaters; (e) Involvement of the local community directly in the program implementation i.e. technical management and planning. (2) watershed management, i.e. (a) rehabilitation of protected forest areas that have been damaged; (b) providing alternative livelihoods; (c) restructuring of the government regulations related to mining.

4. Conclusion

Based on results of analysis and discussion obtained some conclusions as follows:

- The condition of mangrove ecosystems in Binalatung is damaged category with amount of trees is 16-20 trees/ha.
- The potential of mangrove ecosystems in Binalatung consists of *Avicennia* sp and *Sonneratia* sp indicates a density value (RDI) of *Avicennia* sp is 56.25% and *Sonneratia* sp is 43,75%, coverage relative (RCI) of *Avicennia* sp is 51.54% and *Sonneraia* sp is 48.46% and the index of important value (INP) of *Avicennia* sp is 157.79 and *Sonneratia* sp is 142.21.
- Degradation of mangrove ecosystems in Binalatung indicated by sedimentation process. It was triggered by land cover changes that source from people activities.

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References

[1] [BPS] Badan Pusat Statistik. 2015. Kota Tarakan Dalam Angka Tahun 2015. Tarakan.

[2] [MCRMP] Marine Coral Reef Management Project. 2005. Proposal Small Scale on Natural Resources Management MCRMP Kota Tarakan. 45 hlm.

[3] Jusuf, S.K. 2003. Implementasi Otonomi Daerah di Kota Tarakan. Sebuah Gagasan, Wawasan, Terapan dan Renungan. Media OTDA. Jakarta. 241 hlm.

[4] Rachmawani, D., F.Yulianda dan G. Yulianto. 2007. Kajian Pengelolaan Ekosistem Mangrove Secara Berkelanjutan Kota Tarakan Kalimantan Timur (Studi Kasus Desa Binalatung Kecamatan Tarakan Timur). Publikasi Jurnal Aquarine. Vol.1. No. 2. ISSN: 2085-9449.

[5] Kusmana, C. 1997. Metode Survei Vegetasi. Penerbit Institut Pertanian Bogor. Bogor. 173 hlm.

[6] Watthayu, W and Peng, Y. 2004. A Bayesian Network Based Framework For Multi-Criteria Decision Making. Department of Computer Science and Electrical Engineering University of Maryland, Baltimore County. (wwatth1, ypeng)@csee.umbc.edu . 12 hlm.

[7] [KLH] Kementerian Lingkungan Hidup Republik Indonesia. 2004. Keputusan Menteri Lingkungan Hidup. No.201 tahun 2004 tentang Kriteria Baku Kerusakan Mangrove. Jakarta.

[8] [FAO] Food and Agriculture Organization. 1994. Mangrove Forest Management Guidelines. FAO Forestry Paper 117. Rome.

[9] Purbani, D., Boer, M., Marimin., Nurjaya, W. dan Yulianda, F. 2013. Strategi Mitigasi Tsunami Berbasis Ekosistem Mangrove dalam Aplikasi Pemanfaatan Ruang Pantai Timur Pulau Weh. Jurnal Segara. Vol.9. No.2. PDSLP Litbang KKP. Jakarta.

[10] Kusmana, C. 1996. Nilai Ekologis Ekosistem Hutan Mangrove (Ecological Values of Mangrove Forest Ecosystem). Media Konservasi Vol. V (1). April 1996 : 17-24.

[11] Supriharyono. 2007. Pelestarian dan Pengelolaan Sumberdaya Alam di Wilayah Pesisir Tropis. Gramedia Pustaka Utama. Jakarta. 246 hlm.

[12] Hardjowigeno, S. 2003. Ilmu Tanah. Akademika Presindo. Jakarta.

[13] Saefudin. 1989. Ilmu Tanah Pertanian. Pustaka Buana. Bandung.

[14] Aksornkoae, S. 1993. Ecology and Management of Mangrove. Bangkok (TH).

[15] Hanafiah, K.A. 2007. Dasar-Dasar Ilmu Tanah. PT. Raja Grafindo Persada. Jakarta.

[16] Mastaller, M. 1996. Destruction of Mangrove Wetlands-Causes and Consequensces. Natural Resources and Development 43-44, 37-57.

[17] Hastuti, Y. 1994. Pencemaran Minyak dan Pengaruhnya terhadap Ekosistem Hutan Mangrove. Paper. PSIP Pascasarjana Institut Pertanian Bogor. Bogor.

[18] Biggs J., Williams P., Whitfield P.N. and Weatherby A. 2005. 15 years of pond assessment in Britain: Results and lessons learned from the work of Pond Conservation. Aquatic Conservation: Marine and Freshwater Ecosystems 15:693-714. Cross Ref.

[19] Boyd C.E dan B.W. Green. 2002. Coastal water quality monitoring in shrimp farming areas, an example from Honduras. Report prepared under the World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment. The Consortium. 29 pages.

[20] Boyd, C.E. 2001. Management practices for reducing the environmental impacts of shrimp farming. Department of Fisheries and Allied Aquacultures. Auburn University Alabama. p265 – 293.

[21] Wetzel, R.R. 1975. Primary Production in Whitton, B.a (eds) River Ecology. Blackwell Scientific Publication Oxford. 725 p.

[22] Widigdo, B. 2000. Pemanfaatan Pesisir dan Lautan untuk Kegiatan Perikanan Budidaya (Aquaculture). Makalah Pelatihan untuk Pelatih Pengelolaan (TOT) Wilayah Pesisir Terpadu. Kerjasama PKSPL IPB –Proyek Pesisir CRC URI. Bogor.

[23] Asdak, C. 2002. Hidrologi dan Pengelolaan Daerah Aliran Sungai. Gajah Mada University Press. Yogyakarta.

[24] Pa´Ez-Osuna, F. 2001. The Environmental Impact of Shrimp Aquaculture: Causes, Effects, and Mitigating Alternatives. Environmental Management. 28 (1): p131–140.