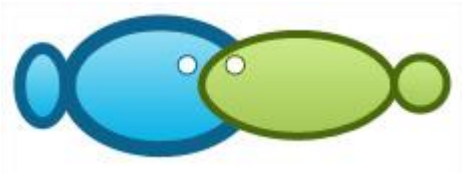

Condition of shore and mangrove area in the coastal area of Karawang Regency, Indonesia

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Abstract. The coastal area of Karawang Regency has the largest mangrove potential in the north of West Java but excessive environmental pressure causing disasters such as shore erosion has inhibited its even spread in the area. This study therefore aimed to determine the condition of the shore and mangrove areas in the coastal region of Karawang Regency. Primary data were collected using field observations while secondary data were obtained from desk studies. The results showed the presence of erosion and accretion on the shore in several areas with the largest erosion found in Subdistricts of Cibuaya, Cilebar and Pakisjaya, while the Subdistricts of Cilamaya Wetan, Cilebar and Tirtajaya had the largest accretion. Moreover, the mangrove vegetation in the accretion area was predominated by *Avicennia marina* spreading evenly to the coastal area while *Rhizophora mucronata* and *R. apiculata* were widely found in aquaculture areas. However, the *A. marina* has a high value of density, frequency, and dominance, at the level of trees, saplings, and seedlings in non-forest areas.
Key Words: DPSIR, coastline changes, coastal rehabilitation.

Introduction. The coastal region of Karawang Regency in the northern part of West Java has the largest conversion of mangrove land but, according to Komarudin (2013), the area has decreased by almost half with 47.8% between 1994 and 2012. This rate of decline requires serious attention due to the desire for sustainable mangrove ecosystems in the Karawang coastal area.

One of the most extensive reasons mangrove land is being converted is because of aquaculture. In agreement with this, conversion activity in the coastal area of Karawang Regency reached 105.79% per year during the 1987-1990 period (Komarudin 2013). Moreover, the damage of these areas was also found to be due to local community activities conducted against the sustainability of the mangrove ecosystem (Budiyana 2005; Amrial et al 2015). This was reflected in the development of shrimp farming accompanied by the clearing of the forests and the high productivity of ponds in the coastal area (Aliah 2013).

The high rate of conversion in the past has led to a significant adverse effect on the environmental and socio-economic conditions of coastal communities such as the damage to the shore which further causes erosion. This situation is considered dangerous and alarming by the Karawang Regency Government (2010) due to the damaging effect it has on many settlements, trading lands, and infrastructures (Fauzie 2016).

Several studies have been conducted on the biophysical condition of the Karawang Regency coastal areas. Fauzie (2016, 2017) identified the changes in shoreline and the impact of erosion on coastal lands, Budiyana (2005), Aliah (2013), Lovapinka et al (2014), Amrial et al (2015), Nugraha (2018) and Muharam (2014) studied the use of mangrove areas for the development of the fisheries sector and the rehabilitation of coastal land. This study was, therefore, conducted to map the condition of the shore and mangrove in Karawang Regency coastal areas.

Material and Method

Research time and location. This research was conducted for 2 months from December 2019 to January 2020 in the coastal area of Karawang Regency, West Java Province, located between 107º02-107º40`East Longitude and 5º56`–6º34`South Latitude as shown in Figure 1. Moreover, the length of the shoreline was found to be reaching 73.65 km (Fauzie 2017) while the land area consists of alluvial plains formed by the rivers passing through the coast into the shore. This region is mainly characterized by sloping land with flatlands and a relatively small height fluctuating between 0-3 meters above sea level (Komarudin 2013). The population of the studied area was 577,231 in 2018 which is 24.71% of the total population of 2,336.009 recorded for the whole of Karawang Regency (BPS 2019).

Figure 1. Map of the Karawang Regency coastal area.

Data collection. This study was conducted through the use of both primary and secondary data. The primary data were obtained in the form of observations and in-depth interviews with several stakeholders and communities in the coastal region while the secondary data were collected from study reports conducted by the Karawang Regency Environmental and Hygiene Office.

Analysis. This research made use of descriptive analysis on the literature study, observation, and in-depth interviews while the conditions of the shore and mangrove areas were described using the Drivers, Pressures, State, Impacts, and Responses (DPSIR) analysis framework to determine the causal relationship between the five categories (Cooper 2013; Semeoshenkova et al 2016) under limited data conditions (Martin et al 2018). The strength of this framework is in its ability to simplify cause-effect relationships between factors in social and natural systems (Svarstad et al 2008; Martin et al 2018).

Results and Discussion

Shore conditions and damage. The shore area of the coastal of Karawang Regency is included in the north of Java Island or Pantura and its length was evaluated at approximately 1,500 km from Labuan of Banten Province in the West and Banyuwangi of

the East Java Province. Moreover, the characteristics of Pantura are significantly similar considering the land-sea transition system exposed to the Java Sea: a nearly flat topography, almost at the sea level, definitory for the areas easily affected by the penetration of currents, waves, and wind. Belonging to this typology, the north shore of Karawang has the natural potential for mangrove ecosystems (Muharam 2014).

Table 1

The area of coastal land affected by coastal erosion and accretion during the observation period 1994-2012 (Komarudin 2013)

No.	*Sub districts*	*Land area (ha) affected by*		*Area balance (ha)*
		Coastal erosion	*Accretion*	
1.	Pakisjaya	-69.28	8.90	-60.38
2.	Batujaya	0.00	24.50	24.50
3.	Tirtajaya	-60.72	70.97	10.25
4.	Cibuaya	-162.10	23.50	-138.60
5.	Pedes	-12.48	12.80	0.32
6.	Cilebar	-85.24	93.17	7.93
7.	Tempuran	-15.35	64.84	49.49
8.	Cilamaya Kulon	-18.71	1.32	-17.39
9.	Cilamaya Wetan	-27.52	152.20	124.68
	Total	-451.40	452.20	0.80

Komarudin (2013) studied the coastal area of Karawang Regency from 1994 to 2012 and found the coastal erosion to be covering 451.40 ha, while the accretions covered 452.20 ha. The largest erosion was identified in Cibuaya with a reduction in the coastal land area of 162.10 ha while the accretions affecting the same coastal area consisted in the addition of 23.50 ha, as shown in Table 1 and Figure 2. Cilebar followed with a reduction of 85 ha and accretions of 93.17 ha as indicated in Table 2.

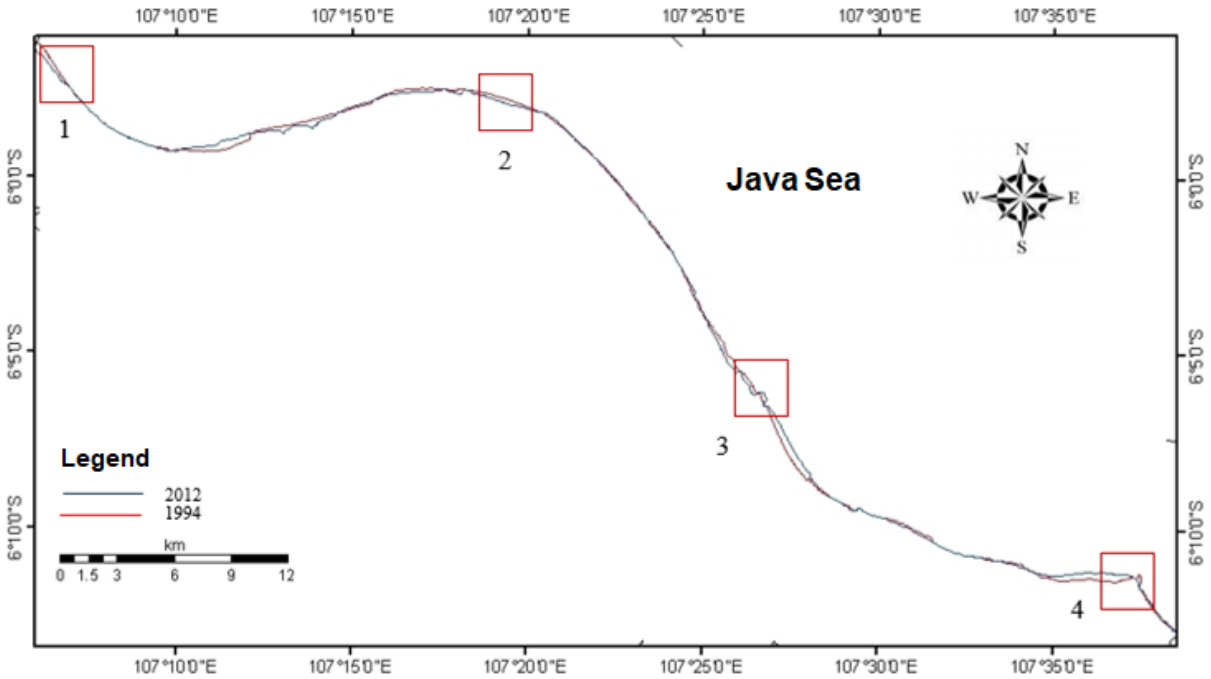
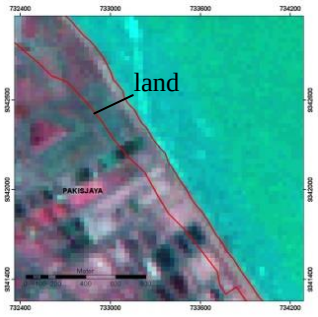
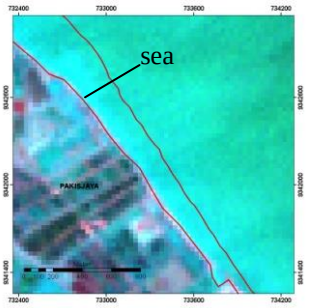
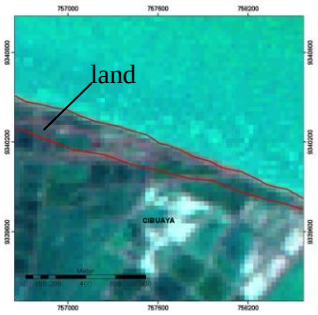
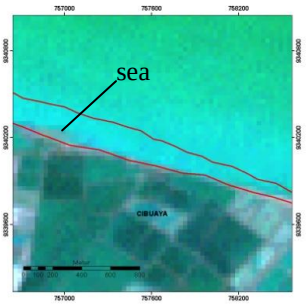
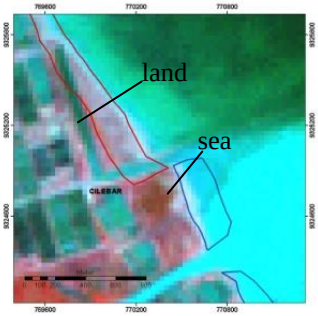
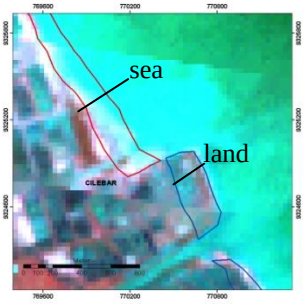
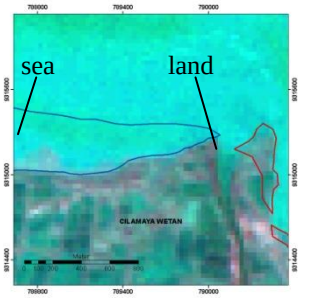
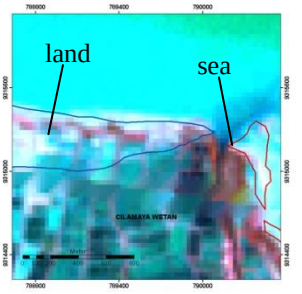


Figure 2. Changes in the coastline in the coastal region of Karawang Regency under observation between 1994 and 2012 (Komarudin 2013).

Table 2

Changes of coastlines of the coastal areas of Karawang Regency, at several locations (Komarudin 2013)

Image number	*Sub districts*	*Coast condition*	
		1994	*2012*
1	Pakisjaya		
2	Cibuaya		
3	Cilebar		
4	Cilamaya Wetan		

In another research, Fauzie (2017) reported the change of the shoreline based on the observations made between 1988 and 2015. The study was divided into four zones covering nine subdistricts in the coastal area of Karawang Regency, as shown in Figure 3. The results demonstrated that in the coastal area of Karawang Regency, accretion was dominant with a land balance of 460.07 ha, as shown in Table 3, its highest value being observed in the Zone IV area with 398.09 ha, while the coastal erosion dominated the Zone II area, with the lost land balance reaching 129.61 ha.

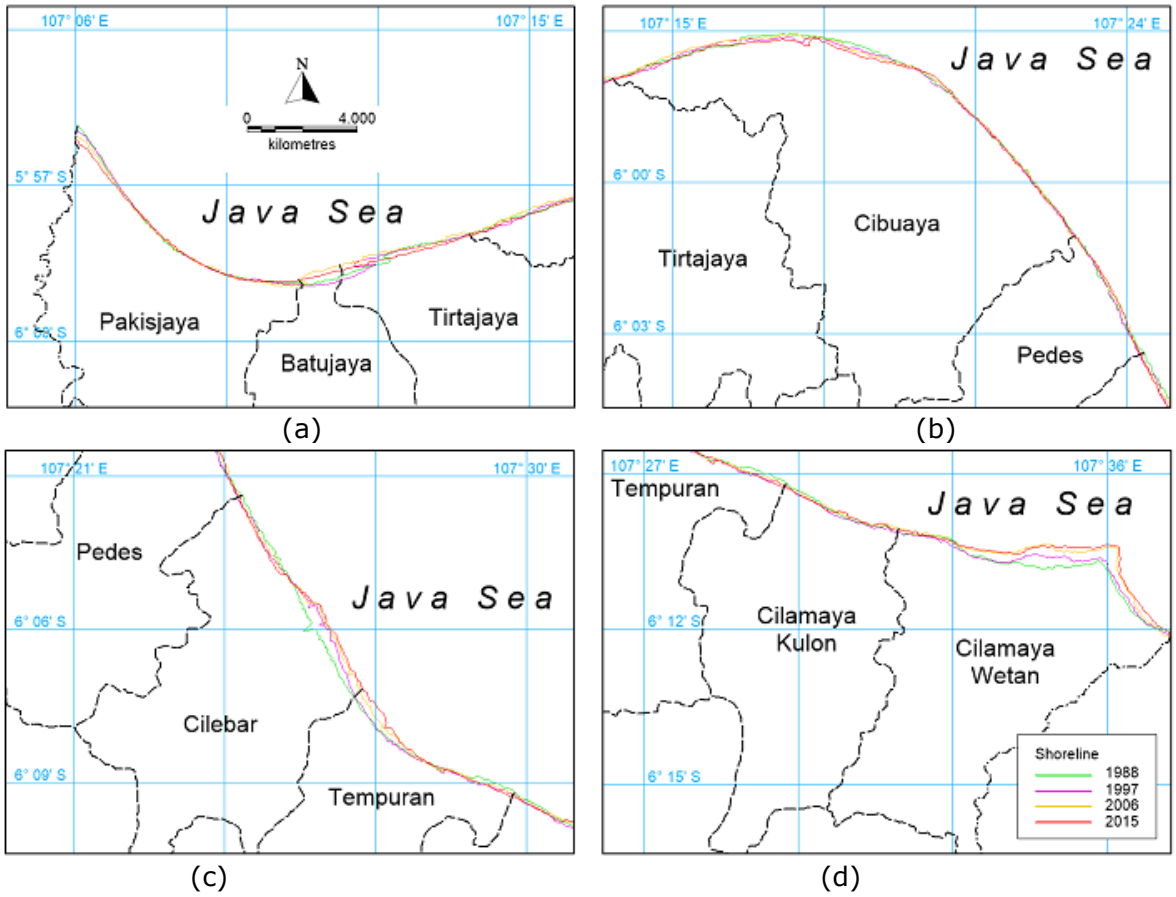


Figure 3. Changes in the coastline of the coastal area of Karawang Regency during observations period from 1988 to 2015, at various locations (Fauzie 2017).

Table 3

Condition of coastlines in the Karawang coastal area, based on zoning

Zone	*Area (ha) affected by*		*Area balance (ha)*	*Shoreline length (km) affected by*		*Coastline retreat (m)*	*Coastline advance (m)*
	Coastal erosion	*Accretion*		*Coastal erosion*	*Accretion*		
I	-107.48	84.22	-23.26	8.63	8.16	-124.50	103.15
II	-186.25	56.64	-129.61	15.56	8.93	-119.72	63.42
III	-100.56	315.41	214.85	6.37	8.84	-157.86	356.79
IV	-24.23	422.32	398.09	3.18	12.24	-76.15	344.89
Total	-418.52	878.59	460.07	33.74	38.18		

In Table 3, zone I refers to the Subdistricts of Pakisjaya, Batujaya, and Tirtajaya, zone II to the Subdistricts of Cibuaya and Pedes, zone III to the Subdistricts of Cilebar and Tempuran, and zone IV to the Subdistricts of Cilamaya Kulon and Cilamaya Wetan (Fauzie 2017).

Mangrove area condition. The mangrove areas of the Karawang regency spread across nine Subdistricts of Pakisjaya, Batujaya, Tirtajaya, Cibuaya, Pedes, Cilebar, Tempuran, Cilamaya Kulon and Cilamaya Wetan and those with the largest colonies of mangrove include the Subdistricts of Tirtajaya, Cibuaya, Cilebar and Cilamaya Wetan.

The extensive and the distribution of potential mangrove area. The analysis of the satellite imagery conducted in 2018 showed that the area covered with mangrove vegetation in the Karawang regency was 421.95 ha while the cumulated areas without vegetation totalized 18,717.58 ha, mostly in the form of ponds. Therefore, the total mangrove potential in the area is of approximately 19,139.53 ha, as shown in Figure 4.

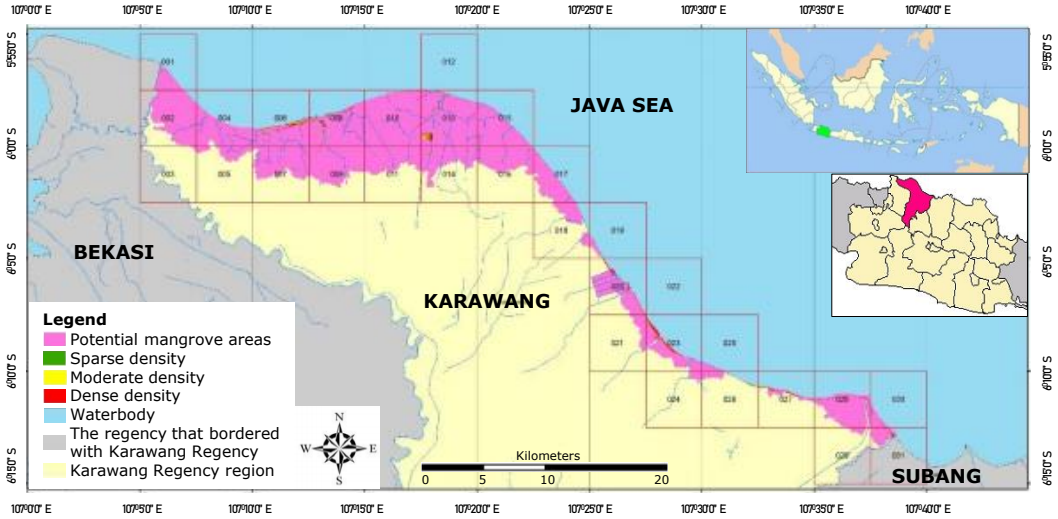


Figure 4. Distribution map of potential mangrove areas in Karawang Regency (DLHK Kab. Karawang 2018).

The distribution of mangrove vegetation area at this time. The mangrove vegetation spread over 17 villages was found to be 421.95 ha in 2018 as shown in Figure 5. In general, mangroves were found to be growing along the shoreline due to the dynamics of sediment transport, as well as in the rivers border and aquaculture ponds.

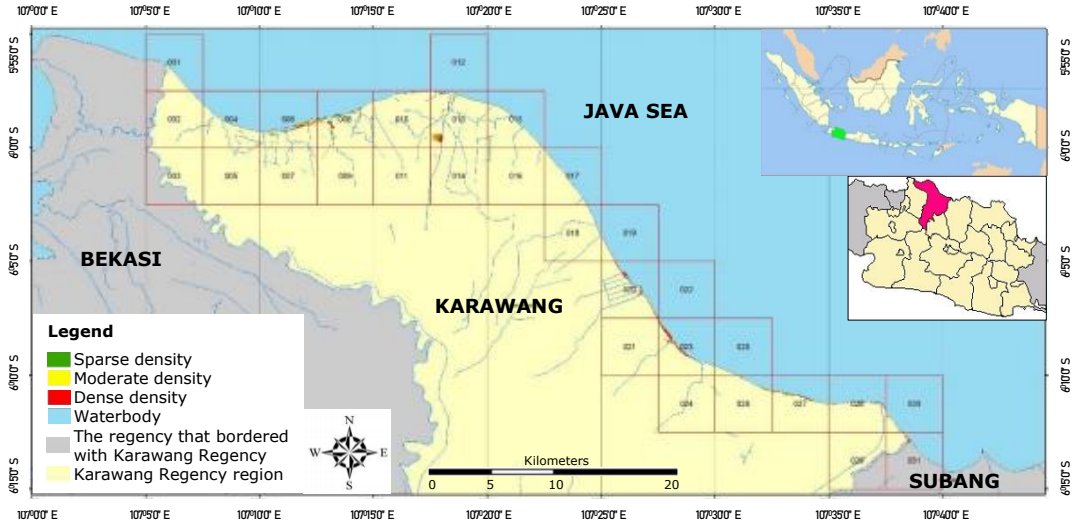


Figure 5. Map of distribution of mangrove vegetation in Karawang Regency (DLHK Kab. Karawang 2018).

The majority of the mangrove in the coastal region studied were found in Other Use Areas (APL) or non-forest areas covering 277.57 ha or 65.78% while those in the Protection Forest Areas were only 144.38 ha or 34.23% of the total area of mangrove vegetation. This means the land use in the regency is not in compliance with the spatial pattern stipulated by the Karawang Regency Regional Spatial Plan (RTRW) and the Zoning Plan for Coastal Areas and Small Islands of West Java Province.

Tirtajaya has the largest mangrove vegetation with an estimated area of 114.30 ha or 26.79% of the total area with the APL covering 58.26 ha or 50.97%, while the remaining 56.03 ha or 49.03% were covered by the protection forest as shown in Table 4.

Table 4

Area of mangrove vegetation based on density class (DLHK Kab. Karawang 2018)

No.	Sub districts	Villages	Density class of mangrove	Status of the region		Total area (ha)
				APL	HL	
1.	Pakisjaya	Tanjungpakis	Sparse	0.51	0.62	1.13
			Moderate	2.08	1.13	3.21
			Dense	1.79	1.72	3.51
	Total of Tanjungpakis			4.37	3.47	7.84
	Total of Pakisjaya			4.37	3.47	7.84
2.	Batujaya	Segarjaya	Sparse	0.93	2.41	3.34
			Moderate	2.02	6.00	8.02
			Dense	3.26	4.37	7.63
	Total of Segarjaya			6.22	12.78	19.00
	Total of Batujaya			6.22	12.78	19.00
3.	Tirtajaya	Tambaksari	Sparse	12.87	11.87	24.73
			Moderate	18.20	15.42	33.62
			Dense	27.19	27.49	54.69
	Total of Tambaksari			58.26	54.78	113.04
		Tambaksumur	Sparse	-	0.34	0.34
			Moderate	-	0.47	0.47
			Dense	-	0.45	0.45
	Total of Tambaksumur			-	1.26	1.26
	Total of Tirtajaya			58.26	56.03	114.30
4.	Cibuaya	Sedari	Sparse	3.57	11.42	14.99
			Moderate	5.20	20.89	26.09
			Dense	13.36	29.10	42.46
	Total of Sedari			22.13	61.41	83.55
	Total of Cibuaya			22.13	61.41	83.55
5.	Cilebar	Mekarpohaci	Sparse	2.53	-	2.53
			Moderate	4.94	-	4.94
			Dense	14.94	-	14.94
	Total of Mekarpohaci			22.41	-	22.41
		Pusakajaya Utara	Sparse	3.51	-	3.51
			Moderate	7.57	-	7.57
			Dense	22.07	-	22.07
	Total of Pusakajaya Utara			33.15	-	33.15
	Total of Cilebar			55.56	-	55.56
6.	Tempuran	Cikuntul	Sparse	1.01	-	1.01
			Moderate	2.61	-	2.61
			Dense	13.29	-	13.29
	Total of Cikuntul			16.92	-	16.92
		Ciparagejaya	Sparse	0.49	-	0.49
			Moderate	0.89	-	0.89
			Dense	1.40	-	1.40
	Total of Ciparagejaya			2.78	-	2.78
		Sumberjaya	Sparse	1.29	-	1.29
			Moderate	3.35	-	3.35
			Dense	6.81	-	6.81
	Total of Sumberjaya			11.45	-	11.45
		Tanjungjaya	Sparse	2.24	-	2.24
			Moderate	4.20	-	4.20
			Dense	27.52	-	27.52
	Total of Tanjungjaya			33.95	-	33.95
	Total of Tempuran			65.10	-	65.10

No.	Sub districts	Villages	Density class of mangrove	Status of the region		Total area (ha)
				APL	HL	
			Sparse	0.08	-	0.08
	Cilamaya Kulon	Pasirjaya	Moderate	0.19	-	0.19
			Dense	0.18	-	0.18
	Total of Pasirjaya			0.45	-	0.45
7.			Sparse	1.83	-	1.83
		Sukajaya	Moderate	4.15	-	4.15
			Dense	10.34	-	10.34
	Total of Sukajaya			16.32	-	16.32
	Total of Cilamaya Kulon			16.77	-	16.77
			Sparse	2.45	1.45	3.90
	Cilamaya Wetan	Muara	Moderate	3.76	1.60	5.37
			Dense	9.85	7.64	17.49
	Total of Muara			16.06	10.69	26.75
			Sparse	2.60	-	2.60
		Muarabaru	Moderate	3.55	-	3.55
			Dense	7.73	-	7.73
	Total of Muarabaru			13.88	-	13.88
8.			Sparse	0.75	-	0.75
		Rawagempol Kulon	Moderate	1.18	-	1.18
			Dense	4.92	-	4.92
	Total of Rawagempol Kulon			6.85	-	6,85
			Sparse	1.08	-	1.08
		Sukakerta	Moderate	3.36	-	3.36
			Dense	7.92	-	7.92
	Total of Sukakerta			12.36	-	12.36
	Total of Cilamaya Wetan			49.15	10.69	59.84
	Total of Karawang Regency			277.57	144.38	421.95

APL-other use areas (non-forest area); HL-protection forest (forest area).

However, Tambaksari village has the largest mangrove area in this subdistrict and in the whole Karawang Regency, with 113.04 ha or 98.90% of the total discovered in Tirtajaya and 26.79% in Karawang Regency with the APL observed to be covering 58.26 ha or 51.54% while Protection Forest covered 54.78 ha or 48.46%.

Subsequently, Cibuaya and Tempuran Subdistricts reached 83.55 ha or 19.80% and 65.10 ha or 15.43%, respectively. For the Cibuaya Subdistrict, 100% of the vegetation is only in one village, Desa Sedari, with an APL of 22.13 ha or 26.49% and a Protection Forest of 61.41 ha or 73.51%, while Tempuran's vegetation was found on the APL of four different villages. Tanjungjaya village has the largest area with 33.95 ha or 52.15% followed by Cikuntul and Sumberjaya with 16.92 ha or 25.99% and 11.45 ha or 17.59%, respectively, while the smallest was found to be Ciparagejaya covering an area of 2.78 ha or less than 5% of the total area, mainly due to the issue of a severe coastal erosion. There is almost no mangrove vegetation in the coastal border of this village and the majority of the ones observed are in the community aquaculture areas.

High-density mangrove vegetation is dominant in almost all the subdistricts considering five of them have densities of more than 50%, with averaging 56.53% and ranging between 40.16 to 75.30%. However, APL have covered most of these areas, namely 172.57 ha or 40.90% recorded.

Tirtajaya Subdistrict has the widest coverage for the high density class, with 55.14 ha, most of which are in Tambaksari Village with APL covering 27.19 ha, while the protection area covered 27.49 ha as shown in Figure 6. The low density coverage was found in Tambaksumur with only 0.45 ha out of the 1.26 ha of mangrove vegetation in the village. It is one of the protected forest areas within the Pangakaran Forest Police Resort (RPH) covering 1,455.60 ha (DLHPE Kab. Karawang 2008). This indicates there

has been a massive conversion of mangrove forest areas into community aquaculture in this village.

Subsequently, Tempuran and Cibuaya Subdistricts covered 49.02 ha and 42.46 ha, respectively. High-density vegetation in Tempuran spread over APL land in four villages including Tanjungjaya with 27.52 ha or 56.14%, Cikuntul with 13.29 ha or 27.11%, and Sumberjaya with 6.81 ha or 13.89%, as well as Ciparagejaya with the low density covering only 1.40 ha or 2.86%. However, for the Cibuaya Subdistrict, the high density is located entirely in the Sedari Village with 42.46 ha occupying the APL area of 13.36 ha or 31.46% and protection forest of 29.10 ha or 68.54%.

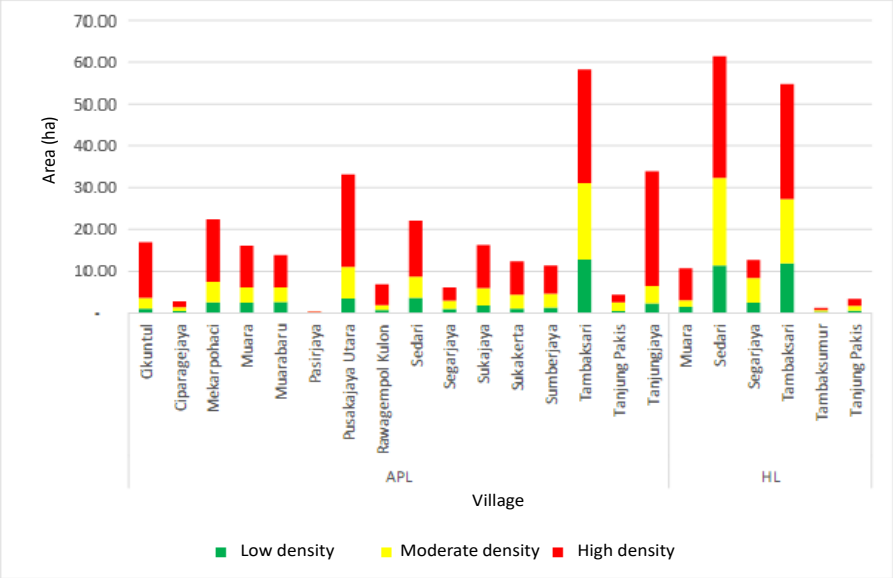


Figure 6. Distribution of mangrove vegetation in various villages based on density class (DLHK Kab. Karawang 2018).

The distribution of the non-vegetation mangrove area. The non-vegetation mangrove potential areas are lands with biophysical conditions suitable for mangrove growing. In the context of mapping, they are open lands with the substrate and hydrological conditions in accordance with the prerequisites for rehabilitation activities, with due consideration for the land use planning in Karawang Regency, as shown in Figure 7. However, some of these areas have been developed for aquaculture and they should be rehabilitated. The potential of these areas was further proven by the presence of Mangrove Nature Tourism in Sedari Village, Cibuaya Subdistrict, which is overgrown by dense and high mangrove vegetation due to rehabilitation activities.

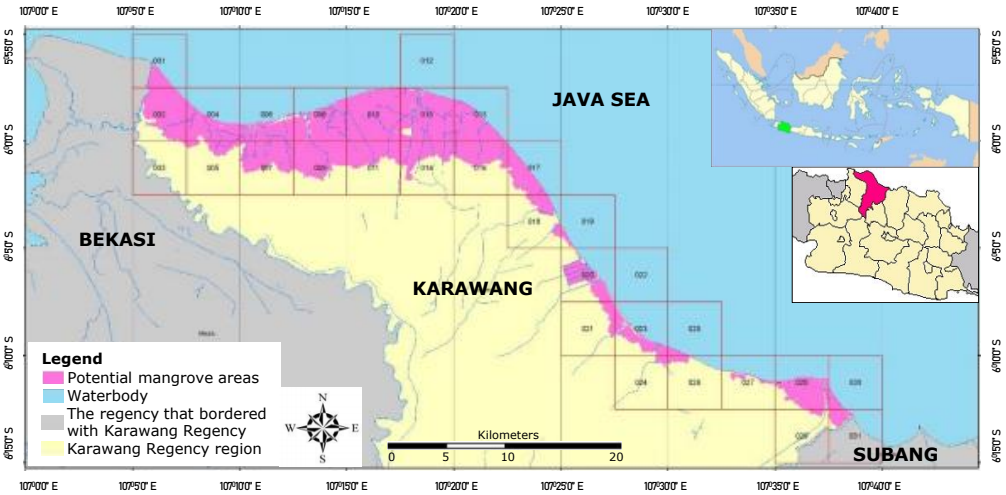


Figure 7. Distribution map of non-vegetation areas potential for mangroves recovery in Karawang Regency (DLHK Kab. Karawang 2018).

The data provided in Table 5 shows that the potential area reaches 18,717.58 ha and is spread over 9 subdistricts and 33 villages, 53.40 percent of which being on the land with APL status. Moreover, the largest coverage is observed in the Cibuaya Subdistrict, with 6,300.59 ha, while the smallest is recorded in Cilamaya Kulon, with only 46.88 ha.

Table 5

Area of non-vegetation with mangrove potential (DLHK Kab. Karawang 2018)

No.	*Sub districts*	*Villages*	*Status of the region*		*Total area (ha)*
			APL	*HL*	
1.	Pakisjaya	Solokan	360.51	-	360.51
		Tanahbaru	37.49	116.50	153.99
		Tanjungbungin	221.79	53.20	274.99
		Tanjungmekar	286.53	77.61	364.14
		Tanjungpakis	699.84	1,041.92	1,741.77
		Telukjaya	8.72	-	8.72
	Total of Pakisjaya		1,614.89	1,289.24	2,904.12
2.	Batujaya	Baturaden	44.94	295.26	340.21
		Karyabakti	42.08	140.80	182.88
		Segarjaya	83.03	764.56	847.59
	Total of Batujaya		170.05	1,200.62	1,370.68
3.	Tirtajaya	Tambaksari	977.11	1,723.90	2,701.02
		Tambaksumur	61.09	1,670.04	1,731.14
	Total of Tirtajaya		1,038.21	3,393.94	4,432.15
4.	Cibuaya	Cemarajaya	1.772.45	2.23	1,774.68
		Gebangjaya	9.16	-	9.16
		Jayamulya	95.41	-	95.41
		Kalidungjaya	54.46	-	54.46
		Kedungjaya	177.13	35.65	212.78
		Sedari	1,668.20	2,485.90	4,154.10
	Total of Cibuaya		3,776.82	2,523.78	6,300.59
5.	Pedes	Sungaibuntu	529.94	-	529.94
	Total of Pedes		529.94	-	529.94
6.	Cilebar	Mekarpohaci	337.96	-	337.96
		Pusakajaya Selatan	114.56	-	114.56
		Pusakajaya Utara	424.00	-	424.00
	Total of Cilebar		876.52	-	876.52
7.	Tempuran	Cikuntul	110.72	-	110.72
		Ciparagejaya	405.09	-	405.09
		Sumberjaya	92.46	-	92.46
		Tanjungjaya	216.64	-	216.64
		Tempuran	12.62	-	12.62
	Total of Tempuran		837.54	-	837.54
8.	Cilamaya Kulon	Pasirjaya	37.98	-	37.98
		Sukajaya	8.29	-	8.29
		Sumurgede	0.60	-	0.60
	Total of Cilamaya Kulon		46.88	-	46.88
9.	Cilamaya Wetan	Muara	576.37	305.47	881.83
		Muarabaru	455.59	-	455.59
		Rawagempol Kulon	23.26	-	23.26
		Sukakerta	58.48	-	58.48
	Total of Cilamaya Wetan		1,113.69	305.47	1,419.16
	Total of Karawang Regency		10,004.53	8,713.05	18,717.58

Mangrove species composition. Mangrove vegetation in Karawang Regency is composed of 16 species which are mostly dominated by Rhizophoraceae, Avicenniaceae, and Sonneratiaceae, as shown in Table 6.

Table 6

The types of mangrove plants identified in the coastal area of Karawang Regency (DLHK Kab. Karawang 2018)

No.	*Family*	*Species*	*Ma/Mi/As*	*Habitus*	*Abundance*
1.	*Avicenniaceae*	*Avicennia marina*	Ma	Tree	+++
		Avicennia alba	Ma	Tree	+
2.	*Rhizophoraceae*	*Rhizophora apiculata*	Ma	Tree	++
		Rhizophora stylosa	Ma	Tree	++
		Rhizophora mucronata	Ma	Tree	+
		Bruguiera cylindrica	Ma	Tree	+
3.	*Sonneratiaceae*	*Sonneratia alba*	Ma	Tree	++
		Sonneratia caseolaris	Ma	Tree	+
4.	*Rubiaceae*	*Morinda citrifolia*	As	Tree	+
5.	*Combretaceae*	*Terminalia catappa*	As	Tree	+
6.	*Malvaceae*	*Thespesia populnea*	As	Tree	+
		Hibiscus tiliaceus	As	Tree	+
7.	*Asclepiadaceae*	*Calotropis gigantea*	As	Herb	+
8.	*Convolvulaceae*	*Ipomoea gracilis*	As	Herb	+
		Ipomoea pes-caprae	As	Herb	+
9.	*Aizoaceae*	*Sesuvium portulacastrum*	As	Herb	+

Ma-major, Mi-minor; As-associates; +++ high; ++ moderate; + low.

Mangroves along the coast are generally dominated by *Avicennia marina* species which grows naturally on accretion land while most of the aquaculture areas include *Rhizophora mucronata* and *R. apiculata*, widely planted and naturally regenerated. Moreover, in the river borders having 0 ppt salinity, *Sonneratia caseolaris* was observed to be growing naturally while mangrove associate groups were also found germinating on some low-salinity soils.

According to the Table 7, the tree species are dominated by *R. apiculate* at high density and *R. mucronata* at moderate density while at the sapling level, *A. marina* species predominate in areas with high and sparse densities. Furthermore, at the level of seedling, *R. mucronata* species dominate in areas of moderate and rare densities while *R. apiculata* takes dominance in high-density areas.

In general, *A. marina* species have high density, frequency, and dominance values, both at the tree and rejuvenation (seedlings and saplings) levels, in non-forest areas. This, therefore, means it is dominant and spreads evenly in the coastal area of Karawang Regency as shown in Table 8. Moreover, the dominant species at the seedling level of areas with high density is *R. apiculata*. However, the index value showed the diversity of the species found is generally classified as low, at the tree and rejuvenation levels, both in the forest and non-forest areas. This indicates there is a need to introduce new species through the process of enrichment to increase diversity in these areas.

Table 7

Quantitative values of the parameters of mangrove vegetation on the tree type and their regeneration levels in the coastal forest area of Karawang Regency (DLHK Kab. Karawang 2018)

No.	*Density class*	*Species*	*K (Ind/ha)*	*F*	*D (m^2/ha)*	*INP (%)*	*H'*
1.	Dense	Tree					
		A. marina	238	0.50	1.63	119.34	0.65
		R. apiculata	444	0.75	2.03	180.60	
		Total	682		3.66		
		Sapling					
		A. marina	3,000	0.50	-	124.60	0.54
		R. apiculata	1,020	0.50	-	75.40	
		Total	4,020		-		
		Seedling					
		A. marina	156	0.25	-	27	0.09
		R. apiculata	8,906	0.75	-	173	
		Total	9,062		-		
2.	Moderate	Tree					
		R. mucronata	350	1	4.55	300	0
		Seedling					
		R. mucronata	625	1	-	200	0
3.	Sparse	Sapling					
		A. marina	67	0.50	-	133	0.32
		R. apiculata	33	0.25	-	67	
		Total	100		-		
		Seedling					
		A. marina	625	0.50	-	67	0.45
		R. mucronata	3,125	0.50	-	133	
		Total	3,750		-		

K-density; F-frequency; D-dominance; INP-Index Value Importance; H'-Shanon-Wiener biodiversity index.

Table 8

Quantitative values of the parameters of mangrove vegetation, at the tree and regeneration levels in the coastal non-forest area of Karawang Regency (DLHK Kab. Karawang 2018)

No.	*Density class*	*Species*	*K (Ind/ha)*	*F*	*D (m^2/ha)*	*INP (%)*	*H'*
1.	Dense	Tree					
		A. marina	288	1	1.29	300	0
		Seedling					
		A. marina	625	0.5	-	54	0.17
		R. apiculata	15,313	0.5	-	146	
		Total	15,938		-		
2.	Moderate	Sapling					
		A. marina	117,600	1	-	200	0
		Seedling					
		A. marina	1,250	1	-	200	0
3.	Sparse	Sapling					
		A. marina	29,200	1	-	200	0
		Seedling					
		A. marina	1,250	1	-	200	0

DPSIR analysis explained the cause-effect relationships in the mangrove forests management of the studied area. The factors related to the drivers, pressures, state,

impacts and responses were obtained based on desk studies, observations, and in-depth interviews with stakeholders. Those related to the rivers include the inconsistent implementation of silvofishery cultivation systems, differences and conflicts over land ownership, implementation of unsustainable tourism development policies and low utilization of law enforcement. The factors concerned with the pressures involve the conversion of mangrove forest areas for several other purposes such as aquaculture, settlements, rice fields, and tourism. Moreover, the ecological state is affected by the degradation of mangrove areas and ecosystem services, while the considered ecological impact consists in the occurrence of the erosion in the coastal region. The factor related to the responses includes the implementation of a coastal rehabilitation program and the technical guidance for the silvofishery cultivation system.

Discussion. The coastal zone is a transitional region affected by changes in land and sea while the shoreline is a meeting line between the land and the sea affected by tides. In general, shoreline changes periodically with natural phenomena such as waves, winds, tides, currents, erosion, or sedimentation (Government of Indonesia 2011; Ekaputri et al 2014). However, most of the shore in the coastal area of Karawang Regency has experienced severe erosion and accretion leading to an estimated retreat of approximately 50-300 meters (DLHPE Kab. Karawang 2008; Fauzie 2017).

The changes in shoreline have also been reported in other areas of Indonesia. According to Suharyo & Hidayah (2019), the phenomenon was observed along the northern coast of the Surabaya city between 2002 and 2017, with an accretion area of 143.06 ha, eroded by 44.9 ha. Furthermore, Kusumawati et al (2014) observed the changes in the shoreline of Banten Bay in two different periods. From 1999 to 2007, the coastal area tended to have an accretion trend with eroded land covering 64.63 ha while the accretion covered 248.06 ha. Between 2007 and 2013 the balance reversed, with the eroded land area being 297.76 ha, while the accretions measured only 31.26 ha. Anggraini et al (2017) observed the shoreline in Ujung Pangkah, Gresik Regency and found a accretion trend where the accreted land area reached 11.35 km^2 while the eroded surface measured 5.19 km^2, between 2000 to 2015. Moreover, the changes in the shoreline in Semarang city, according to Marques & Khakhim (2016), occurred due to reclamation activities, intended to control the processes of shore erosion and accretion. However, from 1994 to 2004 an erosion tendency was observed, with an eroded land area of 108.78 ha, compared to the reclamation activities filling 35.90 ha and an accretion area of 19.34 ha. In another observation made between 2004 and 2014, the shore erosion process reduced to 73.70 ha due to a reclamation of 241.90 ha and to an accretion of 2.14 ha.

Hakim (2003) found a positive and significant relationship between a high damage of mangrove forests and an increase in the rate of shore erosion in the coastal areas of Bengkalis Regency. The uncontrolled use of mangrove forests caused a continuous decrease in the tree density every year and subsequently reduced the forest's ability to withstand erosion. Moreover, Akbar et al (2008) also established a positive correlation between the size of the mangrove canopy area and the decrease in the rate of shore erosion in the coastal areas of West Kalimantan. The relationship between mangrove forest damage and shoreline change was also explained by Soraya et al (2012) to be quite strong in the coastal area of the Subang Regency: erosion surface ranged between 41 and 68% of the total area of lost vegetation.

Some of the causative factors associated with the drivers of these changes have been reported to include: inconsistent implementation of silvofishery cultivation systems, differences and conflicts over land ownership, execution of unsustainable tourism development policies, and low involvement of law enforcement agencies, particularly on the violations of the fishery activities regulations. The implementation of silvofishery cultivation systems is basically an effort to rehabilitate mangrove forests in order to restore the function of the area as a protected forest by combining ponds with mangrove planting. However, this has been discovered not to be effective in protected areas as observed with the presence of damaged mangrove stands in silvofishery ponds (Amrial et al 2015). Moreover, most of the farmers have implemented inappropriate aquaculture

activities against the rules set by the Forestry Company, Perum Perhutani, managing the area (Budiyana 2005).

The differences in aquaculture land ownership influenced the implementation of silvofishery cultivation systems in the coastal area of Karawang Regency, as observed in the imitation of the pond pattern conducted on community-owned APL land by the silvofishery farmers in order to obtain greater economic benefits (Budiyana 2005).

Conflicts over land ownership in relation to the existence of mangrove areas were observed when community-owned ponds generally coincide with coastal borders and serve purposes against the supposed functions of the protected areas. In addition, the plantation of mangrove vegetation on accretion lands, in coastal rehabilitation programs conducted by government, private, and non-governmental organizations, also caused land ownership disputes. Moreover, conflicts were also reported on mangrove lands due to rehabilitation programs conducted through community self-help. This is associated with the difficulty in accepting that the land belongs to the state, in spite of the private expenses, time, and energy invested to ensure that the vegetation germinates well on the accretion lands, following the sedimentation process. Public regulations prevent the communities from developing activities modifying the land structure, due to its role of shoreline stabilizer.

Attention was not paid to the principles of sustainability in the development of coastal tourism areas such as Tanjung Baru Hamlet, Pasirjaya Village, Cilamaya Kulon Subdistrict, as observed in the mangrove land clearing, especially in the coastal border area, on a large scale. However, tourism activity in the area has significantly decreased due to the coastal erosion associated with the implementation of unsustainable tourism development policies in the past, which is now affecting the social economy of the local community.

The decrease in the mangrove area, especially in protected forests, occurred due to the weak supervision of the Forestry Company, Perum Perhutani, managing the area. This is associated with the disproportionate limited number of supervisory personnel in each slaughterhouse compared to the total area of mangrove forest under control, thereby, leading to a lack of patrol and supervision intensity. Moreover, a low understanding of the community, including the silvofishery farmers, on the existence of mangrove forests, has also been identified as one of the reasons for inadequate monitoring (Nugraha 2018). This has also made it difficult to enforce laws on the violations and destruction of mangrove resources.

The pressure arising from the aforementioned drivers include the conversion of the mangrove forest areas for several other uses such as aquaculture, settlements, rice fields, and tourism. This has further led to a decrease in the area, quality, and condition of mangrove forests in the coastal area of Karawang Regency. Moreover, Komarudin (2013) reported that the conversion of mangrove land for other purposes, between 1994 and 2012, reached almost 90%.

This pressure precipitated the degradation of the mangrove area and of the related ecosystem services: only 421.95 ha or 2.25% of the total potential coastal area of 18,717.58 ha was still covered with mangrove in 2018, while high-density vegetation was only on 243.35 ha or 57.67% of the total mangrove area.

The same condition has also been reported in other regions of Indonesia. Tufliha et al (2019) and Novianty et al (2011) studied Karangsong, Indramayu Regency and Subang Regency respectively and found that the conditions of the mangrove forest correspond to the damaged category with less than 1,000 individuals/ha densities. Moreover, in 2016, Ismail et al (2018) reported a decrease in the mangrove area of Laguna Segara Anakan, Cilacap Regency by 2,108.22 ha or approximately 25 percent of what was observed in 2014. Furthermore, a decrease in the conditions of mangrove vegetation biodiversity in Kalukku, Mamuju Regency was reported by Malik et al (2019), as observed over the last two decades in the reduction in the number of species , relative density, frequency. The coverage of all regeneration plants was found to be less than 56 percent of the initial area.

The impact of the observed state of the mangrove vegetation in the coastal region of Karawang was the occurrence of erosion, with the most severe cases discovered in

Cibuaya Beach, followed by Cilebar and Cilamaya Kulon Beaches (DLHPE Kab. Karawang 2008). The lands were damaged and the activities of aquaculture, settlements, rice fields and several infrastructures including roads, worship places, and restaurants were disrupted.

The responses to these damaging effects include the implementation of a coastal rehabilitation program in the form of soft structures involving the plantation of coastal vegetation like mangroves, hard structures like developing revetments, breakwaters and coastal protectors using Elongated Geotextile Bag technology, or a combination of both. The hard structures are expected to reduce the energy of ocean waves, support the growth of mangrove seedlings planted along the shore, and withstand sediments and beach sand transported due to the existence of longshore current. The combination of both soft and hard structures has been implemented in the coastal area of Sukajaya Village, Cilamaya Kulon Subdistrict, the soft structure was used in Sukakerta Village, Cilamaya Wetan Subdistrict while hard structure methods have been implemented in Cemarajaya Village, Cibuaya Subdistrict. Moreover, another possible response is the provision of technical assistance to the silvofishery culture system through awareness rising about the good management of traditional ponds.

Conclusions. The shores of several coastal areas in Karawang Regency are affected by both erosion and accretion. Some of those with the greatest erosion include Cibuaya, Cilebar and Pakisjaya Subdistricts while the highest accretion was observed in Cilamaya Wetan, Cilebar and Tirtajaya Subdistricts. Moreover, *A. marina* mangrove vegetation was found to have dominated the accretion area and spreads evenly in coastal areas while *R. mucronata* and *R. apiculata* were widely discovered in aquaculture areas. *A. marina* has a high value of density, frequency, and dominance at the levels of tree, sapling, and seedling in non-forest areas. However, based on environmental physical factors, *A. marina*, *S. alba*, *R. mucronata*, *R. apiculata* and species of mangrove associates are recommended to be used for rehabilitation activities.

The driving factors of the inappropriate mangrove vegetation include the inconsistent implementation of silvofishery cultivation systems, differences and conflicts over land ownership, implementation of unsustainable tourism development policies, and low utilization of law enforcement. The pressure observed with these driving factors involves the conversion of mangrove forest areas for several other purposes such as aquaculture, settlements, rice fields, and tourism. This further led to a state of degradation of mangrove areas and ecosystem services at a level able to generate a significant negative impact by causing erosion in the coastal region. The response to this effect was the implementation of a coastal rehabilitation program and technical guidance for the silvofishery cultivation system. As a recommendation, the government should conduct mediation and facilitation in the conflict over ownership and control of mangrove areas in the coastal border.

Acknowledgements. The authors are grateful to the Ministry of Education and Culture for providing postgraduate education scholarships, as well as to the University of Singaperbangsa Karawang for funding the present research.

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Received: 29 January 2020. Accepted: 02 March 2020. Published online: 09 March 2020.
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How to cite this article:
Nopiana M., Yulianda F., Sulistiono, Fahrudin A., 2020 Condition of shore and mangrove area in the coastal area of Karawang Regency, Indonesia. AACL Bioflux 13(2):553-569.