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The impact of land used changes on mangrove forest and shoreline dynamic in Muara Gembong, Bekasi, West Java

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Abstract. Muara Gembong used to a large area of mangroves at the northern tip of Bekasi Regency, West Java. Over the last 4 decades, this area has experienced significant changes in land use and loss of environmental and ecosystem services provided by mangroves. Past economic activities have resulted in the conversion of thousands of hectares of mangrove into pond areas in pursuit of fisheries production, which at the time became a national program. This change has resulted in ecological disasters and caused economic losses to coastal communities such as shoreline changes (causing the loss of several coastal villages) and sea water intrusion (damaging pond areas and resulting crop failure). This study assessed the impact of land used changes on mangrove dynamic and shoreline erosion rate along the 5 coastal villages of Muara Gembong over 42 years. Multi-temporal Landsat data set and ground truth survey were applied. The imageries have been classified digitally using Maximum Likelihood Classification (MLC) algorithm and have been validated through the process of accuracy assessment. Digital Shoreline Analysis System (DSAS) in ArcGIS environment was used to create transects and statistical analyses for the shoreline. The results show that since 1976 the area of mangrove forests has decreased by 55% and most of it has changed to become fishponds (increased to 35%). The land conversion has resulted in shoreline changes and the biggest erosion occurred in the Pantai Bahagia village with an erosion rate of 15.46 m/year and lost an area of 330,460 Ha.

1. Introduction

Muara Gembong coastal zone is a protected area of mangrove forest managed by Perhutani Public Corporation where there are many types of mangrove plants consisting of 23 species dominated by Api-api (*Avicennia* spp.), mangrove (*Rhizophorea* spp.), Pedada (*Sonneratia caseolaris*), bintan (*Cerbera odollam*), kiser (*Fimbristylis verruginea*) and ketapang (*Terminalia catappa*) [1]. Based on the data released by Dinas Pertanian Kehutanan dan Kelautan (DPKK) Bekasi in 2016, the area of mangrove forests in Muara Gembong and Tarumajaya Districts is always shrinking by 1,000 ha annually. Moverover the data released by Dinas Pertanian dan Kehutanan Bekasi regency stated that the remaining mangrove ecosystem area is only 16%, it means 84% or about 7,000 Ha of mangrove forest has been damaged.. The decline in the area of mangrove forest in Muara Gembong was largely due to land clearing for the production of new shrimp and fish ponds by local residents (Figure 1). The decline in the area of mangrove forests because ponds will actually reduce the quality and carrying capacity of the environment which will affect the productivity of the pond itself.

The develpment of coastal aquaculture has been considered as destructive of mangrove ecosystem in Muara Gembong for few decades ago [2, 3]. The political ecology and economic policy at that time, to make Indonesia as a major producer on fish product, has supported the intensification of fish farms which led to the ecological tragedy as this policy has negative impacts of such practices—in terms of generating social conflicts, environmental hazard, and poverty of coastal communities [4]. The loss of mangrove forests in the coastal area of Bekasi also poses another threat of abrasion. From the results of interviews with local residents, there have been 3 villages drowned due to abrasion in Muara Gembong. It has caused an increase in coastal abrasion conditions. The worst abrasion conditions are in Muara Gembong Subdistrict with an area of land damage of ± 2800 Ha. Fig. 2 shows the severe abrasion conditions of the Muara Gembong coast, which caused many tall and large mangrove trees to fall (Fig. 2).

Figure 1. The conversion of mangrove area into fishponds in Muara Gembong, Bekasi Regency.

Figure 2. Abrasion and collapsed Mangrove Trees along the Muara Gembong Coastline.

The existence of conflict between policy makers and stakeholders at both central and regional levels in the management of mangrove forests is one of the main obstacles that occur in Muara Gembong [5, 6, 7]. There is a difference in the purpose of spatial use between the Perhutani Public Corporation and the community and the Government of Bekasi Regency. It is the duty of Perhutani to restore the environmental function of the Muara Gembong mangrove ecosystem and its expansion as a protected forest (state forest) but on the other hand the Bekasi District Government through the District Regulation. Bekasi No. 12 of 2011 concerning the Bekasi Regency Spatial Plan for 2011-2031 carried out the conversion of most of the protected forest into permanent production forest so that the community could conduct fish farming cultivation as a livelihood and the biggest contributor to the Regional Original Revenue (PAD). The impact is the collaboration program on mangrove management among Perhutani, Bekasi Regency Government and local community is not running well so that the destruction of mangrove forests became wider.

Another example is the draft Regional Regulation Plan for the Zoning Plan for the Management of Coastal and Small Islands Areas (Raperda RZWP3K) of West Java Province. It is clearly seen that there is an inconsistency in the management program of the Muara Gembong mangrove forest. In the draft, the Muara Gembong area is categorized as a general management area for coastal natural tourism sub-zones and small islands (KPU-WP3K-01) and marine aquaculture sub-zones (KPU-BD-BL-01). Whereas in the same draft specifically related to conservation areas, Muara Gembong is categorized as a mangrove and other protected conservation area (KK-KKP3K-01). This of course will lead to management disputes between stakeholders and future interests.

Mangrove ecosystems as tropical wetland forests are an important component of various climate change mitigation strategies. This is because mangrove forests have the ability to store high carbon compared to the average carbon storage in various other tropical forest types (average sample value 1.023 MgC ha^{-1} + 88 s.e.m). Therefore carbon emissions due to changes in mangrove land use will greatly affect climate change.Deforestation of mangroves causes emissions of 0.02-0.12 Pg of carbon per year, which is equivalent to about 10% of emissions from deforestation globally, although the area is only 0.7% of all tropical forest areas [8]. In essence, the loss of cover The mangrove ecosystem means the loss of the natural ability of the forest to absorb and store carbon.

Based on the results of a joint recommendation between the Coordinating Ministry of Economic Affairs, Bapennas, the Government of DKI Jakarta, Public Works and the Government of the Netherlands in 2014 related to the planned development of reclaimed islands and NCICD and their impact on the existence of mangrove forests in the Jakarta Bay, Muara Gembong is an ideal location as a "compensation area" for the restoration of mangrove forests. Restoration of mangrove ecosystems is expected to increase the acceptance of environmental services for water systems, natural tourism, protection of biodiversity and germplasm banks. But in the context of climate change mitigation, of course, mangrove forests are carbon sinks. So that the parameters that can be used to compensate for the lost mangrove forest is through the addition of land cover area to get the ability of mangroves to absorb carbon as the reference conditions.

This study will try to portray how the land use changes in the coastal area of Muara Gembong over the past 42 years, what the consequences of these changes and what the conservation actions that need to be taken by the central and regional governments and communities to avoid the ecological disaster in Muara Gembong especially the function of mangrove forests as carbon sinks to prevent climate change.

2. Material and Methods

The study was conducted in the coastal area of Muara Gembong, Bekasi, West Java. It is geographically located at positions 06 ° 00 '- 06 ° 05' LS and 106 ° 57 - 107 ° 02 BT. Muara Gembong is adjacent Java Sea in the north, Jakarta Bay in the west, Karawang Regency in the east, and Babelan subdistrict in the south. Muara Gembong is divided into 5 villages namely Pantai Bahagia, Pantai Bakti, Pantai Mekar, Pantai Sederhana and Pantai Harapan Jaya (Fig. 2).

2.1. Data source

The long term coastline changes in Muara Gembong is assessed for a period of 42 years from 1976-2018. Multi-temporal imagery of Landsat MSS, TM, ETM+ and OLI with different resolution have been acquired for shoreline analysis. The multi temporal data has capability to track the changes of land use and shoreline in the study area. All the imagery data were downloaded freely from USGS Earth Explorer (https://earthexplorer.usgs.gov/) wiht the path row of the study area is P131R64. The satellite images of the study region listed in (Table 1).

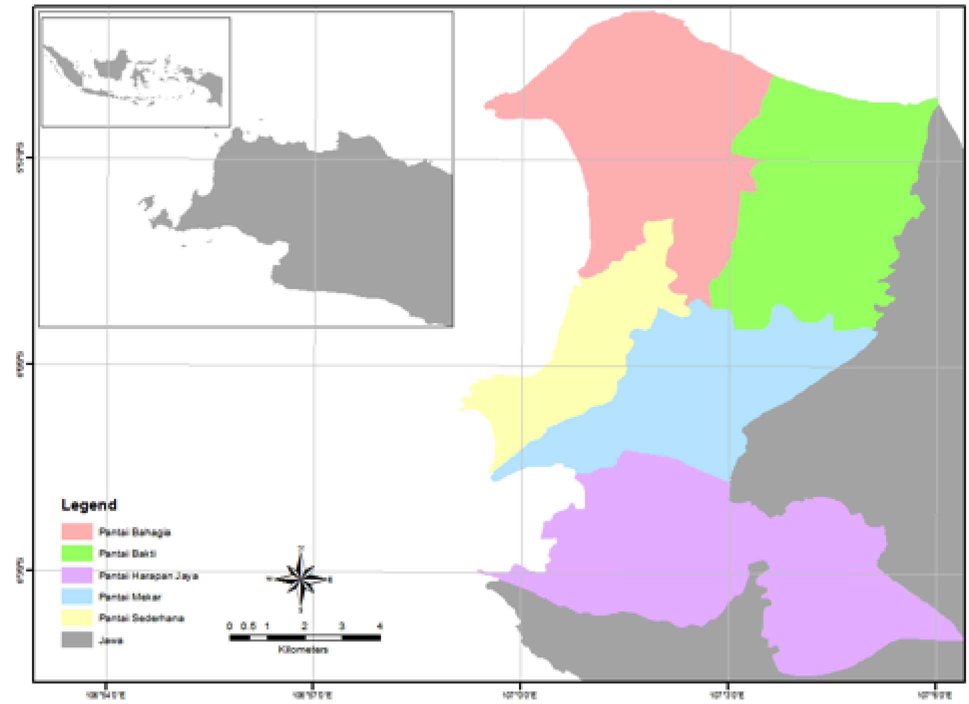

Figure 3. The Study Area of Muara Gembong, Bekasi, West Java.

Table 1. Multi-temporal Landsat satellite images used to obtain shoreline data.

No	Data	Acquisition time	Sensor	Resolution	Source
1	Landsat 2	21/06/1976	Multispectral Scanner (MSS)	60 meter	USGS
2	Landsat 5	3/5/1989	Thematic Mapper (TM)	30 meter	USGS
3	Landsat 5	31/07/1998	Thematic Mapper (TM)	30 meter	USGS
4	Landsat 7	2/7/2008	Enhanced Thematic Mapper Plus (ETM +)	30 meter	USGS
5	Landsat 8	1/4/2018	Operational Land Imager (OLI/TRS)	30 meter	USGS

2.2. Data analysis

The general methodology for data analysis in this study is shown in figure 4 below. There are three major steps, (1) Preparation of satellite image data, (2) Landuse change analysis, (3) Shoreline change dynamic.

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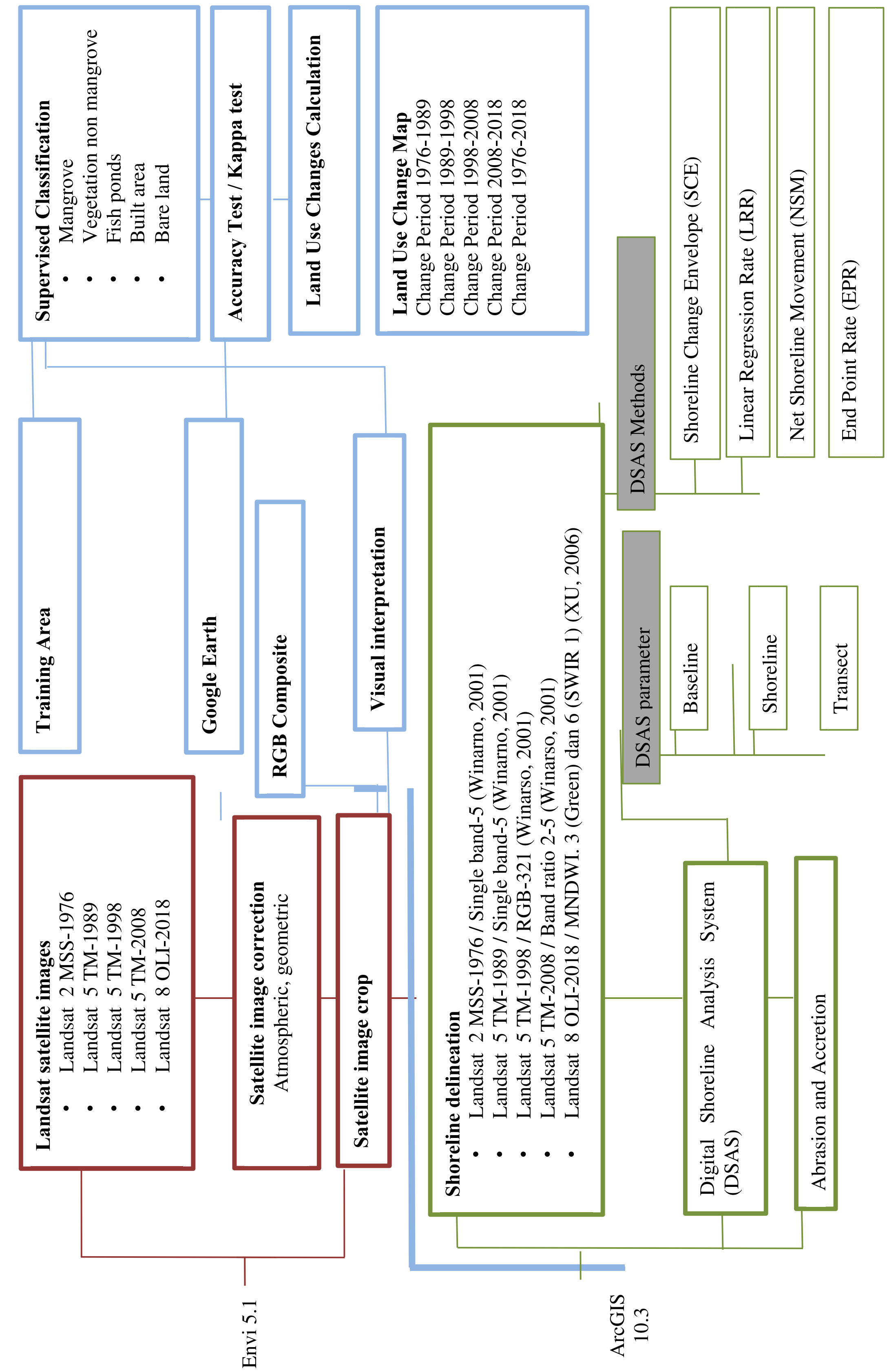

Figure 4. General flow chart of data analysis.

2.2.1. Land use change analysis

The Envi v5.1 and Arcgis v10.3 were used to process the satellite images and assesed quantitatove data for land use change assessement in Muara Gembong. Maximum likelihood classification algorithm was used in order to derive supervised land use classification. This supervised classification is based on user training samples that are representative on the different land use/land cover clasess based on user's knowledge of the area represented by the images. The class of the land use in Muara Gembong was divided into 5 categories (1) mangrove, (2) vegetation non mangrove, (3) Fish ponds, (4) developed land, and (5) bare land. An Accuracy assessment using Kappa index for the supervised land use classification was done for all the data set. The Kappa index was used to have an agreement between classifed raster and ground truth area (derived from field work and google earth). Kappa index is expressed as a value between 0 and 1. The closer to 1 the value is the more accurate the reclassification was.

2.2.2. Shoreline change analysis

To analyze the historical changes of Muara Gembong coastlines, Digital Shoreline Analysis System (DSAS) version 4.4, an ArcGIS extension freely available developed by United States Geological Survey (USGS) (http://woodshole.er.usgs.gov/project-pages/dsas/) was used. The shoreline changes is then analyze based on the statistical options for analyzing shore line data. These options are Shore Change Envelope (SCE), Net Shoreline Movement (NSM), and End Point rate (EPR) [9]. SCE and NSM provide a shoreline distance at each transect; however, their results do not include information on the rate at which the shoreline changes. SCE calculates the greatest distance between all shorelines without factoring in the year of the shoreline, while NSM represents a total distance between the oldest and the most recent shoreline, i.e. 1976 and 2018, respectively. While is the distance of shoreline shift divided by the time elapsed between the 1976 and 2018 shorelines.

3. Results

3.1. Land use changes

Fig. 5-8 shows the spatial distribution of the major landuse classes in Muara Gembong different period of time (1976-1989, 1989-1998, 1998-2008 and 2008-2018). The land use change discussed here mostly is the conversion of mangrove to fish/shrimp ponds considering that these two classes are the most significant natural features in Muara Gembong. Although the area of mangrove forests in Muara Gembong was slightly increased by 2.6 % in the period of 1998-2008, but in general within 42 years, it was decreased significantly and shown to decease year on year. Mangrove Forest experienced approximately a 55 % decline from 1976 through 2018 with an average change rate of around 23 Ha/year. The most significant increases of anthropocentric land used occurred due to converting and clearing the land into fishponds. The increases of commercial aquaculture confidently demonstrate strong correlations to mangrove forest decline (Fig. 9).

The figures have proved that that the fish farming development has been done long time ago and boosted significant since 1970's when the government policy at that time expected Indonesia became one of the world leaders of shrimp farming [10]. The country's political, social and economic conditions had encouraged the exploration and exploitation of natural resources which resulted in changes in land ownership status and massive destruction of Muara Gembong mangrove forest [4]. The situation has become complicated, as there is a different perception among stakeholders (central and local government as well as the inhabitants about the land's function. The issue is the difference in the purpose of spatial use between Perhutani (as the representative of Ministry of Environment and Forestry), local community and the local government of Bekasi Regency. Restoring the environmental functions of mangrove ecosystem in Muara Gembong as a protected forest (state forest) in this case is the priority of Perhutani. However, on the other hand, the Bekasi Regency through the regent Regulation No. 12 of 2011 about the Bekasi Spatial Plan for 2011-2031 to carry out the conversion of most protected areas into production forests, so that the community can do fish farming as a livelihood.

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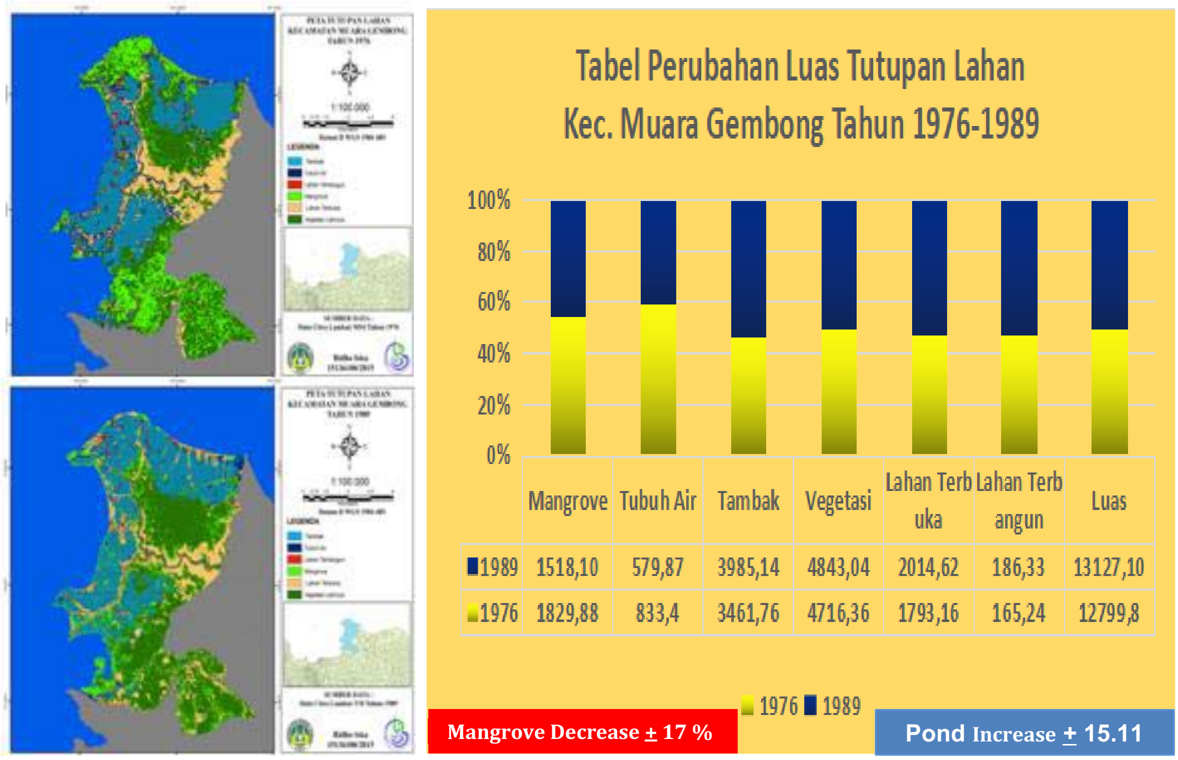

Figure 5. Land use change in Muara Gembong in the period of 1976-1989.

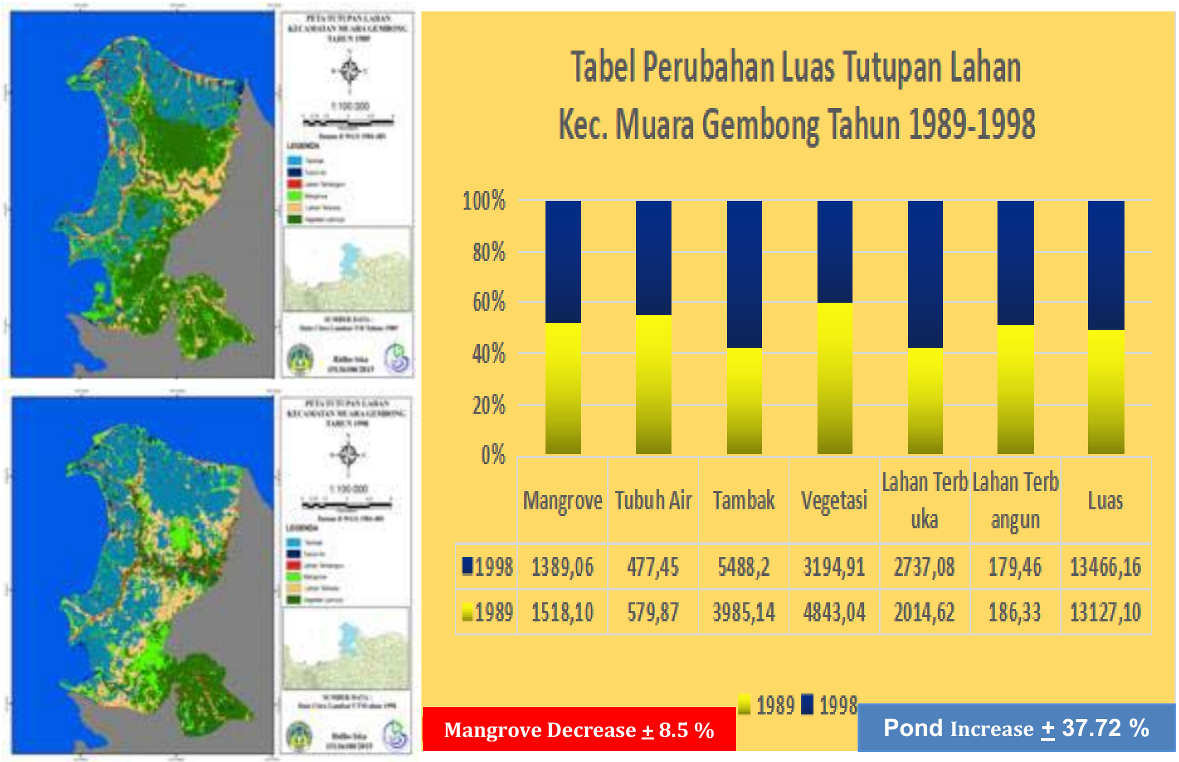

Figure 6. Land use change in Muara Gembong in the period of 1989-1998.

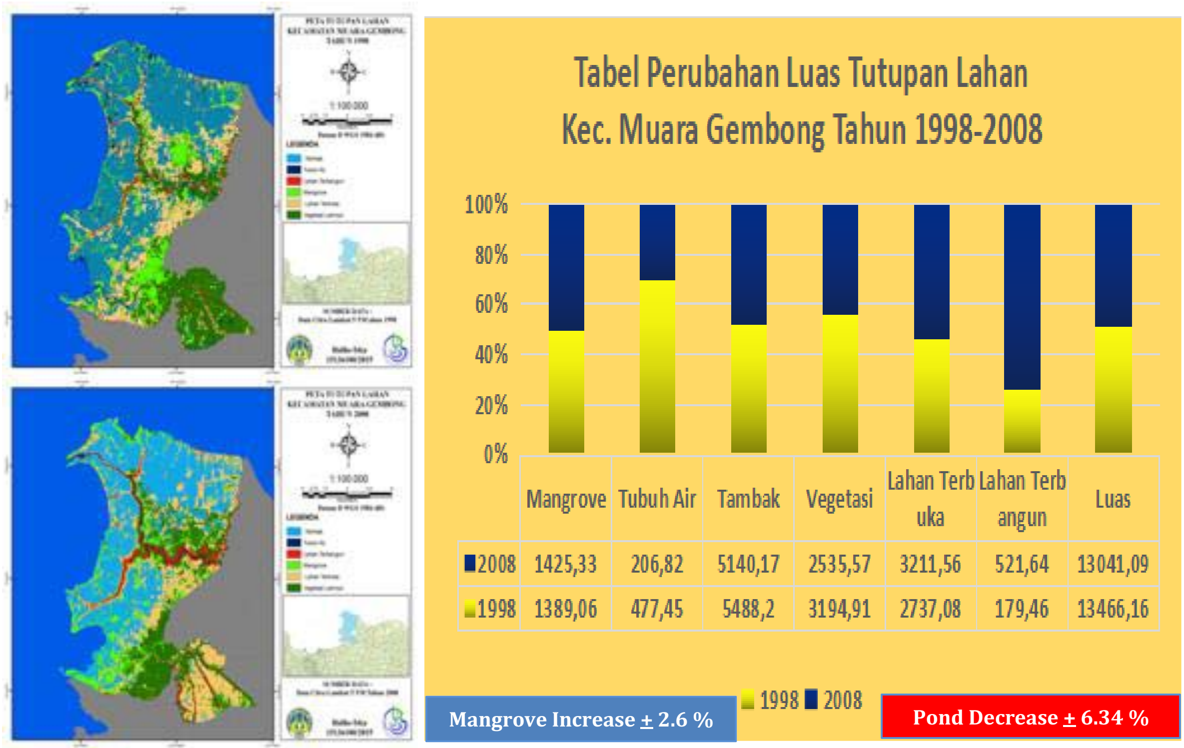

Figure 7. Land use change in Muara Gembong in the period of 1998-2008.

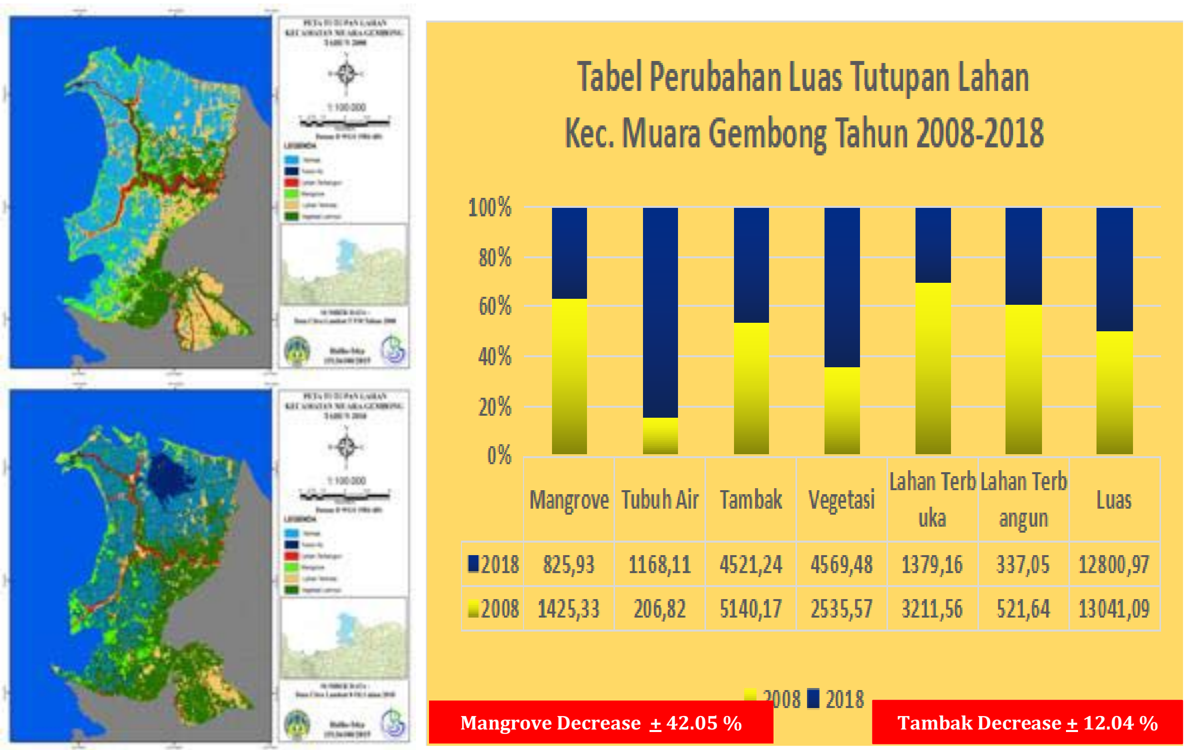

Figure 8. Land use change in Muara Gembong in the period of 2008-2018.

The aquaculture becomes the largest source of contribution to Bekasi Own Source Revenue (Pendapatan Asli Daerah, PAD). The consequence is the forest management program among Perhutani, the Regional Government of Bekasi Regency and local community is not running well so that the destruction of mangrove forests was increasingly widespread [7].

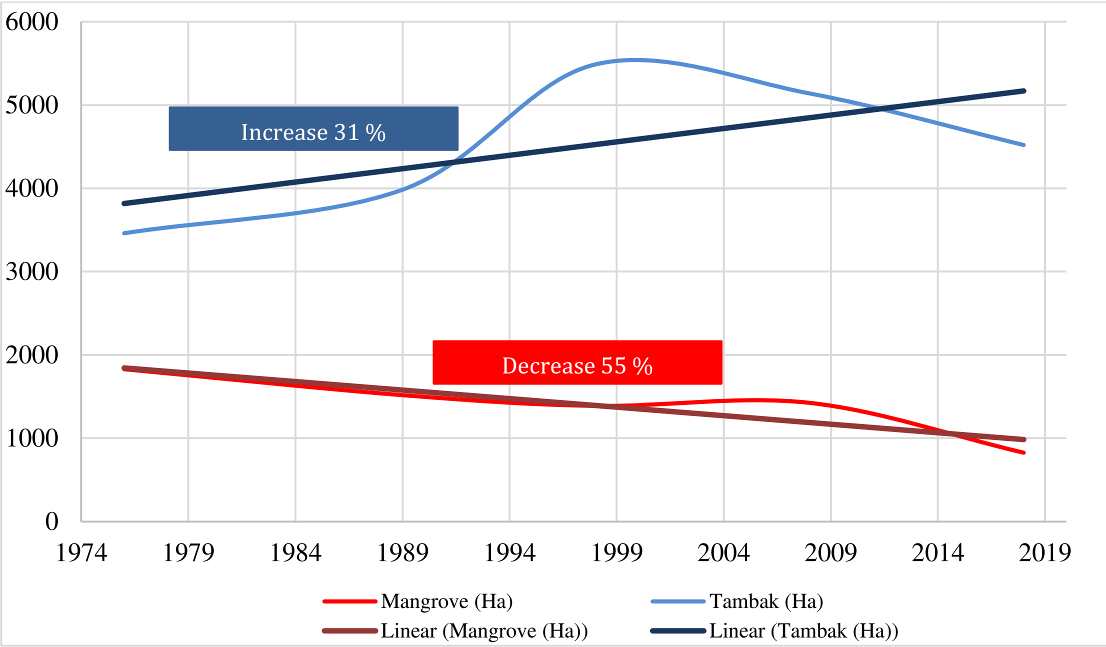

Figure 9. The trend line of mangrove and fishpond changes in Muara Gembong in the last 4 decades.

3.2. Shoreline Changes

Shoreline change statistics (SCE, NSM and EPR) presented for the coastline of Muara Gembong has been able to show the large-scale patterns of retreat and growth of the area (Table 2). The shoreline analysis for the period 1976-2018 revealed that 3 of 5 coastal villages in Muara Gembong experience to abrasion (Pantai Bahagia, Pantai Bakti and Pantai Sederhana villages) (Figure 10). The highest abrasion rate occurred in Pantai Bahagia followed by Pantai Sederhana and Pantai Bakti with the accretion rate respectively -15.46 m/year, -5.86 m/year and -3.76 m/year. The furthest distance due to abrasion is more than half a kilometer (-649.28 m), which occurs on the north coast of Pantai Bahagia. The highest average of accretion occurs in Pantai Harapan Jaya with an additional area of 507.13 m towards the sea with average accretion rate of 16.83 m/year followed by Pantai Mekar with (126.92 m and 3.02 m/year). The interesting thing is eventhough Pantai Sederhana experience to abrasion in the north part but at the same time the village also undergo to accrestion in the west part (Average NSM of 350.92 m and EPR 8.35 m/year). The results of the coastline in Muara Gembong subdistrict tends to retreat due to abrasion event caused by conversion of vegetation lands (mangrove) to fishponds. The existence of land conversion activity becomes the causative factor of coastline change in the coastal area. These results may be useful in providing necessary information for effective ecological mitigation program to protect the coastal area.

Table 2. The Statistical data of NSM and EPR in Muara Gembong in the period of 1976 to 2018

Villages	NSM (m)				EPR (m/th)			
	Highest	Lowest	Average +	Average −	Highest	Lowest	Average +	Average −
P.Bahagia	613.06	-1,333.78	350.92	-649.28	14.61	-31.76	8.35	-15.46
P.Bakti	12.59	-728.10	7.40	-158.2	0.30	-17.34	0.17	-3.76
P. Sederhana	114.98	-1,329.72	50.27	-246.15	2.74	-31.66	1.19	-5.86
P. Mekar	353.90	-99.49	126.92	-30.85	8.43	-2.37	3.02	-0.73
P. Harapan Jaya	1226.24	-0.86	507.13	-0.86	29.20	-0.02	16.83	-0.02

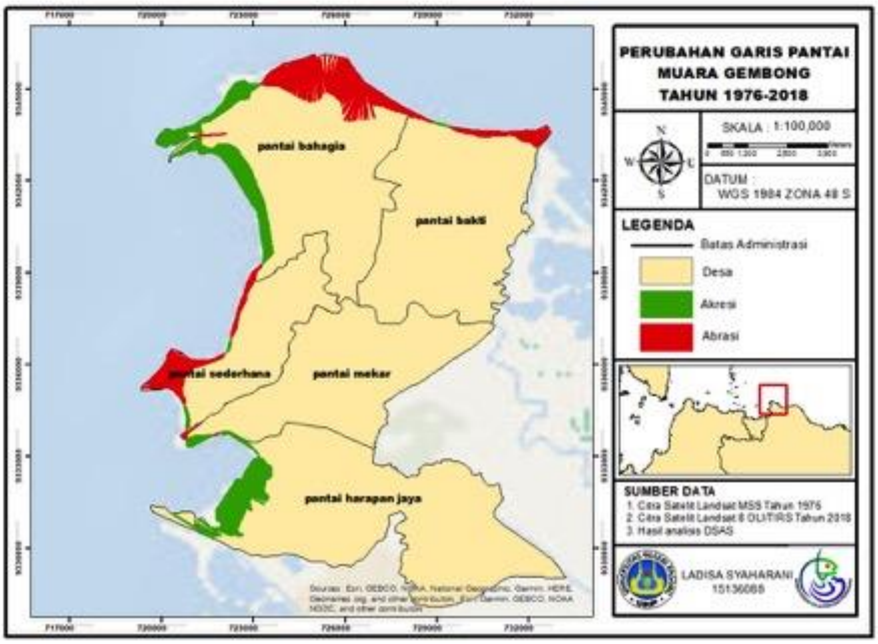

Figure 10. The shoreline movement in 42 year (1976-2018) in Muara Gembong.

From the results of extensive abrasion and accretion in 1976-2018 in each village in Muara Gembong Subdistrict which was dominated by the occurrence of abrasion, Pantai Bahagia Village was 482.94 ha. The area of accretion that occurs in Pantai Bahagia Village is also quite large, covering an area of 330.46 ha. Villages dominated by accretion are Harapan Jaya Village which is an area of 310.52 ha while abrasion in Harapan Jaya Village is only an area of 0.002 ha. The Bakti Beach Village is dominated by abrasion with an area of 73.84 while accretion is 0.4 ha. In the coastal village of Simple abrasion which occurred an area of 160.39 ha and an abrasion area of 7.17 ha. Mekar Beach is dominated by accretion. Accretion that occurs on the blooming beach covering an area of 22.88 ha.

Table 3. Area of Abrasion and accretion in 42 year (1976-2018) in Muara Gembong.

Villages	Area (Ha)	
	Abrasion	**Accretion**
Pantai Bahagia	482.945	330.460
Pantai Bakti	73.845	0.404
Pantai Sederhana	160.393	7.172
Pantai Mekar	0.848	22.888
Pantai Harapan Jaya	0.002	310.524

The area around Muara Gembong is geomorphological located in the lowlands in one watershed (Citarum River Basin) composing material in the form of surface sediment (P3G Map Geology, 1992). Surface deposits are ore deposits that form relatively on the surface. Surface deposits are divided into two types, namely alohton (allochtonous) and autohton (autochtonous) deposits. Alohton deposits are deposits that are transported from other places (from outside the depositional environment). Autohton deposits are deposits formed in the depositional environment. Alohton deposits associated with ore deposits or economically are often referred to as placer deposits. Autohton deposits associated with ore deposits are commonly known as residual deposits and deposits of chemical precipitation or evaporation [11]. Conditions in Muara Gembong are autohton deposits formed from the depositional environment. Autohton deposits form residual deposits. which occurs due to intensive chemical weathering, especially for tropical regions with high rainfall. In these conditions most of the rock will produce soil that loses soluble materials. Soils like this are known as laterites (laterites). Conditions like this apply in Muara Gembong and its surroundings, the constituent material is very soluble, so that abrasion is easy.

Stratigraphically, the surface sediment of the research location of the Geological Map sheet consists of:

- Qa (Young River Deposition): Sand. Mud, gravel and greed.
- Qsd (Swamp Deposition): Humus clay, peat clay, silt, and thin layer of peat.
- Qnd (shallow sea deposits): Interference between sand, silt, clay and a thin layer of tuff, containing shells.

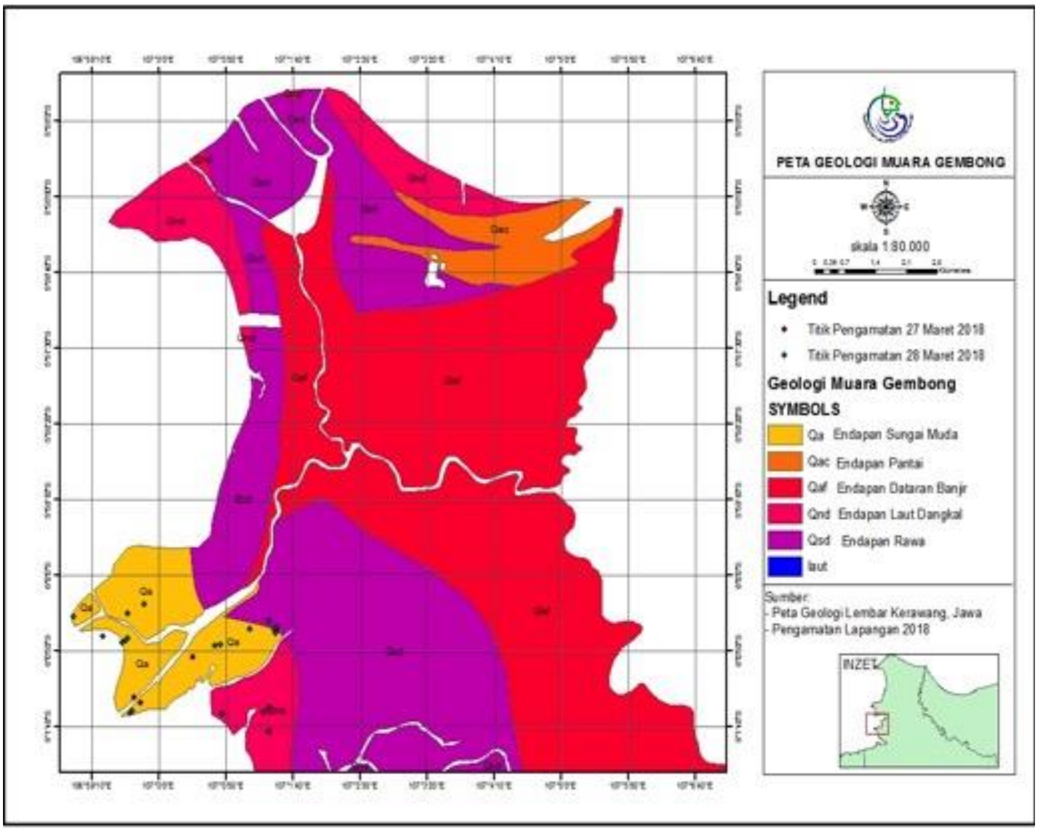

Figure 11. The geological map of Muara Gembong.

4. Conclusion

There has been a large change in land cover in Muara Gembong over the past 42 years (1978-2018) which was caused by the main factor in the conversion of mangrove forests into ponds. The change in land use causes imbalance of coastal ecosystems, especially mangroves as coastal protection ecosystems. The decline / degradation of mangrove forests on a large scale causes changes in shoreline structure due to the loss of mangrove function as a coastal protector. This is characterized by severe abrasion and accretion in some parts of the village. Muara Gembong and potentially eliminate other parts of the village directly adjacent to the beach / estuary for the next few years

References

[1] Pribadi R, Khakim A, and Nurdianto F. 2016. *Struktur dan Komposisi Vegetasi Mangrove Di Desa Pantai Mekar dan Pantai Harapan Jaya, Kecamatan Muara Gembong, Kabupaten Bekasi, Provinsi Jawa Barat*. Prosiding Aplikasi Iptek Perikanan dan Kelautan dalam Pengelolaan Mitigasi Bencana dan Degradasi Wilayah Pesisir Laut dan Pulau-Pulai Kecil. Seminar Tahunan Hasil Penelitian Perikanan dan Kelautan VI. ISSN: 2339-0883.

[2] Suwargana N. 2008. Analisis Perubahan Hutan Mangrove Menggunakan Data Penginderaan Jauh Di Pantai Bahagia, Muara Gembong, Bekasi. *Jurnal Penginderaan Jauh dan Pengolahan Data Citra Digital*. Vol. **5** LAPAN. http://repository.lapan.go.id/index.php?p=show_detail&id=4259.

[3] Asyiawati Y and Akliyah L S. 2014. Identifikasi Dampak Perubahan Fungsi Ekosistem Pesisir Terhadap Lingkungan Di Wilayah Pesisir Kecamatan Muara Gembong. *Jurnal Perencanaan Wilayah dan Kota*. Vol. **14** No 1. https://ejournal.unisba.ac.id/index.php/planologi/article/view/2551/1664.

[4] Nihayah RW. 2017. *Shrimp Aquaculture Versus Mangrove in Indonesia: Power Contestation, Environmental Degradation, and A Coevolutionary Environmental History in the Ujung Krawang (Muara Gembong) Mangrove Protected Forest*. Thesis. The Hague, The Netherlands.

[5] Susilowati. 2015. Konflik Tenurial dan Sengketa Tanah Kawasan Hutan yang Dikelola oleh Perum Perhutani. *Jurnal Repertorium* Edisi 3 ISSN: 2355-2646.

[6] Ambinari M, Darusman D, Alikodra H S and Santoso N. 2015. Community-based Mangrove Management: The Relationship between Perhutani and Cultivators in Muara Gembong, bekasi Regency, West Java Province. *International Journal of Sciences: Basic and Applied Research* (IJSBAR). ISSN 2307-4531. file:///Users/badhityan/Downloads/4295-10509-2-PB.pdf.

[7] Ambinari M, Darusman D, Alikodra H S and Santoso N. 2016. Penataan Peran Para Pihak Dalam Pengelolaan Hutan Mangrove di Perkotaan; Studi Kasus Pengelolaan Hutan Mangrove di Teluk Jakarta. *Jurnal Analisis Kebijakan* Vol. **13** No. 1. Hal 29-40. ISSN 0216-0897. https://repository.ipb.ac.id/handle/123456789/82375.

[8] Donato D, Kauffman J B, Murdiyarso D, Kurnianto S, Stidham M, and Kaninnen M. 2012. *Mangrove adalah Salah Satu Hutan Terkaya Karbon di Kawasan tropis*.

[9] Thieler E R, Himmelstoss E A, Zichichi J L and Ayhan E. 2009. *Digital Shoreline Analysis System (DSAS) version 4.0*. An ArcGIS Extention for calculating shoreline changes: U.S. Geological Survey Open-File Report 2008-1278. Available online at http://pubs.usgs.gov/of/2008/1278/.

[10] Veuthey S and Gerber J. 2012. Accumulation by Dispossession in Coastal Equador: Shrimp Farming, Local Resistance, the Gender Structure of Mobilizations 22. *Global Environmental Change* 611-622.

[11] van Bemmelen RW. 1949. *The Geology of Indonesia Vol 1. A General Geology of Indonesia and Adjacent Archipelagoes*. Goverment Printing Office, The Hague 1949.

Further reading

Hidayatullah I, Subardjo P and Satriadi A. 2016. Pemetaan Genangan Rob di Pesisir Muara Gembong Kabupaten Bekasi Dengan Menggunakan Sistem Informasi Geografis. *J-OCE Undip Jurnal Oseanografi* Vol. **5** Nomor 3. 359-367. Brief-CIFOR.

Ridwan F. 2014. *Pemodelan perubahan penutupan/penggunaan Lahan dengan pendekatan artificial neural network dan logistic regression (Studi kasus: DAS Citarum, Jawa Barat)*. IPB. Retrieved from http://repository.ipb.ac.id/handle/123456789/ 72176.