Asian Journal of Scientific Research 7 (4): 513-524, 2014
ISSN 1992-1454 / DOI: 10.3923/ajsr.2014.513.524

Coastal Conservation Strategy using Mangrove Ecology System Approach

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ABSTRACT

Coastal erosion and sedimentation often occur due to the impact of development in coastal areas. One of the reason is less or no attention to the function of mangrove ecosystems. This study was conducted in Indah Kapuk Beach, North Jakarta, Indonesia with 5.06 km length of coastal, which was divided into two regions, namely A (West) and B (East). Primary data was collected using transect-squares and spot-check methods to determine the existing condition of mangrove vegetation. Condition of mangrove has various densities ranging from 13-509 m. In region A, mangrove thickness was "small" in mangrove average of 40 m and the inland activities were aquacultural pond. Mangroves in region B were "large" 400 m average and many development activities were carried out in this area. Density of mangroves in the region A was "sparse" (<1000 trees ha^{-1}) and that in region B was "fair" (1000-1200 trees ha^{-1}) and "very dense" (>1,500 trees ha^{-1}). The mangrove density of each region influenced less significantly on the development activities. The biggest influence in maintaining the stability of the beach was the thickness of mangroves growing on the seashore. The correlations were as; when the mangrove density was "sparse", the mangrove thickness was "small", otherwise when the mangrove density was "very dense", the mangrove thickness was "large". Rehabilitation was done in two areas, namely region A which was planted mangroves in about 200-300 m thickness and region B which was planted mangroves in about 400-600 m thickness. It is concluded that the conservation of the coast can be successful when the ecological systems of mangrove work entirely.

Key words: Ecology of mangrove, coastal conservation, species density, mangrove thickness

INTRODUCTION

The term "mangrove" is loosely used to describe a wide variety of trees and shrubs (around 80 species) that share characteristics of being adapted to conditions of high salinity, low oxygen and changing water levels (Saenger *et al*., 1983). The mangrove biome dominates tropical and sub-tropical coastlines between latitudes 32°N and 38°S and covers approximately 22 million hectares. About 28% of global mangroves are located in Southeast Asia and Indonesia alone accounting for 25%.

The existence of the mangrove ecosystem has ecological functions namely, stabilizing coastal waters, protecting the coast against erosion and wind blows, controlling flood (water reservoir), filtering toxic materials, shelterring and spawning areas of various types of shrimp, fish and various other marine life as well as providing a source of marine food (Sasekumar *et al*., 1992; Kathiresan and Bingham, 2001). The importance of mangrove ecosystems for coastal fisheries has been described by many authors (Chong *et al*., 1996; Twilley *et al*., 1996; Giri *et al*., 2008).

Mangroves provide a number of valuable ecosystem services that contribute to human well being, including provisioning (e.g., timber, fuelwood and charcoal), regulating (e.g., flood, storm and erosion control, prevention of salt water intrusion), habitat (e.g., breeding, spawning and nursery habitat for commercial fish species, biodiversity) and cultural services (e.g., recreation, aesthetic, non use) (Spaninks and van Beukering, 1997; Brown, 2006; Kumar, 2010). Many of these ecosystem services have the characteristics of 'public goods' such that the people who benefit cannot be excluded from receiving the services provided (e.g., habitat and nursery service supporting fisheries) and that the level of consumption by one beneficiary does not reduce the level of service received by another (e.g., beach protection and storm buffering). Due to these characteristics, the potential for private incentives to sustainably manage mangrove ecosystem services is limited and markets for such services do not exist. In other words, there is a'market failure' and by the inherent nature, mangrove ecosystem services are under supplied by the market system (Brander *et al*., 2012).

Mangroves are generally under valued in both private and public decision-making relating to their use, conservation and restoration. Lack of understanding of information on, the values of mangrove ecosystem services has generally led to their omission in public decision making. Without information on the economic value of mangrove ecosystem services, that can be compared directly against the economic value of alternative public investments, the importance of mangroves as natural capital tends to be ignored. A number of studies have developed and applied methods to calculate the monetary value of mangroves (Ahmad, 1984; Barbier, 1994; Bann, 1998).

Mangroves, throughout the world, face a number of threats including pollution, deforestation, fragmentation and sea-level rise (Giri *et al*., 2011). The main drivers underlying these threats are increasing populations and development in coastal areas and the climate change. Mangroves are being converted to other land uses such as aquaculture ponds, urban developments, agriculture and infrastructure. In Asia there has been large scale conversion of mangrove forests to shrimp farms (Barbier *et al*., 2011).

The function of the mangrove ecosystem is to act as a habitat for a variety of wildlife including the protected animals which are used for research, education and other activities that support the cultivation such as utilization of genetic resources in the type and captive breedings (Bengen, 2002). Rapid population growth mainly led to the changes in land use and excessive use of natural resources, so that the presence of mangrove ecosystems becomes rapidly reduced and damaged (Lewis *et al*., 2011; Peixoto *et al*., 2011; Penha-Lopes *et al*., 2011).

Mangrove ecosystem has an important role in ecological and socio-economic terms (Rasolofo, 1997; Sathirathai and Barbier, 2001; Moberg and Ronnback, 2003; Ronnback *et al*., 2007; Walters *et al*., 2008). Mangrove ecosystem is a great base for nursery ground-spawning variety of fish, shrimp, mammals, reptiles, insects and besides that, it also becomes natural habitat of other organisms (Laegdsgaard and Johnson, 2001; Nagelkerken *et al*., 2008).

Physically, mangrove ecosystem becomes the buffer zone from encroachment of sea water, protects the coast from sea erosion and supports the formation of a new plateau. Economically, mangrove ecosystem becomes a source of fuel (wood), building materials, fishing ground, clothing material, paper raw material, alcohol, drugs and other commercial products (Sathirathai and Barbier, 2001; Islam and Wahab, 2005; Shervette *et al.*, 2007).

Due to increasing population pressure, especially coastal areas, it results in a change in land use and utilization of natural resources excessively, mangrove forests are quickly becoming more and more depleted and damaged throughout the tropics (Lewis *et al.*, 2011; Peixoto *et al.*, 2011; Penha-Lopes *et al.*, 2011). Balance needs between fulfilling the needs of economic development and environmental conservation support system must be achieved. Growing awareness of the functions of protection, productive, socio-economic mangrove ecosystems in the tropics and decreasing amount of natural resources, encourage the lifting of the need of an integrated conservation and sustainable management of resource-value resources. Because of the multipurpose potential of natural resources, it is necessary to conduct the management of mangrove forests based on marine and terrestrial ecosystems in relation to the intregated planning of coastal zone management. To determine the importance of mangrove, complexity and the influence of environmental factors have been the focus of many research fields (Faunce and Serafy, 2006; Nagelkerken *et al.*, 2010; Vaslet *et al.*, 2010). However, the influence of mangroves on the coastal conservation also became an important part of any research. The purpose of this study was to determine how good the mangrove ecological system's ability to maintain coastal stability.

MATERIALS AND METHODS

Study area: The study location was in Pantai Indah Kapok, Penjaringan North Jakarta, Indonesia. Location of the study was divided into two areas, namely region A in the Western part of the study area and region B in the Eastern one. Region A is a residential area and B is the area of housing and settlements (Fig. 1).

Methods: There were two kinds of data collection methods namely, Transect-squared and Spot check (English *et al.*, 1994). Both of them were applied to obtain compositional information types such as vegetational structure, community and types. The Transect-squared method was done by drawing a line perpendicular to the coast, then squares of size 10×10 m was placed above the line, distance between squares was established systematically, mainly based on the difference of vegetational structure. Next, in every square, the calculation of the number of individuals (trees, seedling and saplings), the diameter of the trees and the tree height prediction for each type was conducted. Spot check method was used to supply the information in species composition, distribution type and general condition of mangrove ecosystems that were not observed in the Transect-squares method. This was applied by observing and examining specific zones in the mangrove ecosystems that have specific characteristics. Information obtained through these methods was descriptive.

The mangrove vegetation data retrieval was divided into two regions. In region A, the data was taken from two stations, A1 and A2. In region B, the data was taken from four stations namely B1, B2, B3 and B4. The data retrieval in region A was in less amount than that in region B because the mangroves grew widely in the region B.

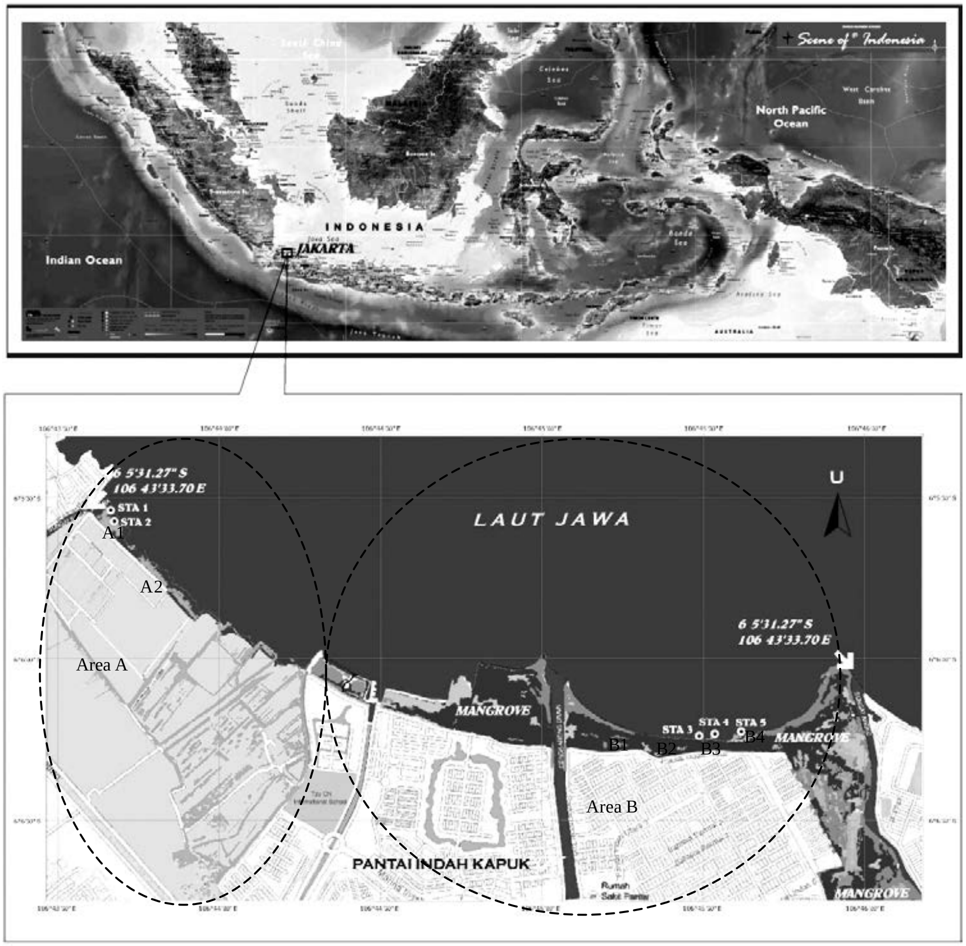

Fig. 1: Map of the research location

RESULTS

Mangrove vegetation: The length of the coastline in the study area was 5.06 km, measured from Kamal river to Angke River (Fig. 2). The thickness of the mangroves along the coast study sites varied. The mangrove thickness of 509 m located at a distance of 3 km was the maximum thickness. The mangrove thickness in distance of 1.25 km was very thin. The thickness of mangroves was only about 13 m. The coastal morphology was seen that the region A got erosion and region B got sedimentation. In region A, abrasion occurred so fast.

Therefore, the current construction has been installed to slow down the rate of abrasion in these regions. The constructions were fences, rocks or dead mangrove. Housing and residential areas were abundant in region B while region A was the area of an aquaculture pond that was no longer active. Cessation of pond aquaculture activities was caused by the abrasion and contamination.

The density of mangroves in region A was in the "sparse" category (<1000 trees ha^{-1}) and that in region B was in "fair" (1000-1200 trees ha^{-1}) and "very dense" (>1,500 trees ha^{-1}) categories (Herison *et al*., 2014a). These data shows that region A was sparse area over grown with

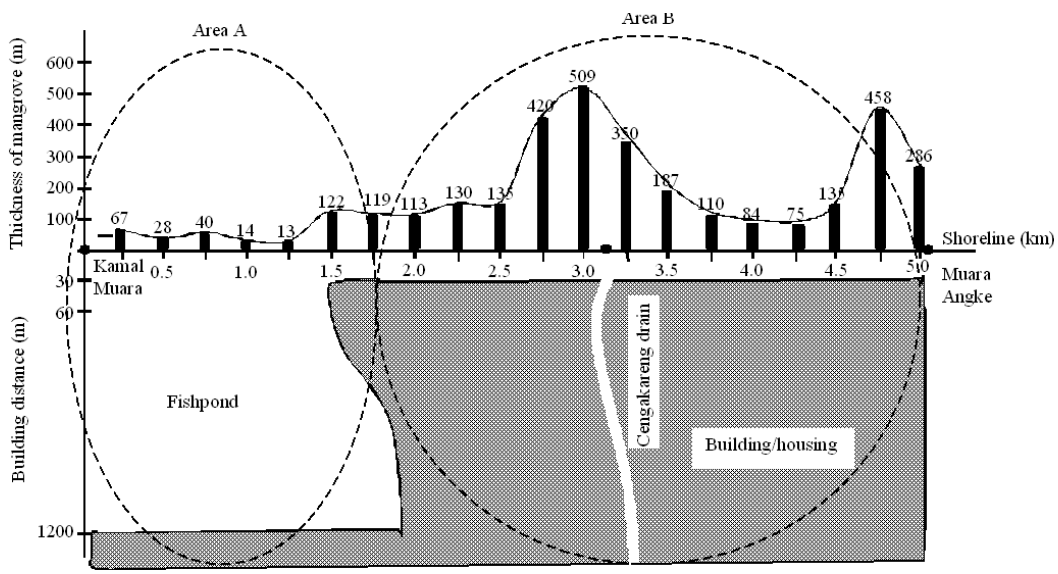

Fig. 2: Map of existing condition of mangrove thickness

Table 1: No. of individual trees, stem diameter and type of substrate

	Avicennia marina			
Station	Trees No.	Average diameter (cm)	Type of substrate	Transect size (m^2)
A1	5	12.62	Dominant sand	100
A2	8	13.99	Dominant sand	100
B1	6	12.48	Dominant dust	100
B2	15	12.53	Dominant sand	100
B3	12	11.39	Dominant sand	100
B4	6	12.48	Dominant sand	100

mangroves while the region B have more mangroves that grew and thrived. Mangrove ecosystem contained in the Indah Kapuk Beach Area (PIK) is generally dominated by *Avicennia marina,* which has leaves with a characteristic rounded egg strands to elliptical and the salt gland leaves. Type of *Avecennia marina's* root (pneumatofor) is similar to a pencil, sometimes like a root. The potential existence of mangrove forest vegetation constituent in Indah Kapuk Beach (PIK) can be described by the parameter number of individual trees, tree trunk diameter at breast height and the type of substrate (Table 1). Results described that the number of individual stands of *Avicennia marina* were 5-15 trees per 100 m^2, while the diameter of trunks of mangrove species ranged from 11.39-13.99 cm where, size of the trees >10 cm.

Thickness of the mangrove can determine the volume scale of building and infrastructure development activities done in this area. Function of mangrove as green belt was instrumental in the development process. The thicker mangrove means the more opportunities which enable the development activities. Region A was highly recommended, not to do the building and infrastructure development activities, since the mangrove was thin. The aquaculture pond was the most likely built in the region with the terms forming a green belt by mangrove reinforcing.

The development of mangrove based on data showed (Herison *et al*., 2014b) an increase in mangrove area from year to year. The increase could occur because of the efforts of rehabilitation and restoration of mangroves in regions A and B. The development of an area still has the same composition as the relative thickness of the current mangrove conditions. The possible morphology of the beach was same with mangrove condition at present. The sea current with a small wave incidence angle, continuously caused shoreline erosion. The sea current angle should be addressed on a region so that mangroves can grow well and region B also avoids sedimentation.

DISCUSSION

Ecological system of mangrove area: Region A is necessary for maximum conduct of mangrove rehabilitation and restoration efforts. Whatever activities to be carried out on the land area will not run maximized if the condition is not addressed. Mangroves will experience death if it is not solved. This study is part of an effort to change the pattern of coastal currents and bathymetry. Building breakwaters is one of solution. Region B is good enough for growing mangrove therefore, there are many building and infrastructure development activities. As shown in Fig. 3, the increasingly thick mangrove as green belt serves as the distance of the building closer to the beach, which means building more secure than physical wave pressure, on the other hand, marine ecological system is relative to greater environmental pressures from building activities.

The mangrove density of each region is having a less significant influence on the ecological function of mangrove compared to the thickness parameter. However, the best mangrove type is the mangrove with a “very dense” density and “large” thickness so the mangroves can keep the beach from abrasion and erosion. The thickness of the mangrove can be realized by taking into account all aspects that affect both growth and coastal physiographic aspects of physical oceanography. It is recommended to do rehabilitation and restoration of mangrove holistically, using both coastal engineering and ecosystem science so that the process of the mangrove rehabilitation and restoration can succeed. Thus, area A can also perform the development activities or aquaculture integratedly and sustainably.

To overcome the coastal morphology, which makes difficult to develop the mangrove is made current and wave regulator in a form Groin or Breakwater. Groin is a coastal protection structure that is built relatively protruding and perpendicular to the direction of the beach. The material construction is generally made of concrete, steel, wood and stone. Installation of groin can withstand waves and reduce currents. Groins are installed in pairs in one group and this needs a separate study. Breakwater is a structure built parallelly to the shoreline which serves to reduce waves. The position of groin is placed in front of region A with contour of the structure Groin Y and in region B, a breakwater is placed parallelly to the shoreline. Thus, the currents can be minimized and switched current angles coming not to sweep to coastline.

Coastal conservation areas: Area of Indah Kapuk Beach is characterized by mangrove ecosystem as a major function in the coastal ecological systems. The coastal balance is largely

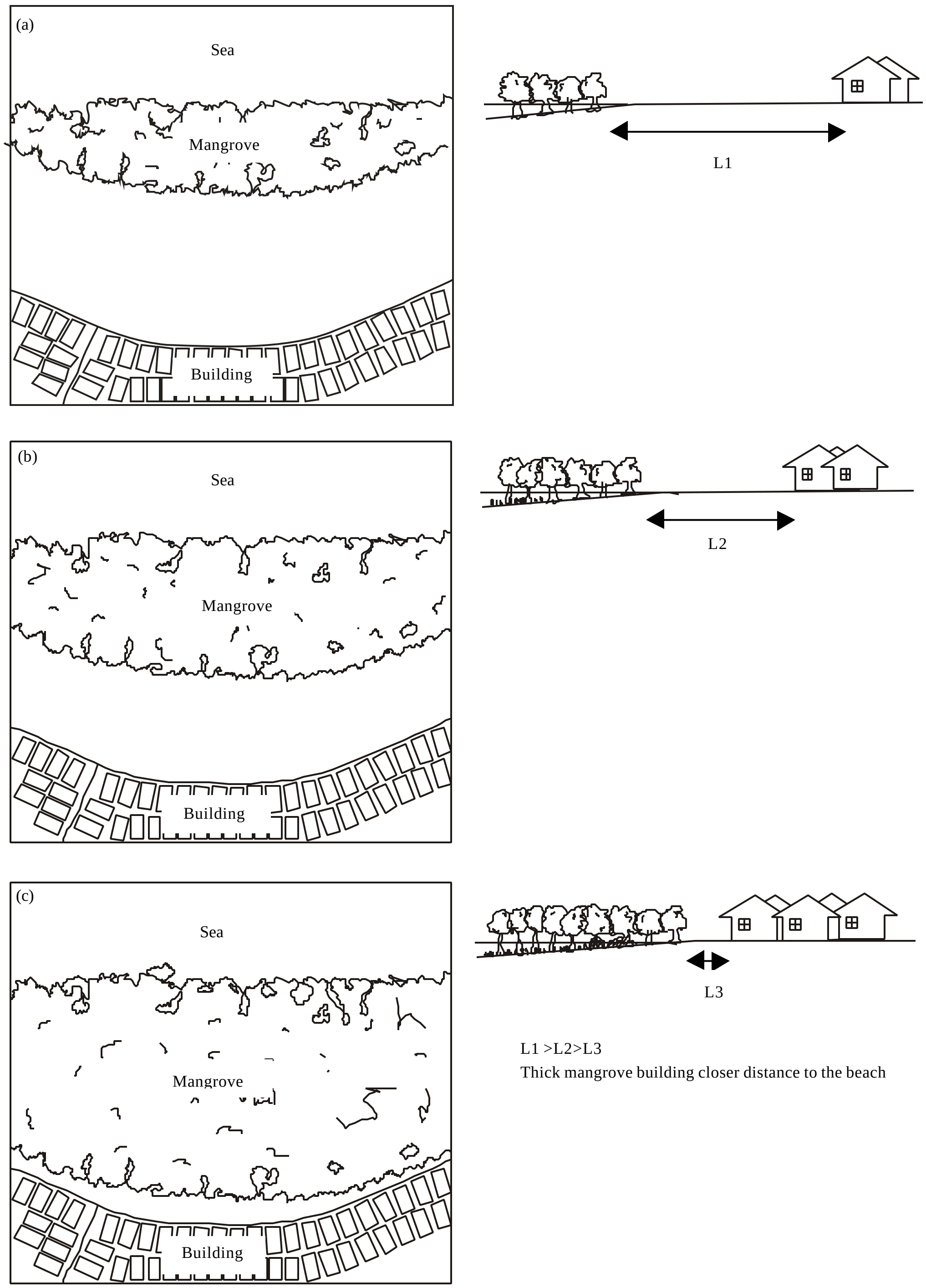

Fig. 3(a-c): Design of coastal area with magrove thickness, (a) Small, (b) Medium and (c) Large. L1: Distance of the building which is far away from the beach, L2: Distance of building which is medium away from beach, L3: Distance of the building close from beach determined by the role of coastal mangrove ecosystems along the Indah Kapuk Beach. Economic development in the area of Indah Kapuk Beach can trigger ecological imbalance through the landscape change, coastal land use change, mangrove space reduction, waste disposal, coastal building addition and direct activities in coastal areas. Ecological imbalance is indicated by coastal erosion and disturbed function of nursery ground and spawning ground, reduced the fish caught by fishermen, water quality degradation and sedimentation.

Conservasion of beach through ecology system approach is the most appropriate strategy for maintaining the ecological functions in Indah Kapuk Baech area. Mangrove ecological function will work when the maintaining existence of mangroves, setting the physical construction and layout of the building are kept. The factors of density and thickness of the mangrove will determine the mangrove ecosystems' ability to run their ecological functions in the coastal area, so the stability of the beach as a conservation area can be sustainably managed. Therefore, it takes the design or layout of the physical construction of the building, which considers the existence of mangroves on the edge of the shoreline. The mangrove species density in region A was 625 trees ha^{-1} or in sparse category (0-916 trees per 100 m^2 and mangrove average thickness of 40 m or in category of small (0-178 m). The density of mangroves in the area B was 1500 trees ha^{-1} or in category of very dense (1208-1500 trees per 100 m^2 and mangrove average thickness of 350 m or in category of large (343-509 m). It is not much different from the study of Purbandini (2012), who stated that the region that has a high density of mangrove species was positively correlated with the thickness of the mangrove.

Planning to increase the thickness of mangroves in the area of research is carried out by some of the following:

- Bathymetry owned in the category of gentle so it enables to facilitate the process of planting, region B is more gentle compared to region A, the depth of water on a regional bathymetry deeper than the region B
- Depth of water that still allows for the planting of mangroves to the outermost point towards the sea, the region A allows a thickness ranging 200-300 m and the region B allows 400-600 m measured from the shoreline
- Groin and breakwaters which have been built first in order to minimize the current. The buildings are as mandatory requirement in order to be successful in mangrove planting process

The effort of development without undermining coastal conservation can be realized through developing layout design of the coastal mangrove ecological systems approach (Fig. 4). Coastline landscape changes, function of mangrove services and development activities can be complemented with the pattern formation of an integrated and sustainable coastal protection. Income from fisheries sector will increase as well as the prosperity of the population also increases without decreasing mangrove area as a fundamental change in land use. In region A, the mangrove thickness ranges of 200-300 m with inland pond activities. It can be a generator for the life and direction of ocean fisheries and it will also increase the income of fishermen. The mangrove thickness in region B ranges from 400-600 m and the existing activities such as residential buildings, offices and infrastructures can be developed. Mangrove function as a greenbelt,

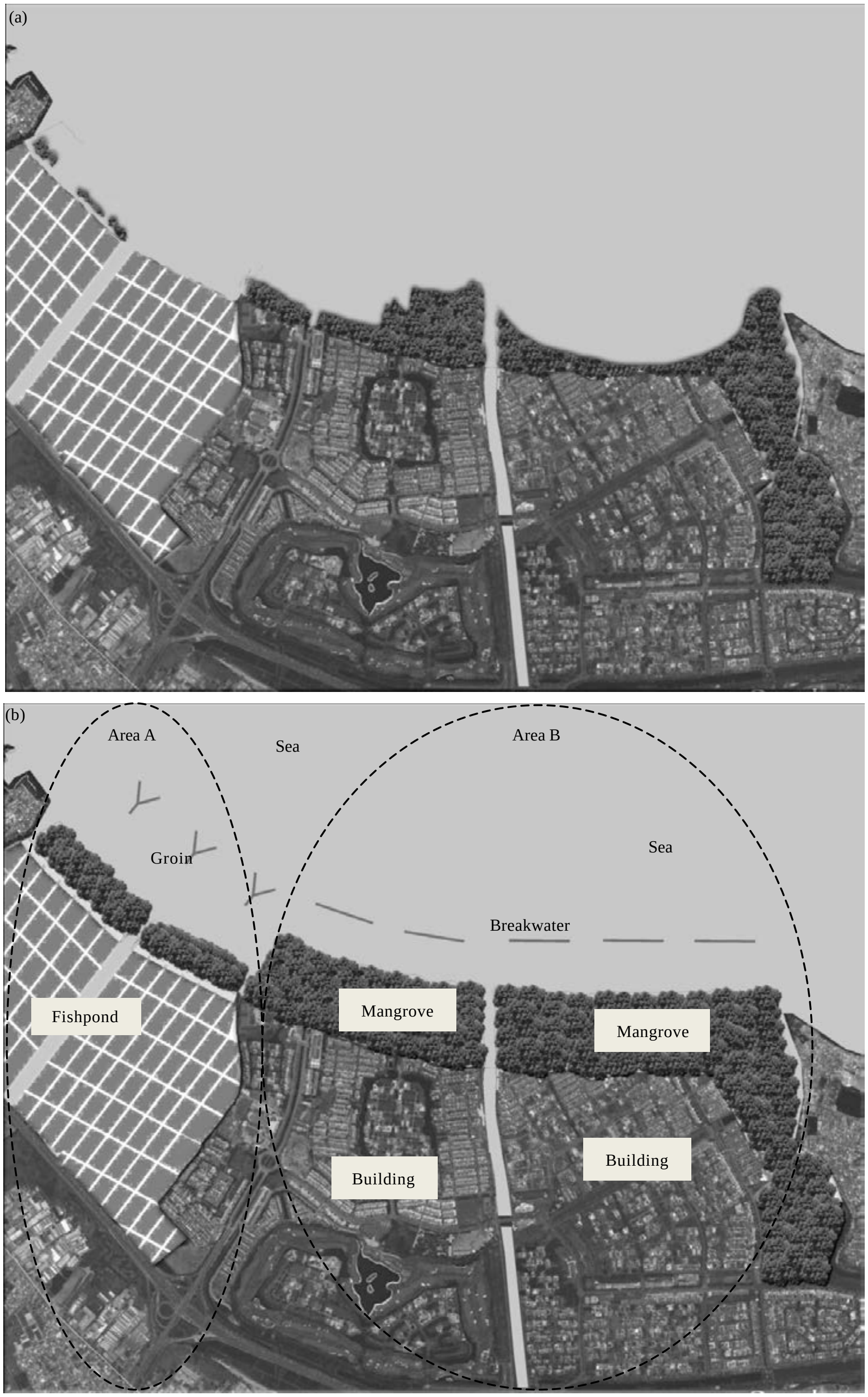

Fig. 4(a-b): Design of coastal conservation areas with ecological system of mangrove (a) Existing and (b) Design layout spawning ground, nursery ground, mangrove services, beach protection from waves and wind and ecotourism will run when the conservation of mangrove based coastal ecology system can be applied in Indah Kapuk Beach.

CONCLUSION

Coastal area has a good mangrove ecological system that will maintain the functionality of fisheries, as well as providing an environmentally friendly development activity, so that the activity based management of coastal mangrove ecosystem conservation can improve people's lives economically and socio-cultural sustainability through ecological functions of coastal areas which contributes fishing, aquaculture and coastal protection. The coastal conservation is successful factor of mangrove growth. The ecological functions of mangrove will run better if the mangrove seaward is thicker.

ACKNOWLEDGMENTS

This study was supported by Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Bogor Agriculture University. We would like to thank BOPTN of Higher Education for funding this study.

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