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Detection of Mangrove Disruption due to Anthropogenic Factor in Protected Area using GIS Model : A Case Study in Konawe Selatan, Southeast Sulawesi

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Abstract

Coastal area is one of the rapid developing area in the world. Many activities have been running in this area such as fisheries, aquaculture, transportation, tourism and others. Mangrove is one of dominant, potential, productive, and high-value benefits of coastal ecosystems. Unfortunately, mangrove ecosystems have been damage across the country where it growths. Degradation of mangrove also happening in Konawe Selatan. Within 2009 to 2014, about 48% mangrove lost. Anthropogenic factor identified as the main drivers of mangrove ecosystem damage. Protected area can potentially conserve tropical coastal resources and provide social and economic benefits to the local communities. Delineation of protected area of mangrove is one approach being taken for environmental conservation in the tropical areas. Unfortunately, only 6,9% of mangroves worldwide are located within protected area.

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The aim of this study is to define mangrove disruption level due to anthropogenic factor inside the protected area in Konawe Selatan. The result shows that in protected area, there are 23,70% of mangrove indicated in low level of disruption and 63,63% in high level of disruption due to anthropogenic factor.

Keywords: mangrove; anthropogenic; protected area; geospatial model.

1. Introduction

Coastal area is one of the rapid developing area in the world. Many activities have been running in this area such as fisheries, aquaculture, transportation, tourism and others. Those activities give some impact to the ecosystems, either directly or inderectly, causing destruction and disruption to the ecosystems. One of the coastal ecosystems has been changing around the world is mangrove.

Mangrove is one of dominant, potential, productive, and high-value benefits of coastal ecosystems. Mangrove is a plant community or an individual plant species that form a community in tidal areas [1]. Mangrove has a several benefit, both direct and indirect. Direct benefits of mangrove ecosystem are the benefits could be felt directly usefulness for human life and measured, either production or services. Indirect benefits are often difficult to felt and measured, but these benefits actually have a strategic value in supporting human life, such benefits in the area of research and education, germplasm resources, maintain the climate and hydrology, and others.

Mangrove also has several important functions such as ecological, socio-economic [2] and physical function [3]. In ecological function, mangrove forests have a significant value as the main key to the provision of food for organisms living around the mangrove, such as shrimp, crabs, fish, birds, and mammals. Mangrove is an area of feeding ground for organisms inside. Because the density of mangrove allows to protect the living organism in it, then the mangrove forests also serve as a nursery grounds or the breeding, especially for shrimp, fish, and other marine life. In addition, with its unique shape, mangrove forests also provide a good and ideal spawning ground. In social-economic function, mangrove forests, both timber and non-timber, can be used by the community as a construction material, wood, pulp and paper, foodstuffs, handicrafts, pharmaceuticals, tourism, and others. This greatly helps the economy of local communities. Meeting the needs of the community, both mangrove forest products and services, will contribute in improving economic and social conditions in the communities around the forest. Developing mangrove ecotourism site and forest education can also create a new jobs for the local communities. Some physical function of mangrove forests are (1) Keeping the shoreline and riverbanks from erosion / abrasion to remain stable; (2) Accelerate the expansion of land; (3) Controlling seawater intrusion; (4) Protecting the area behind the mangrove forest from the pounding waves and strong winds; and (5) Processing of organic waste.

Mangrove ecosystem support the conservation of biodiversity. Mangrove ecosystems can also protect coral reef and sea grass. Various types of fish, whether commercial or non-commercial, also depend on the existence of mangrove ecosystems [4]. It has been estimated that nearly 90% of all marine animals spend some part of their life cycle within a mangrove ecosystem [5]. Mangroves play an important role within these areas as they guard the low-lying coastal land by forming a protective barrier. This biological barrier reduces damaged caused by storms by limiting wave energy and preventing the land from being flooded. This has become even more apparent after the 2004 Asian tsunami [6]. Mangrove also provide various ecological and economical ecosystem services contributing to coastal erosion protection, provision of building material and medicinal ingredients, and the attraction of tourists [7].

FAO [8] reported that mangrove in Indonesia about 3.0623 million ha. It covers about 19% of the total area of mangrove in the world. In 1980 the mangrove forests in Indonesia reached 4.2 million ha. Unfortunately, there was a decrease of 1.8% in 1990 to 3.5 million ha. Then it continues decreased by 1% in 2000 to 3.15 million ha. Currently, although the degradation of mangroves has been decreasing, but it is still happening around the world.

Degradation of mangrove also happening in Konawe Selatan. In 2009, mangrove area reached 23.195 ha in Konawe Selatan and approximately 2.940 ha was in a critical condition [9]. In 2011, Statistical Agency of Konawe Selatan [10] reported that mangrove area is about 15.522 ha. It shows that about 33% mangrove lost in 2 years.

The influence of human activities are the main drivers of global ecosystem damage [11,12,13]. The pressure of human activities on coastal ecosystems are often very high through the competition of land use for aquaculture, agriculture, infrastructure construction and tourism [4]. Changes in the size, composition, and distribution of human populations affect coastal regions by changing land use and land cover. Fishing or harvesting, the destruction of mangroves, and pollution and sedimentation from human activities all can affect the coastal environment [14]. Mangrove has been degraded as a result of natural factors and human activities [15]. Aquaculture, the world’s fastest growing food production activity, can lead to the destruction of mangroves and may lead to irreversible damage to both estuarine and offshore fisheries and by modifying habitats [14]. Unconventional mining activity damages of the mangrove forest. Mining activity causes loss and reduces mangrove area. This condition makes the mangrove lost its function, in ecological, physical, and economical benefit [16]. In Southeast Sulawesi, mangrove mostly converted into fishponds and settlements, the use of firewood, industrial, raw materials household furniture, as well as roads and ports [17].

Protected Areas is a region defined by the primary function of protecting the environmental sustainability that include natural resources, artificial resources and historical and cultural values of the nation for the benefit of sustainable development. Including in the protected areas here are protected forest (HL) and forest preserves (HSA). Management of protected areas aims to prevent any damage to the environment. Management goals of protected areas are: (a) Increase protection function against soil, water, climate, flora and fauna and historical and cultural values of the nation; and (b) Maintaining the diversity of plants, animals, ecosystems, and natural uniqueness [18,19]. Protection of forest areas is directed to maintain the existence of forests and biodiversity and to keep continueing the role of forests as a life support system. Unfortunately, according to Giri et al. [20], only 6,9% of mangroves worldwide are located within protected area, therefore additional protected area should be urgently deliniated in the effort to reduce the rate of loss [21]. Protected area can potentially conserve tropical coastal resources and provide social and economic benefits to the local communities.

The spatial model is a representation of the real world in the form of thematic layers of digital maps. A variety of complex natural phenomena can be simplified and managed by a spatial model [22]. The spatial model can be used to represent natural phenomena and predictions about how the phenomenon occurs in nature. In management activities, it is necessary to have an adequate database.

This database can be used as a basis for planning and decision making, including in the management of mangrove forests. Mangrove forest management can be facilitated by utilizing remote sensing applications and Geographic Information System (GIS).

The aims of this study is to define the spatial model of mangrove disruption level due to anthropogenic factor inside the protected area. Geospatial model approach was used to map the zone with the disruption level is high and low, based on the anthropogenic factor. Through the analysis of the conditions and the level of disruption to the mangrove ecosystem, expected to assist in the planning of mangrove forest management, especially those in protected area.

2. Material and Method

2.1. Study Area

Research was conducted in Coastal Area of Konawe Selatan Region, Southeast Sulawesi Province, on March 2015 to July 2016. This area consist of 8 district, namely District Tinanggea, Palangga Selatan, Laeya, Lainea, Kolono, Laonti, Moramo and Moramo Utara. Figure 1 shows the location of research.

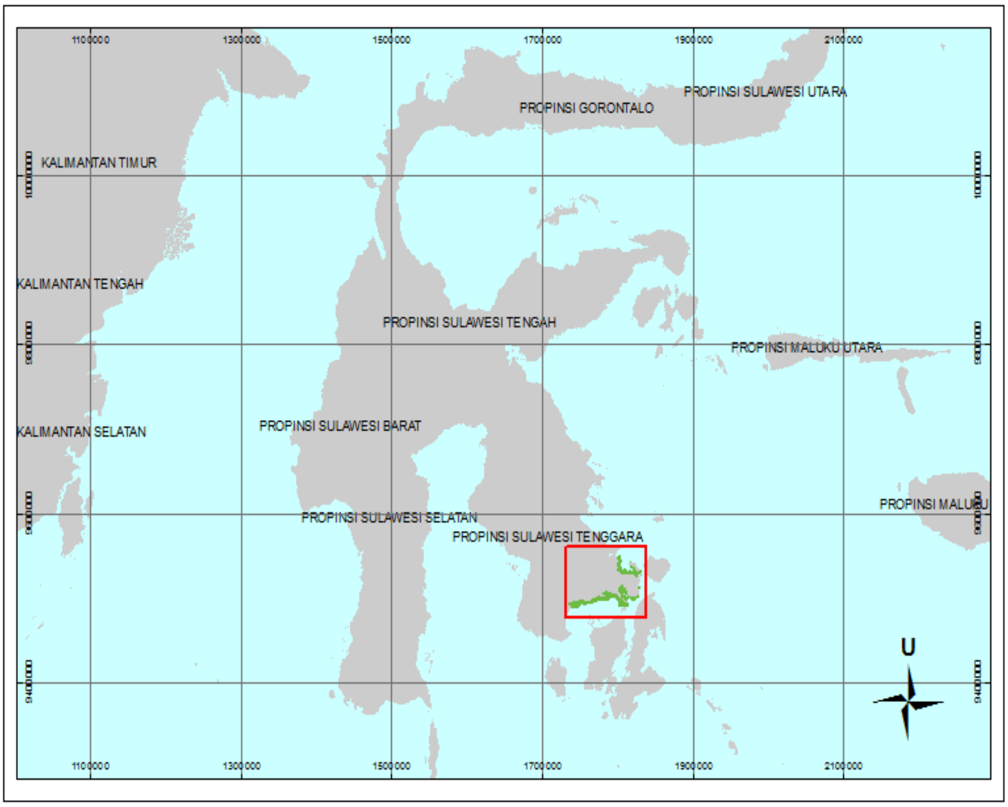

Figure 1: study area

2.2. Tools and Materials

The tools used in this research including NIKON Digital Camera, Garmin GPS V+, Global Mapper, ESRI ArcGIS 10.1 and ERDAS ERMapper 9.1 and a set of HP laptop Core i3 RAM 2 GB. The materials used in this research including interview guideline; Ground Control Point (GCP); Landsat-8 path 112 row 63, recorded on 9 October 2014 ; thematic layer road, river and coastline year 2009 in shape file format obtained from Geospatial Information Agency of Indonesia; thematic layer port, mining and designation type of forest area year 2013 in shape file format obtained from Planning and Regional Development Agency of Konawe Selatan; population growth and majority type of worker per district year 2014 in tabular data obtained from Statistical Agency of Konawe Selatan Region; and literature.

2.3. Research Procedure

Step by step procedure of research as following in table 1.

Table 1: The procedure of research

No	Activity	Description
1	Literature study and deep-interview	- Literature study was obtained from various sources, such as book reports, theses, journals, internet and other documents related to the research subject. Literature study aims to obtain secondary data that can be used in completing the research data. - Interview with the expert aims to get more specific and in-depth information. - Identification of parameters as a driven of disturbance on mangrove ecosystem due to human activities through the literature study and interview to get many information from stakeholders about the condition of mangrove ecosystem on the site.
2	Initial processing of satellite imagery	- Radiometric correction; histogram adjustment method used in radiometric correction. - Geometric correction; the nearest neighbor method used in rectification prosess based on several considerations, which are the process does not use complex mathematical models, computational process is faster and does not change the value of pixel image produced [23]. - Composites, fusion and sharpening image contrast; the colour composite used in image analysis was the original true color composite RGB channel 321 and false color composite RGB channel 432. Pan sharpened image process conducted on satellite images Landsat-8 multispectral channel which have a 30m spatial resolution with panchromatic channel which has a 15m spatial resolution in order to improve the quality of visual display of imagery

		for the purposes of interpretation and digital classification.
3	Land cover mapping	Supervised classification digital feature extraction method used for land cover classification mapping. Class of land cover mapped in this research were forest, crop, mangrove, settlement, bush, aquaculture ponds, open land and farm-field. The aims of this step is to get thematic layer of mangrove, settlement and aquaculture ponds as an input parameters in the spatial model of mangrove disruption level due to anthropogenic factors.
4	Accuracy assessment	Accuracy assessment aims to measure the validity of the thematic layer data to be accepted as an input parameters in the spatial model of mangrove disruption level due to anthropogenic factors. We tested the accuracy of the land cover map through a set of GCP. Accuracy assessment were done using both Confusion Matrix [24] and Kappa Index Method [23].
5	Mangrove cover (canopy) density	Layer of canopy density obtained from the polynomial regression correlation between NDVI values with the calculated mangrove canopy density (%) in the field using a measuring instrument canopy density [25]. The calculation formula is as follows: $\textit{Mangrove cover density (\%)} = 99.739x^2 + 44.942x + 7.4204 \quad (1)$ *Where* $x = NDVI$
6	Spatial model of mangrove disruption level due to anthropogenic factor	- Weighting of each parameters based on the level of disruption. Expert interview aims to get the information of which parameters considered the most influential among all others. Pair-wise comparison method applied in this step [26]. - Each layer of input parameter reclassified based on the range value of parameter to get the same unit of each parameter ongoing process the data. - Configuring the model on cell-based GIS model and distance model. - Spatial model of mangrove disruption level due to anthropogenic factor compiled through the following function: $\textit{Mangrove disruption level } (Lgi) = (Lgi.Ak \times 0{,}25) + (Lgi.Plb \times 0{,}1) + (Lgi.Ptb \times 0{,}2) + (Lgi.Apt \times 0{,}1) + (Lgi.Tjm \times 0{,}1) + (Lgi.Kkv \times 0{,}15) + (Lgi.Km \times 0{,}1) \quad (2)$
7	Identification of mangrove disruption level inside protected area	- Define mangrove disruption level inside protected and non protected area through overlay maps of disruption level of mangrove due to anthropogenic factor and designation type of forest area.

Table 2: Weight and value of parameters and variabels in mangrove disruption level due to anthropogenic factor model

No.		Parameters / Variabels	Weight	Value		
				1	2	3
1		Access to the mangrove area (Lgi.Ak)	**0,2500**			
	a	Distance from settlement (Lgi.Akm)	0,1125	4 - 19.9 km	2 - 4 km	0 - 2 km
	b	Distance from main road (Lgi.Akj)	0,0625	2 - 10.5 km	1 - 2 km	0 - 1 km
	c	Distance from river (Lgi.Aks)	0,0375	500m - 2.5 km	250 - 500 m	0 - 250 m
	d	Distance from coastline (Lgi.Akp)	0,0375	500m - 2.5 km	250 - 500 m	0 - 250 m
2		Port activities (Lgi.Plb)				
		Distance from port	**0,1000**	2 - 15.5 km	1 - 2 km	0 - 1 km
3		Aquaculture ponds activities (Lgi.Ptb)				
		Distance from aquaculture ponds	**0,2000**	4 - 26.9 km	2 - 4 km	0 - 2 km
4		Mining activities (Lgi.Apt)				
		Distance from mining	**0,1000**	> 2 km	1 - 2 km	0 - 1 km
5		Mangrove cover (canopy) density (Lgi.Tjm)				
		Percentage of mangrove cover (canopy) density	**0,1000**	> 60%	30 – 60%	0 – 30%
6		Conservation Area (Lgi.Kkv)				
		Types of designation forest areas	**0,1500**	HSA & HL	HPT	HP & APL
7		The capacity of local communities (Lgi.Km)	**0,1000**			
	a	Population growth (Lgi.Kml)	0,0500	0 - 3 %	3 - 6 %	> 6 %
	b	Community work in sector: farming, fishing, hunting, forestry, plantation, mining and quarrying (Lgi.Kmu)	0,0500	0 - 30 %	30 - 60 %	> 60 %
		Commulative	1,0000			

3. Result

There are 8 classes of land cover mapped in this study through Landsat-8 image processing, which are forest area about 131.695,449 ha, crop 75.322,070 ha, mangrove 11.849,992 ha, settlement 5.979,207 ha, bush 25.074,413 ha, aquaculture ponds 4.202,614 ha, open land 49.536,326 ha and farm-field 22.978,604 ha. Land cover mapping accuracy assessment shows that the value of overall accuracy about 89,22%. In user accuracy assessment of each classes of land cover show that the value range between 80 to 100%. This indicate that each layer of land cover assessed has a good accuracy and can be used for next analysis. In Kappa Index assessment, the accuracy value is 0.87.

There is 48% lost of mangrove from 2009 [9] to 2014 (this study). Acces to the mangrove area indicated as the main factor with highest weight (0,25), especially distance from settlement and main road. Infrastructure building is one of the important thing in development, but also become a bridge that could threaten the natural ecosystems.

Aquaculture ponds activities also indicate as the important factor causing the damage of the mangrove with weight of 0,20. Mostly, aquaculture ponds opened by illegal-cutting of mangrove. Once these area opened, then mangrove area around it becomes more vulnerable to damage.

Port activities, mining activities, mangrove cover (canopy) density and the capasity of local communities also contributing as the factor causing the damage of mangrove ecosystems with weight of 0,1.

In figure 2 showing the distribution of most and less effected level of disruption. The red colour showing the area with high level of disruption, the middle and low level of disruption showing in yellow to green colours.

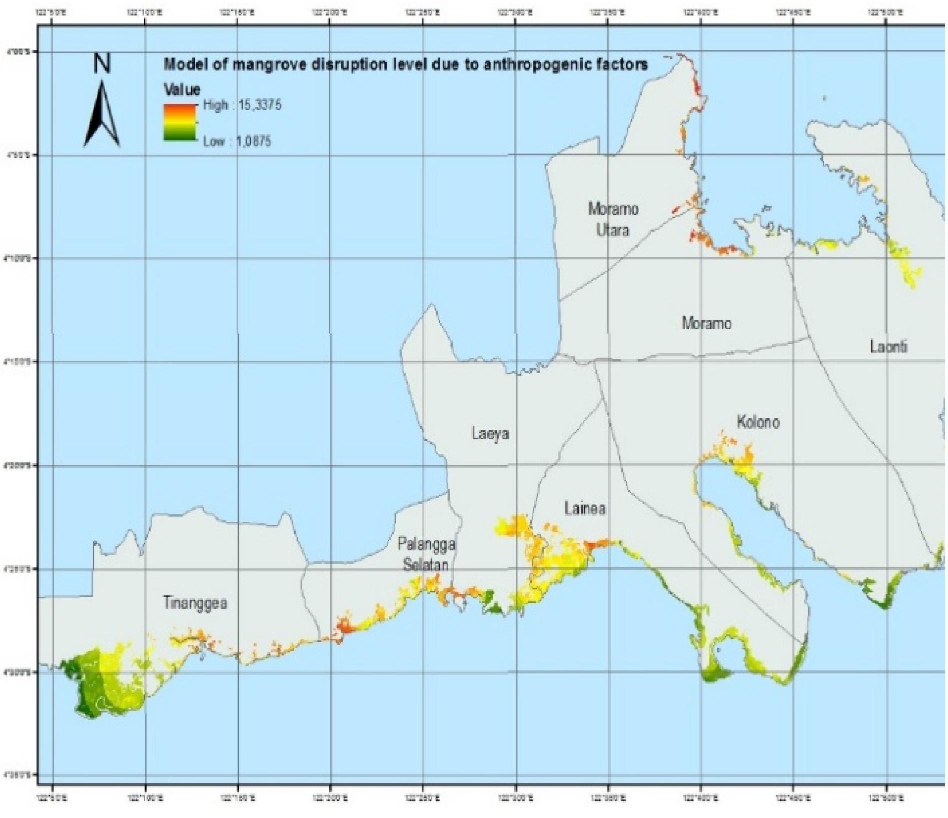

Figure 2: spatial model of mangrove disruption level due to anthropogenic factors

Reclassified model of mangrove disruption level into 2 class, low and high level, and designation type of mangrove which are protected area (HL and HSA) and non protected area (production forest and another area of use), showing in figure 3.

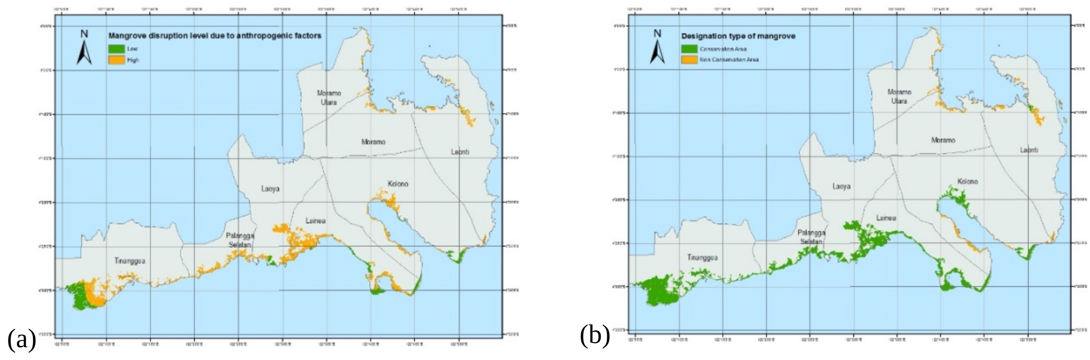

Figure 3: (a) reclassify of mangrove disruption level due to anthropogenic factors model; and (b) designation type of mangrove

Protected forest area is a specific area designated and/or assigned by the government to be maintained as a protected forest. The protected forest area located in District Moramo, North Moramo, Kolono, Lainea, South Palangga and Tinanggea.

Natural Reserve Area is an area with specific characteristics, both on land and in the waters that have a principal function as a preservation area of plant and animal diversity and the ecosystem that also serves as an area of life support systems. Natural reserves and conservation are forest areas of conservation (HK) is located in the District Tinanggea, Lainea, Kolono, Laonti and Moramo.

Protected area is a protected area that is ecologically is an ecosystem located in the rural districts, protected areas that provide protection against regional subordinates, located in the district, and protected areas other under the terms of legislation management the authority of district governments [19].

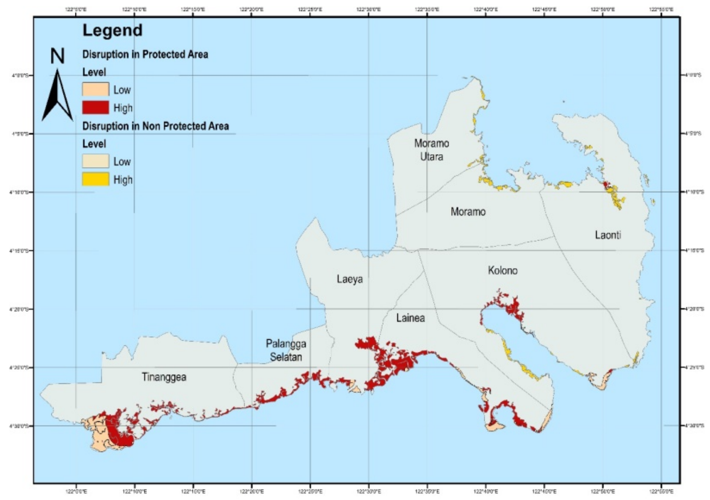

Figure 4: mangrove disruption level due to anthropogenic factors in protected and non protected area

From the study, the highest disruption level is in the protected area consist of 63,63% of all mangrove area or about 7.540 ha. Low level of disruption also found in the protected area about 23,7%. There is also found high disruption level of mangrove in non protected area about 12,67%. Result presented in table 3.

Table 3: Area of mangrove disruption level due to anthropogenic factors and designation type of mangrove

No.	Disruption Level	Designation Type	Area (ha)	Percentage (%)
1	Low	Protected Area	2.808,32	23,70
2	High	Protected Area	7.539,99	63,63
3	Low	Non Protected Area	0,03	0,00
4	High	Non Protected Area	1.501,64	12,67
	Amount		11.849,99	100,00

Creating a protected area is intended to counter the effects of human activities on the environment is a significant step towards the preservation of coastal and marine ecosystems [21]. Designation area as protected forest (HL) and natural reserve area (HSA) supposed to be a barrier of mangroves destruction, but in this case, designation area of forest is not much help. This shows the lack of supervision and weakness of law enforcement. Evidenced by illegal logging for household use and land conversion into fishponds and settlements, even the mining activity, are found in this protected area. This has become the greatest threat to mangrove ecosystems both inside and outside the protected area. Supervision and law enforcement must be upheld, building partnerships with the community both in terms of supervision and management of forests mangrove, and community education for sustainable utilization.

Based on Regional Regulation [9], the strategy in the control and regulation of strictly protected area by taking into account environmental aspects, consisting of:

a. Restore function in the damaged area through the technical handling and vegetative;
b. Maintaining the water catchment area;
c. Enhance community participation around the area to participate in the conservation of protected areas;
d. Preserving area including the river banks by developing forest or plantation crops; and
e. Raising environmental awareness through education, tourism, research and cooperation area management.

4. Conclusion

From the study, it can be concluded that the spatial model with cell-based data analysis given the objective and effective result in zoning the mangrove area for management purpose. High disruption level and low disruption level of mangrove located in protected area are respectively 63,63% and 23,7 %, while high disruption level of mangrove in non protected area is 12,67%. Spatial model of mangrove disruption level due to anthropogenic factors may be determined more closely to the factual situation by involving more recently socio-economic data such as the educational degree of local communities and other spatial layer of human activities such as fishing activities, agricultural activities and shipping-channel.

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