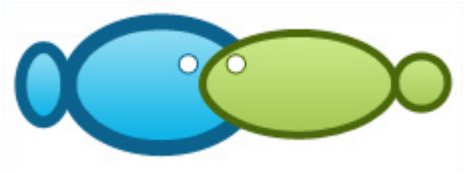

Spatial analysis of mangrove deforestation and mangrove rehabilitation directive in Indramayu Regency, West Java, Indonesia

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Abstract. This study was conducted to analyze spatial mangrove deforestation occurred in Indramayu Regency from 1989 to 2015 and to determine the directive of its rehabilitation. The methods used in this study were remote sensing technique and geographic information system assisted by SAGA GIS and Quantum GIS software. The data were analyzed through overlay analysis on landsat imagery and some of land suitability parameter maps for various types of mangrove vegetation. The results show that mangrove areas in Indramayu Regency were decreased by 2,345 ha and the worst damage was in Cantigi District. The directive of mangrove rehabilitation plan in Indramayu Regency ranked from worst to least damaging are Cantigi District, Pasekan District and Losarang District. Recommended vegetation based on physical parameters i.e.: *Avicennia sp., Bruguiera sp., Nypa Fruticans, Rhizophora sp. and Sonneratia sp.*

Key Words: geographic information system, land suitability, landsat imagery, remote sensing, spatial mangrove.

Introduction. Populations increase in coastal areas automatically increases the need for clothing, food, shelter, clean water and energy. This has resulted in higher exploitation of coastal resources. One of the coastal resources that are currently under threat is the mangrove ecosystem. The National Coordinating Agency for Surveys and Mapping (2009) stated that the vegetated area of mangrove forests in Indonesia is around 3,244,018.46 ha. However, the mangrove area has been decreased in quality and quantity due to conversion activities (ponds, settlements, rice fields) and irresponsible logging. The tendency of mangroves conversion into other forms of land use is increasing rapidly; basically it depends on economic interests and there is less focus on sustainability of ecological and social interests (Aksornkoae 1993). Kusmana & Onrizal (1998) reported that in 1982 mangrove forests in Indonesia were recorded at 4.25 million ha while in 1993 it was 3.7 million ha, which 1.3 million ha had been leased to 14 forest concession companies (HPH).

Indramayu has a forest potential of 43,027.41 hectares, divided according to the state control of 40,653.41 hectares and community forest area of 2,374 ha. The cultivated commodities comprises teak forests of 21,144.37 ha, brackish/mangrove forest (protected forest area) of 8,023.55 ha and 5,303.75 ha of timber forest. Mangrove area in Indramayu Regency is divided into two categories including mangrove area managed by Perum Perhutani and mangrove area managed by the community. In 1990s, the development of ponds in Indramayu Regency continued to increase (Directorate General of Fisheries 1991) people flocked to open land for the pond cultivation so that many areas of mangrove are converted into pond farming areas, settlements, rice fields, and others which resulted continue decrease of mangrove areas in Indramayu.

Based on the data from the Department of Fisheries and Marine Indramayu Regency (2012), Indramayu Regency is one of the areas that have the worst level of mangrove destruction in West Java. The area of 17,782 ha of forest, 50% of them were classified as severely damaged. Therefore, most of Indramayu coastal areas were exposed to abrasion with a speed of 9-10 m per year. Around 8,233 ha areas covering in 8 districts were categorized as critical. This is in line with study from Onrizal (2002) presented that at the district level, potentially mangrove within the forest area classified as heavily damaged is located in Indramayu Regency. Coastal rehabilitation activities by mangrove planting have been started since the nineties. Data on mangrove planting from Ministry of Forestry from 1999 to 2003 have been realized for 7,890 ha, but the success rate was still very low. This data showed that mangrove forest rehabilitation rate was about 1,973 ha/year. In addition, the community was not fully involved in mangrove rehabilitation efforts; moreover there was tendency of plant disturbance by community through different interests.

The aims of this research are to analyze spatial mangrove deforestation and the directive of its rehabilitation plan in Indramayu Regency.

Material and Method

Study sites. The study was conducted in Indramayu Regency which is located at Longitude 107° 52° - 108° 36° E and Latitude 6° 15° - 6° 40° S. Location of the study is shown in Figure 1. As Indramayu Regency is stretched along the north coast of Java Island, the air temperature in this area is considerably high, ranging from 22.9°C to 30°C while the average rainfall during 2014 was 2.104 mm with the number of rainy days occurred approximately 103 days. Altitude range of Indramayu Regency is 0-100 masl where the elevation tends to increase from the northern to the southern part. The tides in the North Coast region of West Java including Indramayu Regency based on forecasting data from two stations (Tanjung Priok and Cirebon), were classified as mixed tidal type leads to semi-diurnal (multiple mixture).

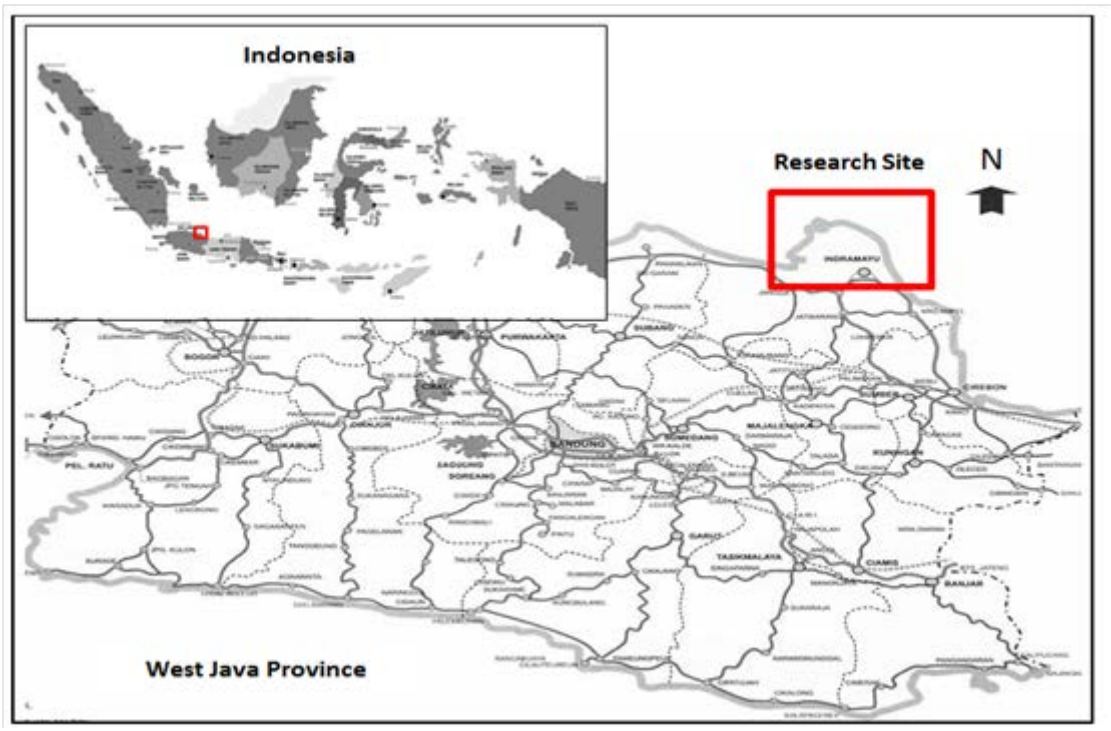

Figure 1. Map of the research location.

Materials. Materials used in this study included Citra Landsat MMS 1989, Landsat TM Image Year 2002, and Citra Landsat 8 OLI Year 2015. The tools used in this study were GPS (Global Positioning System) 60 Garmin within accuracy of 3 m, Refactometer, Roll

meter and meter with accuracy of 1 cm, ground drill, water sample bottle, camera and introduction to mangrove guidebook (Rusila Noor et al 2006), a computer equipped with SAGA GIS 4+ and Quantum GIS.

Methods. The data were collected by downloading landsat images from http://glovis.usgs.gov/, further analysis were carried out to determine the mangroves area in 1989, 2002, and 2015. The salinity data was obtained directly from the field by taking samples of seawater using pipettes and measured it with refactrometer, samples were taken at every distance of 250 m, 500 m, and 1000 m from the beach at study area. At each point of sampling, 3 samples were taken to determine the average salinity in study area. Soil texture data were collected by transect method with distance 250, 500, and 1000 m from the beach in all sample villages. The five soil samples were composted for laboratory analysis.

Data analysis

Mangrove changes rate analysis. This analysis was conducted to observe the change of mangrove cover by using multitemporal data and comparing two imagery data. Based on combination of land cover classification in 1989 2002, and 2015 change in mangrove cover can be obtained. Area and its changes can be calculated from the number of pixels by the formula:

$$\Delta L = \frac{Lt_2 - Lt_1}{\Delta t} \quad (1)$$

Where: ΔL is the rate of change of the area, Lt1 is the area in early observation year (ha) and Lt2 is the area in the next observation year (ha). Δt is the difference between the early observation period (year) and final observation period (year).

The result of the change analysis using the imagery data of 1989 and 2002 is referred to rate of change I. The result of the change analysis using the imagery data of 2002 and 2015 is referred to rate of change II. Stages of analysis are presented in Figure 2.

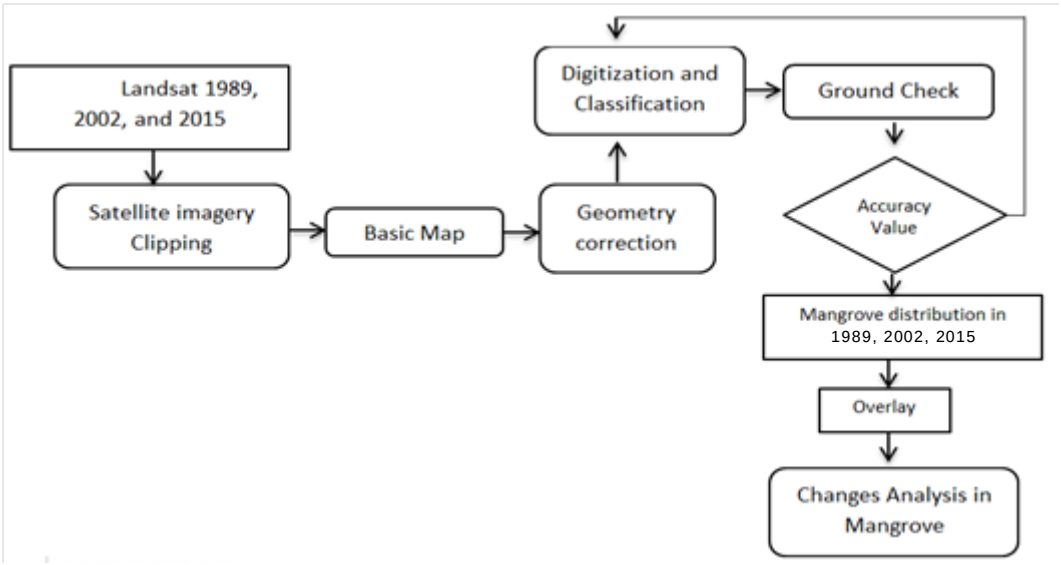

Figure 2. Flowchart of mangroves deforestation.

Analysis of priority planning directive and vegetation type for mangrove rehabilitation in Indramayu Regency. The priority directive of mangrove rehabilitation in Indramayu Regency is based on the level of mangrove damage that

occurred from 1989 to 2015 and the result of land suitability analysis for mangrove vegetation type. This is carried out in order to emphasize a priority in conducting mangrove rehabilitation strategy, the higher mangrove damaged then the area will be the main priority in mangrove rehabilitation plan. The directive of suitable type of vegetation for mangrove rehabilitation in Indramayu Regency is developed by referring to matrix of mangrove species selection in suitable land area as shown in Table 1.

Table 1

Matrix of mangrove species selection in suitable land area

Watson's inundation classes (1928)	*de Haan's inundation classes (salinity and tides frequency) (1931)*	*Soil texture*	*Dominant species*
All high tides	Brackish to saline, salinity 10-20 ppt, always flooded (1-2 times day^{-1}, minimum 20 days month^{-1}) Brackish to saline, salinity20-30 ppt, always flooded (1-2 times day^{-1}, minimum 20 days month^{-1}) Brackish to saline, salinity >30 ppt, always flooded (1-2 times days^{-1}, minimum 20 days month^{-1})	Coarse, sandy, sandy loam	*Avicennia* sp., *Sonneratia* sp., *Rhizophora* sp.
Medium high tides	10-19 days month^{-1}, salinity 10-20 ppt 10-19 days month^{-1}, salinity 20-20 ppt 10-19 days month^{-1}, salinity >30 ppt	Silty to silty clay	*Bruguiera gymnorrhiza*
Normal high tides	9 days month^{-1}, salinity 10-20 ppt 9 days month^{-1}, salinity 20-30 ppt 9 days month^{-1}, salinity >30 ppt	Silty, Silty clay to clay	*Xylocarpus* sp., *Scyphiphora* sp., *Lumnitzera* sp.
Spring tides only	Only a few days/month, salinity 0 ppt	Sandy to silty clay	Marginal types on *mangrove* such as: *Xylocarpus moluccensis, Intsia bijuga, Nypa fruticans, Ficus retusa, Glochidion littorale.*
Storm high tides only	Only a few days month^{-1}, salinity 0 ppt (rarely under tidal influence)	Sandy to silty clay	*Oncosperma* sp., *Cerbera* sp.

Source: Kusmana et al (2005).

Results

Mangrove deforestation in Indramayu Regency from 1989 to 2015. In general, change in mangrove area in Indramayu Regency based on total area of each district tended to decrease from year to year, this is in line with the finding of Onrizal (2002). The situation of mangroves spread is shown in Figures 3 and 4.

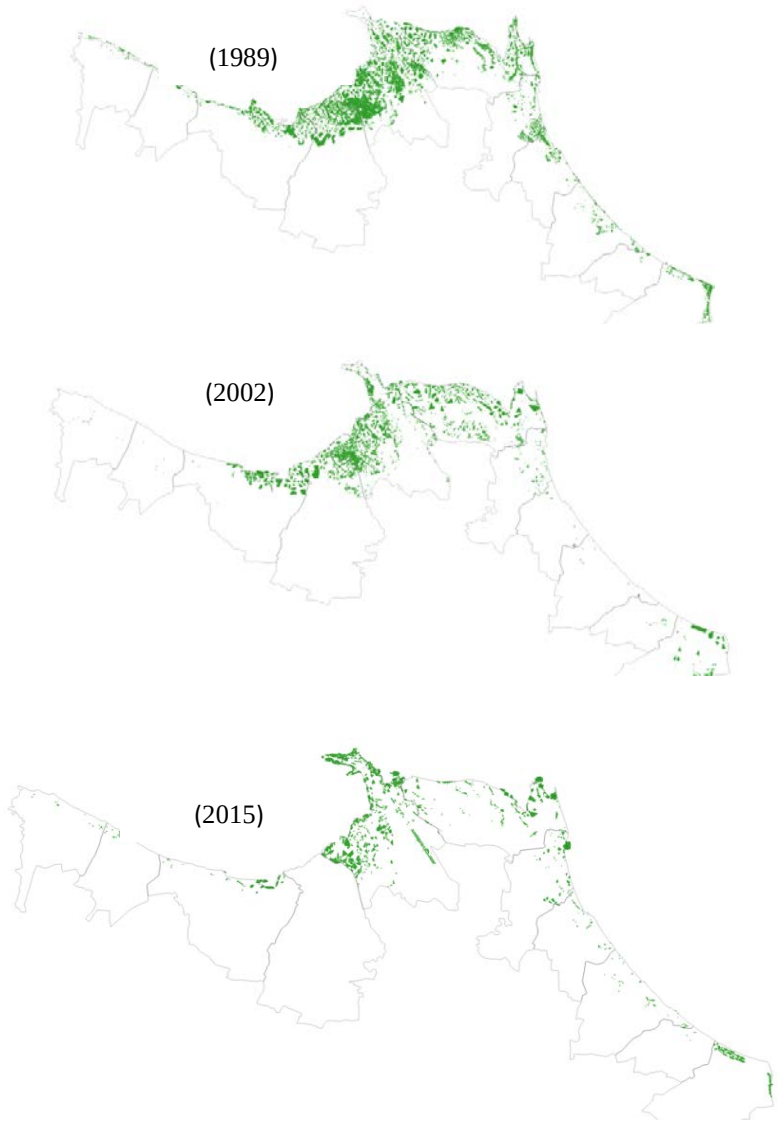

Figure 3. Mangrove distribution in 1989, 2002 and 2015.

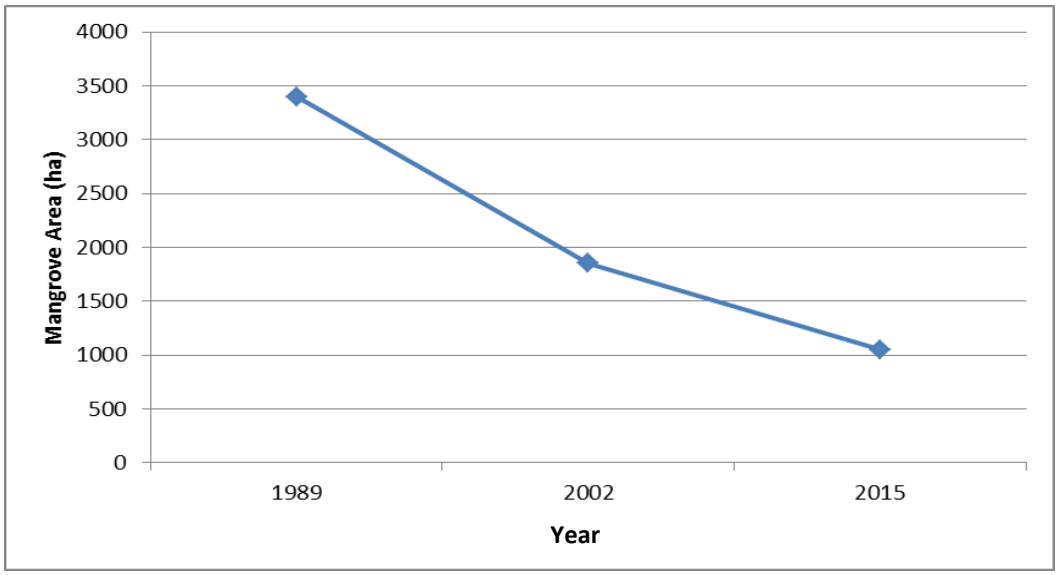

Figure 4. Mangrove area changes in Indramayu Regency in 1989, 2002 and 2015.

Figure 3 and 4 showed that mangroves in Indramayu from 1989 to 2015 tended to decrease. In 1989 the mangrove area in Indramayu was 3397.81 ha, but in 2002 the mangrove area in Indramayu became 1.852.42 ha, and in 2015 was 1.052.79 ha. The biggest change occurred in the range of 1989 to 2002 which was 1.545.39 ha, while the mangrove changes that occurred between 2002 and 2015 was 799.63 ha. This situation was caused by the conversion of mangrove area into land farms, public ignorance of the benefits of mangrove forests, and the economic pressures of the community who lives around the mangroves. This findings are in line with research result of Fiselier et al (1990), Soesanto & Sudomo (1994) and Yumna & Halid (2015).

Directive of mangrove rehabilitation plan in Indramayu Regency. Directive priority of mangrove rehabilitation in Indramayu was based on the level of mangrove destruction that occurred from 1989 to 2015 and on the results of the analysis of land suitability for this type of mangrove vegetation. In order to carry out mangrove rehabilitation strategies, there should be a main priority, as higher the mangrove damage in an area, it would be a main priority in mangrove rehabilitation plan. Mangrove area reduction in Indramayu from 1989 to 2015 is listed in Table 2.

Table 2

Mangrove reduction in Indramayu Regency from 1989 to 2015

District	*Mangrove area (ha)*		*Total changes (ha)*
	1989	*2015*	
Sukra	16	3	- 13
Patrol	19	2	- 17
Kandanghaur	302	44	- 258
Losarang	557	236	- 321
Cantigi	1501	409	- 1092
Pasekan	663	207	- 456
Indramayu	109	72	-37
Balongan	65	9	- 56
Juntinyuat	40	9	- 31
Karangampel	7	0.35	- 6.65
Krangkeng	85	69	- 16

Based on Table 2, directive priority of mangrove rehabilitation in Indramayu was arranged and recommended mangrove species that was resulted from the analysis of suitable environmental conditions for mangrove. These parameters are: the type of inundation, water log class (salinity and tidal frequency), and the type of soil texture (Kusmana et al 2005), as presented in Table 3.

Table 3

Mangrove rehabilitation plan priority in Indramayu Regency

Priority	*District*	*Mangrove species recommendation*
I	Cantigi	*Bruguiera sp., N. fruticans, Rhizophora sp., Sonneratia sp.*
II	Pasekan	*Avicennia sp., Bruguiera sp., N. fruticans, Rhizophora sp., Sonneratia sp.*
III	Losarang	*Bruguiera sp., Sonneratia sp., N. fruticans*
IV	Kandanghaur	*Avicennia sp., Bruguiera sp., Rhizophora sp., Sonneratia sp.*
V	Balongan	*Avicennia sp., Bruguiera sp., Rhizophora sp., Sonneratia sp.*
VI	Indramayu	*Avicennia sp., Bruguiera sp., N. fruticans, Rhizophora sp., Sonneratia sp.*
VII	Juntinyuat	*Avicennia sp., Bruguiera sp., Rhizophora sp., Sonneratia sp.*
VIII	Patrol	*Avicennia sp.*
IX	Krangkeng	*Avicennia sp., Bruguiera sp., N. fruticans, Rhizophora sp., Sonneratia sp.*
X	Sukra	*Avicennia sp., Bruguiera sp., Rhizophora sp.*
XI	Karangampel	*Bruguiera sp., Sonneratia sp.*

Spatially, directive of mangrove rehabilitation priority areas in Indramayu Regency is shown in Figure 5.

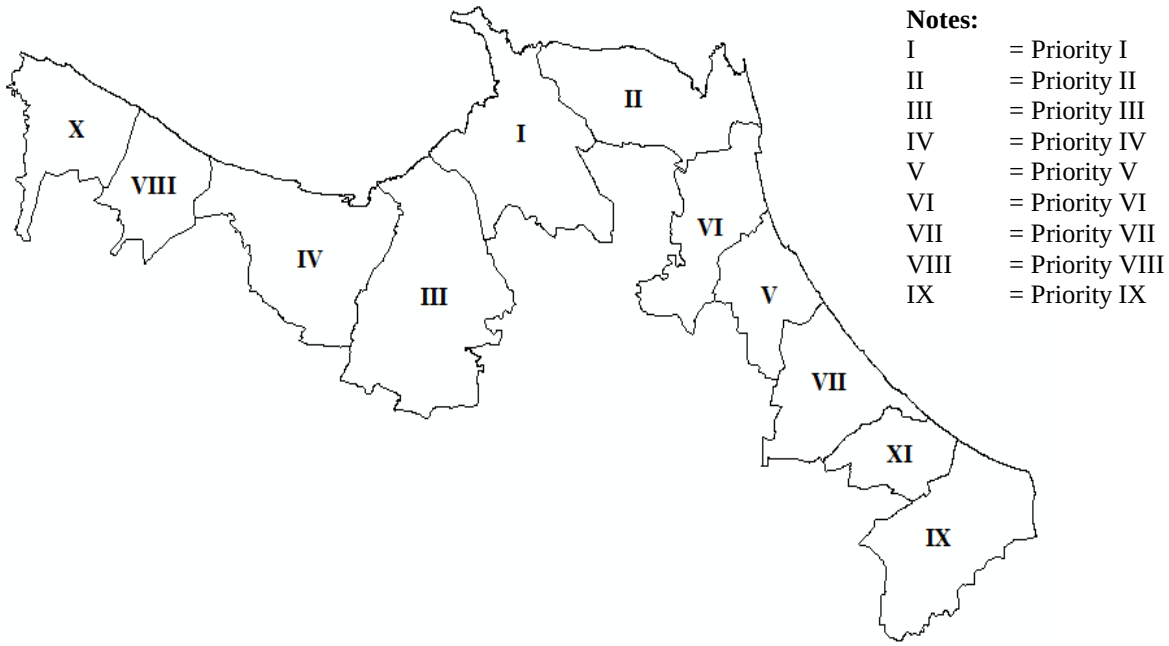

Figure 5. Map of directive priority on mangrove rehabilitation plan in Indramayu Regency.

Spatially, directive of suitable mangrove vegetation for mangrove rehabilitation in Indramayu Regency is presented in Figure 6.

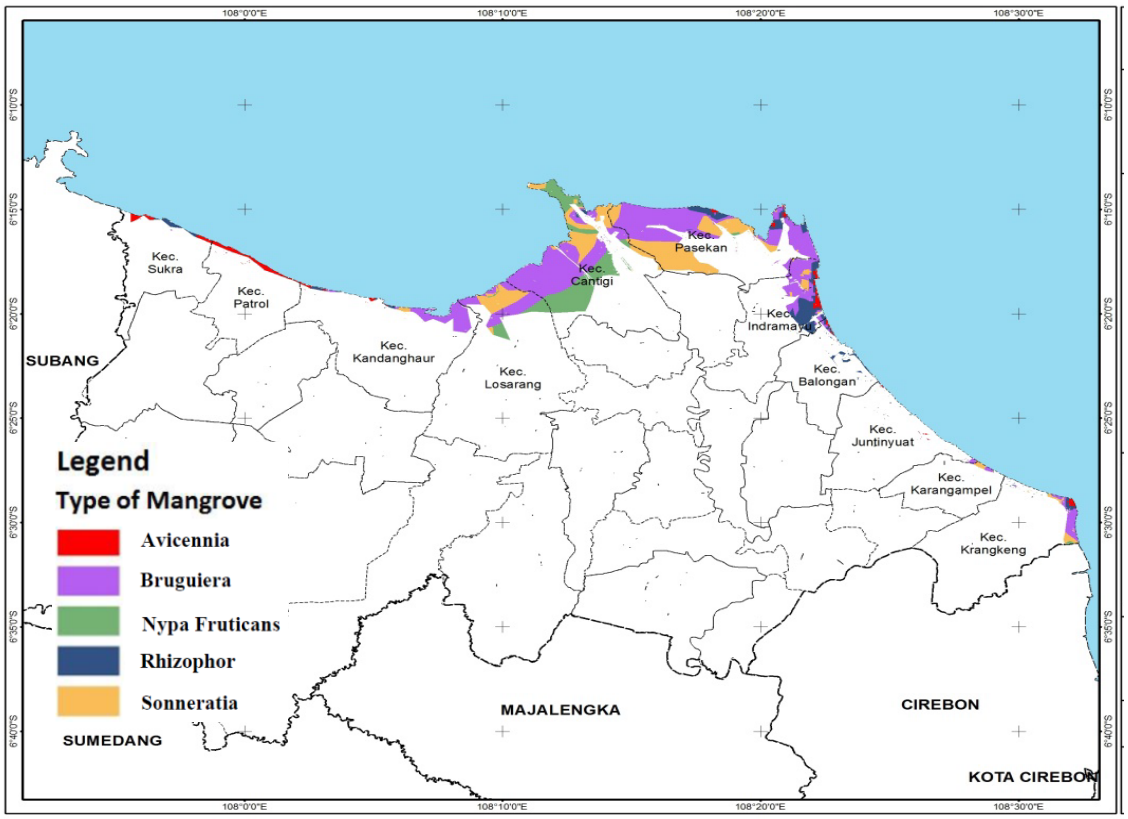

Figure 6. Map of mangrove species suitability in Indramayu Regency.

Conclusions. Mangrove area changes in Indramayu Regency from 1989 to 2015 have decreased by 2,345.02 ha. From eleven districts that are located entirely in mangrove areas have been damaged. The worst damage was recorded in the Cantigi District on 1989-2015. Directive of mangrove rehabilitation plan in Indramayu was sorted into three top district level of damage, namely Cantigi, Pasekan and Losarang and recommended vegetation based on the existing physical parameters were *Avicennia sp.*, *Bruguiera sp.*, *N. fruticans*, *Rhizophora sp.*, and *Sonneratia sp.*

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