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Isolation Hope and Threat of Mangrove Restoration Program in Bogowonto Lagoon, Yogyakarta—Indonesia (2002–2014)

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Abstract

Bogowonto Lagoon has the largest mangrove ecosystem in southern coast of Yogyakarta, Indonesia. Several activities on mangrove restoration have been conducted to escalate this remnant mangrove forest area. Conversely, rapid increase of shrimp pond area become threat for mangrove ecosystem in Bogowonto lagoon since the early of 21st century. Hence, This study is aimed to investigate mangrove composition, distribution and abundance, progress of mangrove restoration program and shrimp pond extensification in 2002 to 2014. Conducted from April 2015 to May 2015, this research consists of several steps namely survey, vegetation analysis, literature study, sociological study using questionnaire, measurement of mangrove and shrimp pond area using Landsat 8 imageries and Arc GIS 10.1. We determined 15 sites along Bogowonto Lagoon using random sampling by quadratic plot (10 m × 10 m for tree, 5 m × 5 m for sapling) and total counts (for seedling). The result showed that there were seven species of mangrove and six species of associate mangrove. *Rhizopora mucronata* Lamb. was dominant in each growthform with clumped distribution. *R. mucronata* and *Avicennia marina* (Forssk.) Vierh. also dominate from backswamp to rivermouth. Satellite imageries revealed that there was a hope due to upward trends of mangrove area in last 12 yr (approximately 5 ha). However, the significant increase sof shrimp pond area (approximately 34 ha) surrounding mangrove area become current and future threat. Based on sociological study, most of people around Bogowonto Lagoon have high awareness, but less participated on mangrove restoration program. Besides, the river mouth covered by sand become another obstacle of it.

Keywords: Bogowonto lagoon; mangrove restoration; shrimp pond; vegetation analysis

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1. Introduction

Presence of mangrove ecosystem in the southern coast of Yogyakarta was very low due to unfavorable ecological condition. Mostly the main cause was the substrate in the intertidal zone which was more composed by sandy soil from volcanic activity of Mount Merapi. This substrate only suitable for few mangrove species. However, Bogowonto Lagoon in Yogyakarta has different characteristic since its watershed not lies in Mount Merapi. Hence, the intertidal zone in this lagoon more composed by mud and clay. This soil is one favorable composition for most of mangrove species [1, 2]. As a unique ecosystem, mangrove has irreplaceable services as they can provide numerous ecosystem services, including nutrient cycling, sediment trapping, protection from cyclones and tsunamis, habitat for numerous organisms and wood for lumber and fuel [3]. However, in the past 12 yr there were several human activity pertaining shrimp aquaculture extensification around this mangrove ecosystem. This activity was widely known as the major factor of mangrove devastation in the world. Eventough this lagoon has recorded minimal changes of mangrove areas to aquaculture activities since aquaculture activity widely used non-mangrove land, this activity still become a high threat for this remnant mangrove ecosystem. To have a better understanding of the basic biology and ecology of mangrove ecosystems, there is an increasing need to monitor and assess mangrove forest structure and dynamics which will also help to guide efforts of conservation, restoration and better management of the ecosystems [4]. However, managing the mangrove forest is a challenging task which involves a complex balancing act between protecting the ecosystem and enabling humans to enjoy and use these natural resources. Therefore, monitoring and evaluation of the structure and dynamics of land cover, and its effects on mangrove forests are of importance in order to obtain a better understanding of the condition of the mangrove forest as a guide in conserving and maintaining the resource. Hence, study the mangrove forest structure and dynamics.

2. Materials and Methods

This research was conducted from April 2015 to May 2015 in mangrove ecosystem area around Bogowonto Lagoon located in Pasir Mendit Village, Jangkaran, Kulon Progo, Yogyakarta. This is located at coordinate of 7°53′10.41″S and 110°0′30.51″E. There were 15 sites selected by random sampling based on the distribution of mangrove. Sites were distributed alongside Bogowonto Lagoon and Backswamp area (Figure 1). Materials used in this research are quadrat plots; Global Positioning System, hand counter, roll meter, data table, ruler, digital camera, hand refractometer and questionnaire.

There were several steps namely survey, vegetation analysis, literature study, sociological study using questionnaire, measurement of mangrove and shrimp pond area. Survey at mangrove ecosystem area aimed to observe mangrove species and to tag the coordinate of sampling location. Besides, it was also used to know the mangrove distribution generally. Vegetation analysis used quadrats with 10 m × 10 m for tree, 5 m × 5 m for sampling and total count for seedling [5]. The data obtained were

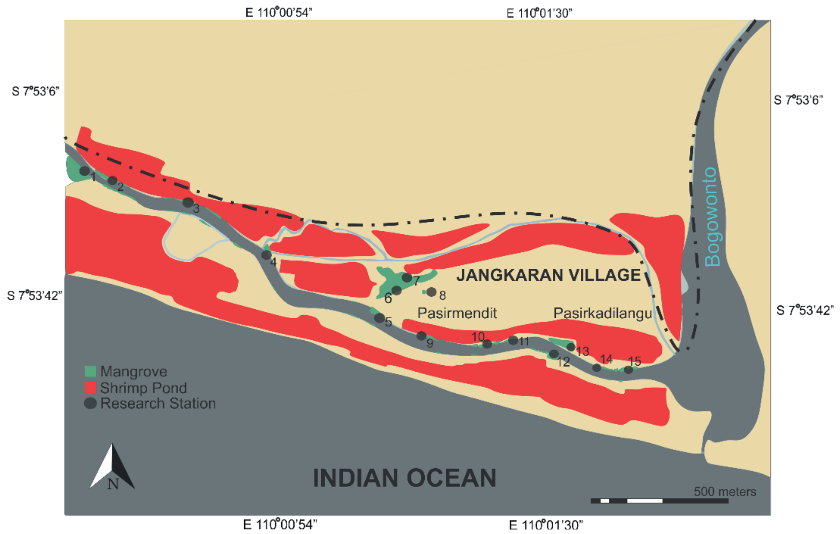

Figure 1: Research station along bogowonto lagoon and backswap area.

mangrove composition including species richness, identification mangrove species, mangrove abundance each species and growthform. In addition, physical parameter namely salinity also measured in several sites using refractometer. The data was collected in every site without replication. Literature study used to compare this study with previous similar studies in 2002, 2007, 2013 and 2014 about mangrove vegetation analysis and mangrove restoration program in Bogowonto Lagoon. Sociological study using questionnare was done by interviewing twenty one participants which is person around Bogowonto Lagoon. Measurement of mangrove and shrimp pond area using Landsat 7 and 8 imageries satellite imageries and Arc GIS 10.1 for spatial analysis. The data analysed were the increasing of mangrove and shrimp pond area in several years from 2002 to 2014. For data analysis, data including mangrove species and abundance composition, growthform composition years by years were presented in form of histograms. Increasing of mangrove and shrimp pond area were represented in Arc GIS 10.1 maps.

3. Result and Discussion

3.1. Diversity

This research shows there were 14 species of mangrove consists of 8 true mangroves and 6 associate mangroves. True mangrove species were *Rhizopora mucronata*, *R. apiculata*, *Avicennia alba*, *A. marina*, *A. officinalis*, *Bruguiera sexangula*, *Sonneratia alba* and *Nypa fruticans* while associate mangroves consists of *Acanthus ilicifolius*, *Acrostichum aureum*, *Ipomoea pes-caprae*, *Pandanus tectorius*, *Acanthus volubilis* and *Derris heterophylla*. There are several research have been conducted in Bogowonto Lagoon (Table

1) concerning diversity and abundance of mangrove vegetation. Five publication were published and the earliest records was conducted by Djohan [6] that provides arobust data and sharp analysis on mangrove ecosystem. Subsequently this research followed by other research. Based on the results from year to year, almost all of research show similarity on species composition and revealed that genus Sonneratia was dominant species in tree growthform. In contrary, there was a big diifference of these results on sapling growthform dominant species. According to Djohan [1], Sonneratia alba was dominant species, but Sawitri [7] and Nahdi [8] reported that *Avicennia marina* and Rhizopora mucronata were dominant species, respectively. Interestingly, in the present study, *R. mucronata* was dominant species both for tree and sapling growthform (Figure 3). Primary reason of this discrepancy lies on the different research station even though in same location and almost same sampling method. Djohan [1, 6] and Nahdi [8] research station distributed from backswamp to river mouth, while Sawitri [7] more distributed nearby river mouth. In this research, station distributed along Bogowonto lagoon, backswamp and also river mouth.

3.2. Distribution

In general, distribution of mangrove in Bogowonto Lagoon distributed along Lagoon with clumped distribution The functional type of mangrove ecosystem in this site is riverine mangrove ecosystem. Hence, it did not form any zonation that mostly found in common mangrove ecosystem (Figure 2). According to Kathiresan [9], this ecosystem was influenced with the incursion of large amount of freshwater with fluvial nutrients and thus making the system highly productive with trees growing taller. However, the average heights of *Rhizophora* tree in Bogowonto Lagoon was about 4 m to 5 m.

Obviously, they can grow higher (approximately more than 1 m per year) in suitable habitat [10]. Probably it was related to ecological system of Bogowonto Lagoon that flooded daily and occurance of stagnant water in the dry season due to sand sedimentation in the river mouth. Moreover, this area surrounded by sand dune that will closed the river mouth if freshwater flow from the river is low in the dry season. Surprisingly, salinity in this lagoon can reach 0‰ in the dry season. Whereas, the optimal salinity for *R. mucronata* was 8‰ to 26‰ [10]. Based on measurement in the present research, salinity during low tide about 0‰ to 8‰ with lowest salinity was located near to the river mouth that shows incursion of freshwater. Furthermore, when soils are inundated with water, anaerobic condition usually result, reducing the rate oxygen can diffuse through the soil. Besides, this stagnation in long period will cause depletion of dissolved oxygen (anoxic) [6]. If frequent flooding and drying out occurs, hypersaline conditions can develop that negatively affect mangrove distribution and growth [11].

Study Reference	Method	Vegetation Structure	Dominant Species
Djohan (2000)	Six Research Station Quadrate Plot 10 m × 20 m with two replications	*Sonneratia alba, Nypa fruticans, Acanthus ilicifolius, Derris heterophylla, Acrostichum aureum, Pandanus sp, and Cynodon dactylon*	*Sonneratia alba*
Setyawan *et al* (2002)	Quadrate Plot 20 m × 20 m	*Sonneratia alba*	*Tree: Sonneratia alba*
Djohan (2007)	Six Research Station Quadrate Plot 10 m × 20 m with two replications	*Sonneratia alba, Nypa fruticans, Acanthus ilicifolius, Derris heterophylla, Acrostichum aureum, Pandanus sp, and Cynodon dactylon*	*Tree: Sonneratia alba* *Sapling: Sonneratia alba*
Sawitri (2012)	Two Research Station Nested Plot with 10 m × 10 m (tree), 5 m × 5 m (sapling), and 1 m × 1 m (seedling) with tree replications on each station	*Avicennia marina, Avicennia alba, Rhizopora mucronata, Sonneratia caseolaris, Acanthus ilicifolius, Acrosticum aureum, and Nypa fruticans*	*Tree: Sonneratia caseolaris* *Sapling: Avicennia marina* *Seedling: Avicennia marina*
Nahdi and Kurniawan (2013)	Three Research Station Quadrate plot with 10 m × 10 m (tree), 5 m × 5 m (sapling), and 1 m × 1 m (seedling and understory) with six replications on each station	*Avicennia marina, Avicennia alba, Rhizopora mucronata, Rhizopora apiculate, Sonneratia alba, Nypa fruticans, Acanthus ilicifolius, Ipomoea pescaprae, Derris trifolia, Acrosticum aureum, Panicum repens, Penisetum purpureum, Cynodon dactylon, Achyrantes aspera, Imperata cylindrica,* and *Ischaemum muticum*	*Tree: Sonneratia alba* *Sapling: Rhizopora mucronata* *Seedling: Rhizopora apiculata*

Table 1: Previous study of Mangrove ecosystem in Bogowonto Lagoon, Yogyakarta.

In this study we compare the abundance of mangrove species in all growthform. Based on figure xy, *Rhizopora mucronata* was dominant species in all growthform. It has density 272, 332 and 363 individual number/100 m^2 for tree, sapling and seedling growthform, respectively. Interesting to notice that *R. mucronata* present in all growthform while the other species not. Furthermore, it was present at all research station except in river mouth. This results gave us an insight that in the future, this ecosystem will largely occupied by *R. mucronata* due to its sapling high abundance. The other abundant species was *Avicennia marina* which appeared at almost all station near the river mouth. Its density were 100 and 57 individual number/100 m^2 for tree and sapling, respectively. Interestingly, this research fit with report from Lugo & Snedaker [12] and

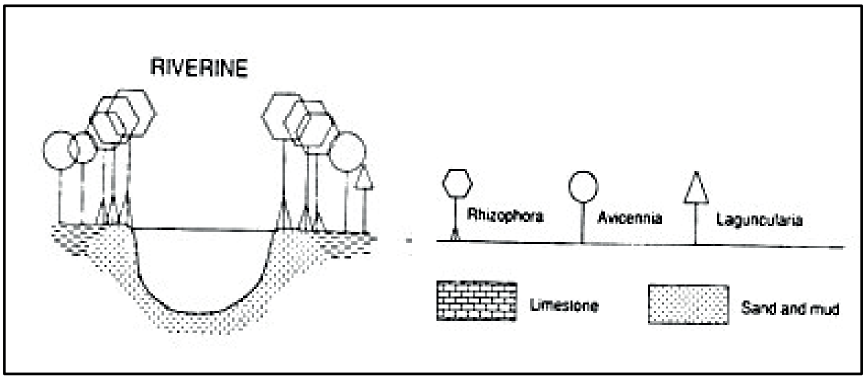

Figure 2: Riverine mangrove ecosystem (From Lugo & Snedaker [12]; Woodroffe [13].

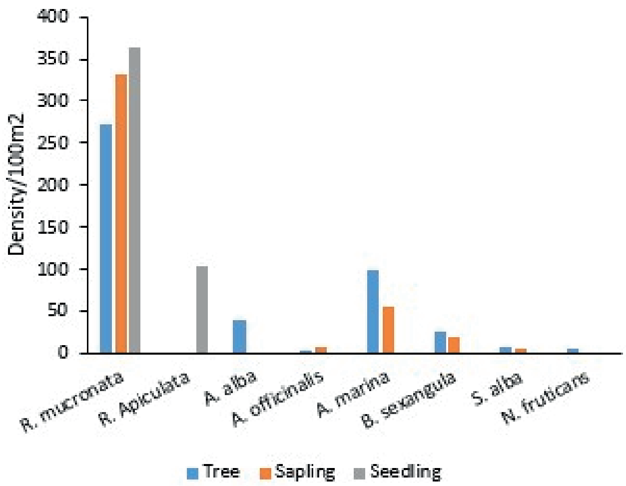

Figure 3: Abundance of mangrove species per growthform.

Woodroffe [13] that stated *Rhizophora* and *Avicennia* were the main components of riverine mangrove ecosystem.

3.3. Abundance

In the present study, *R. mucronata* as the non-native species was the most abundant species and it shows that *R. mucronata* highly adapt to a wide range of salinities (euryhaline) due to daily tidal flooding and stagnant water in the dry season. According to Robertson and Alongi [14], this is a hardy species that is easily propagated and is fast-growing. It can grow up to 35 m, and can grow to 6 m high within seven years on plantations. Moreover, this species regenerates easily from its viviparous seed and start to develop whilst still attached to the tree [15, 16]. Vivipary as a life history strategy helps mangroves cope with the varying salinities and frequent flooding of their intertidal environments, and increases the likelihood that seedlings will survive.

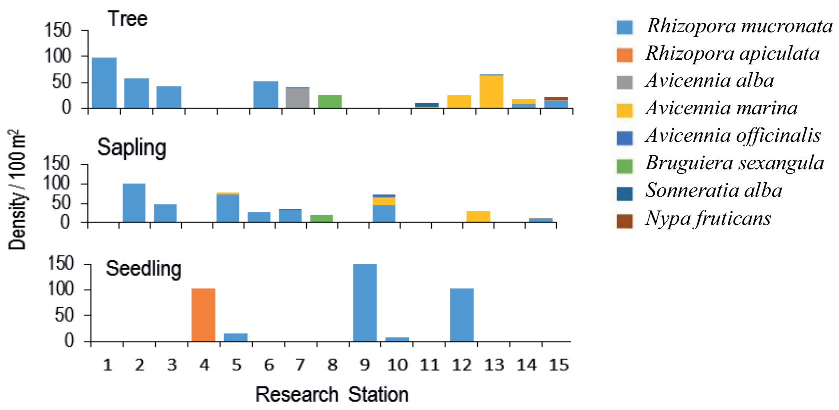

Figure 4: Mangrove abundance per growthform per research station from the farthest, back swamp and to the river mouth.

Since most non-viviparous plants disperse their offspring in the dormant seed stage, vivipary presents a potential problem for dispersal. Most species of mangroves solve this problem by producing propagules containing substantial nutrient reserves that can float for an extended period. In this way, the propagule can survive for a relatively long time before establishing itself in a suitable location. In *R. mucronata* The propagule then becomes detached from the branch when sufficiently well developed to root in the mud below and easily regenerates [17, 18]. Reported by Orwa et al [19], this species was most profusely developed on the banks of tidal creeks, in estuaries and on low coastal areas flooded by normal, daily, high tides and seems to be more tolerant of inundation than other mangrove species and often forms an evergreen fringe to mangrove areas. It sometimes occurs as a pure stand or may grow with Rhizophora apiculata. In certain favourable habitat, they may occupy considerable large areas. According to Duke [20], *R. mucronata* helps prevent coastal erosion and in restoration of mangrove habitats.

From the previous explanation, *A. Marina* was the second abundant species. It is a hardy species in natural conditions and regenerates quickly from coppices, both as individuals and as a species. It is a colonizing species on newly formed mudflats and has a high tolerance to hypersaline conditions [21]. However, in the present study *A. marina* seedling absent in all station. It probably correlated with ecological system (daily flooded and water stagnation) of mangrove ecosystem in Bogowonto Lagoon. According to Ball [22], salinity and *A. marina* seedling growth has possitive correlation where the increasing salinity would stimulate the growth and the best salinity range for *Avicennia* seedling growth is 5‰ to 30‰. Below 5‰, no new leaves formed and make them failed to grow [23]. Moreover, according to McKee [23] *Avicennia* was vulnerable to lack of dissolved oxygen (DO) where *A. marina* would experience hypoxia which leads to decrease of respiration rate to the root system and decrease of root development. This hypoxia condition may occur during long period of water stagnation in the dry season.

This result revealed the distribution and abundance of mangrove along Bogowonto lagoon. Station 15 was located near the river mouth while station 1 is the farthest. Besides, station 6 and 7 represent the backswap area. From this result, *R. mucronata* as a dominant species distributed evenly in almost all research station except station 13, 14 and 15 which were near the river mouth. In contrary, the second most abundant species, *A. marina* highly distributed near the mouth of the river. This interesting results was corresponding with the composition of soil. Area near the river mouth (station 12, 13, 14, 15) contains more sandy soils while the others more dominated by mud soils. According to Lacerda [24] and Orwa et al [19], *R. mucronata* are dominant on muddy soils and often form extensive pure stands. On sandy soils, however, species fails to compete with others. Conversely, *A. marina* more suitable in the sandy soils and can tolerate varied flood regimes and newly deposited sediments. This is a pioneer species on newly formed habitats of mud with a high proportion of sand, but does not seem to grow on pure mud [25].

In the present study, it was quite difficult to find seedling growthform of mangrove. *R. mucronata* seedling only present in 4 research station (Figure 1). Eventough every year there is mangrove seedling planting in Bogowonto Lagoon but the presence of living seedling is very low. The main obstacle for seedling growth lies in the flooding regimes and water stagnation. Moreover, seedling planting usually did not consider those obstacles. According to Djohan [1] inundation level determine seedling height that will be planted. Because, if inundation level is higher than seedling height, they will be wiped out during stagnant waters or even tidal flooding. In addition, low presence of seedling probably correlated with anthropogenic activity such as local use of mangroves as a source of fire wood or consumed by water buffalo (*Bubalus bubalis*).

3.4. Hope and threat

Variation in total area of mangrove ecosystem can be observed among the years. Four analysis of the 2002, 2007, 2013 and 2014 Landsat 7 and 8 image estimated the total mangrove area to be 2.65 ha, 1.40 ha, 6.95 ha and 7.11 ha, respectively. This positive trend highly correlated with mangrove planting program as part of mangrove restoration program. According to Lewis [26], combining with suitable management approaches, plantations have become one of the most important ways for the mangrove ecosystem restoration. Although there are greater variations in the attributes of planted mangrove stand than of the natural mangrove stand, at age 50 the planted mangroves are comparable in stand structure and species association. Reforestation could be a feasible and effective way to not only reverse the declining trend of mangroves but also restore the structure and function of mangrove ecosystems.

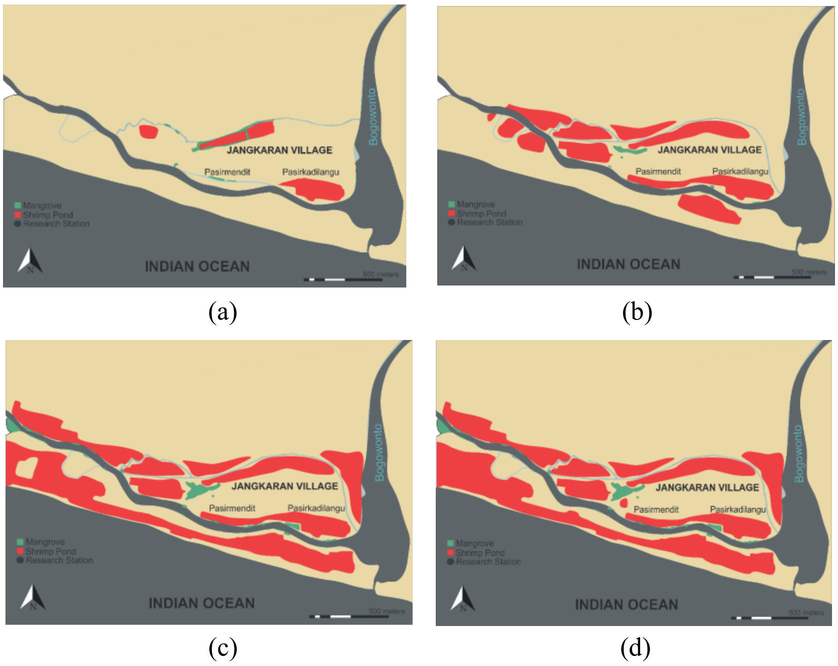

Figure 5: Mangrove and shrimp pond area (a) 2002; (b) 2007; (c) 20013; (d) 2014.

In Bogowonto lagoon, there were several planting program have been recorded such as 10 500 mangrove seeds planting in 2000, 11 500 in 2008, 67 000 in 2009 and hundreds of thousands from 2009 to 2015. However, there was a downward trend from 2002 to 2007. Sawitri [7] stated that in 2003 there was a massive land clearing in order to construct aquaculture pond. Moreover, in 2004 there was canal building to support this pond, whereas in this area there was vast native mangrove stands, *Sonneratia alba*. This was main cause that there was significant decrease of native mangrove abundance. Although several mangrove planting have been conducted, this program frequently used introduced species such as *Rhizopora* spp or *Avicennia* spp that became dominant species in this study. The emergence of aquaculture areas started rapidly after the beginning of 21th century, covering only a small area alongside the backswap area and lagoon. Based on satellite imageries, there was a steep increase of shrimp pond from 2002, 2007, 2013 and 2014, that was 3.97 ha, 35.28 ha, 29.52 ha, 65.39 ha, respectively. Arguably, the Bogowonto mangrove ecosystem has recorded minimal changes of mangrove areas to aquaculture activities since aquaculture activity widely used non-mangrove land. However, although aquaculture construction is not acting directly on the mangrove forest land cover, it can however alter the system dynamics, interrupting the continuity of natural events such as local dispersion and migration offlora and fauna species, and modifying the local hydrology. In addition, water pollution from aquaculture farms negatively impacts adjacent mangrove ecosystems. Aquaculture waste, including particle load that leaves the dissolved nutrient fraction untreated [27] initiates pollution and eutrophication within the mangrove area.

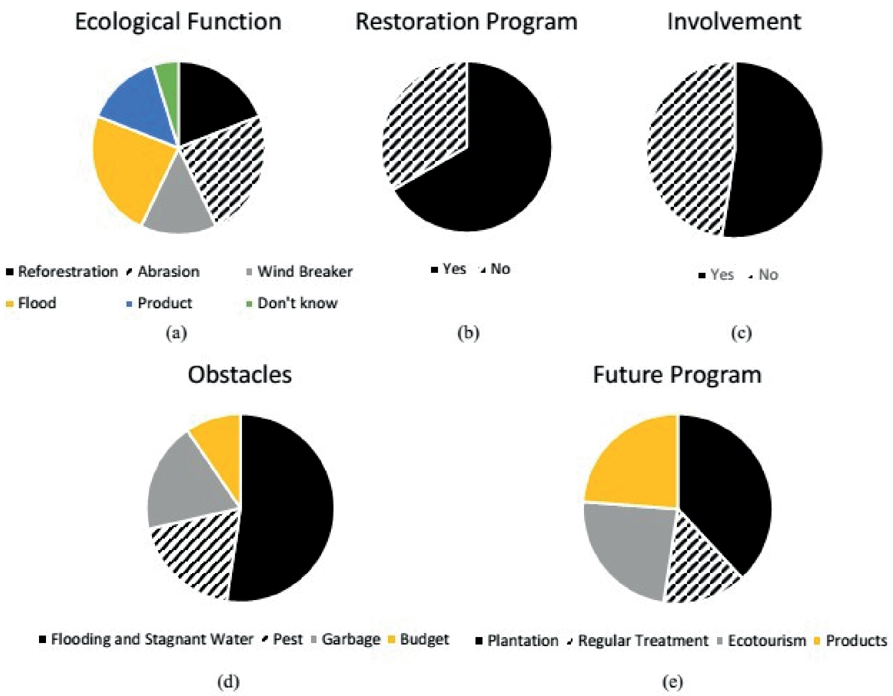

Figure 6: Results of sociological study of local people around Bogowonto Lagoon on five main points: (a) Ecological function; (b) Restoration program; (c) Involvement; (d) Obstacles; (e) Future program.

An increase in the area of aquaculture ponds, without prior knowledge of the natural channels of communication among wetlands, puts the natural production of the system at high risk by reducing wetland areas and the connectivity among them [28].

3.5. Sociological study

In the present sudy, we did a rapid sociological assesstment using questiionnaire and disseminated to local people around Bogowonto lagoon. Twenty one people involved, six people was aquaculture labor, four people were housewife, three people were civil servants, four people were farmers and four people were private sector worker. There are five main points of this questionnaire pertaining perspective of local people about mangrove and its function, mangrove restoration program, obstacles in this program, their involvement on it, and hope for future program. Based on sociological study, most of people around Bogowonto Lagoon have high awareness on mangrove restoration program and have quite knowledge on its function either in ecological function or economical and only one people do not know. Highest answer was mangrove for flood prevention during dry season that usually wiped out their paddy field and pond. Furthermore, almost all respondent knew about mangrove restoration program from year to year and very familiar with obstacles such as flooding and stagnant water (see Figure 1a, 1b and 1c). However, only just above a half respondent have been involved in this program, such as mangrove planting (see Figure 1c). After further questions, all of respondent who have never been involved stated that lack of information was the main cause, even they have strong desire to get involved. On the last question, almost people focusing their hope on increase of mangrove planting activity as they deeply knew its role in ecosystem. Besides, they hope can increase their income both from sustainable management of mangrove ecotourism or selling products from mangrove such as syrup or *kerupuk* (Indonesian chips).

4. Conclusion

Rhizopora mucronata Lamb. and *Avicennia marina* (Forssk.) Vierh. as the most abundant species in this study and frequently used in planting activity predicted to be dominant species in the future. Mangrove planting as the main part of restoration program give a hope since there was a significant increase of mangrove area. Moreover, high participation from local people will accelerate this program since they have high awareness but less participated. Shrimp aquaculture still remain as a high threat as non-mangrove land in Bogowonto Lagoon rapidly decreasing.

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