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IDENTIFICATION AND ANALYSIS OF SHORELINE CHANGES OVER FISHERMEN SETTLEMENT ALONG THE COAST OF SUNGAIBUNTU AND CEMARAJAYA VILLAGE, KARAWANG REGENCY, WEST JAVA

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Abstract. Shoreline changes, that occur along the coast, gives negative effects to the environment and also social-economic activities on the fishermen's livelihood. Study about shoreline changes, its trends, and its causes are important for the development of economic and sanitation vulnerability assessment on fishermen community caused by shoreline changes. Thus, environmental sustainability criteria within the local scale and specific to fishermen community takes into account and the implementation of the instrument become more appropriate to reduce the undesirable effects.This research aims to identifying and analysing shoreline changes trend and its factors over the fishermen settlement area along the coast of Sungaibuntu and Cemarajaya village, Karawang Regency, West Java. Data used in this study are Landsat-7 1999, 2002, 2007, and 2012 as well as Landsat-8 2017. To enhance Landsat-7 images, band 2-4-5 are used, meanwhile Landsat-8 employs band 3-5-6. Later, the shoreline was extracted by applying band rationing techniques, Band2/Band5 for Landsat-7 and Band3/Band6 for Landsat-8. The rate of shoreline changes along the coast of Sungaibuntu is -0.15 m/yr and -2.89 m/yr along Cemarajaya. The periodic phenomena that affect shoreline changes consist of tidal range with a mean value of 0.796 m, significant wave height (Hs) of 0 - 2.9 m with the dominant direction heading to the southeast, and also sea level rise (SLR). Besides, there is an anthropogenic factor of land use and land cover changes as the significant feature shown by the managed system of ponds, cropland, farmland, paddy field, along with the settlement. As for the instrument development of economic and sanitation vulnerability on fishermen community, it is important to take shoreline changes rate and its causes into account and consider it as vulnerability criteria.

Keywords: band rationing, coastal hazard, fishermen community, sea level rise

1. INTRODUCTION

Coastal community, including fishermen, who are living in hazard prone locations along the coast or river, is vulnerable to the negative impact of shoreline changes [1-29]. Shoreline changes either in the form of abrasion as the shore retreating landward or accretion as the shore advancing seaward. The shoreline is a dynamic environment as it is strongly influenced by air-land-sea interactions. Shoreline changes occur in response to short-term event, such as tide, wind wave, and current. It also arises in response to a long-term event of sea level rise. Moreover, anthropogenic activity, such as land reclamation, port to settlement development, as well as river damming and diversion, along the coast contributes to shoreline changes.

The process of both abrasion and accretion affected the environmental sustainability, its physical aspect in particular. The degree of shoreline changes in the northern part of West Java is varied yet nominated by abrasion [7, 8, 11, 23, 26]. Such condition will later threat fishermen’s livelihood whom reside along the northern coast of West Java. It was shown that high degree of abrasion along with coastal flooding has disturb transportation infrastructure and service, crop or harvest failure to loss of paddy field and fish pond, loss of mangrove ecosystems, not to mention damage on port facilities, settlement, and public facility [7, 14, 15, 18, 19]. Eventually, those potential damages put fishermen’s livelihood at risk and their opportunities to fulfil socio-economic sustainability at cost.

According to Fauzie [8] prior to shoreline change analysis in Karawang, West Java, over a 27-year period between 1998 and 2015, abrasion mainly occur in Pakisjaya, Tirtajaya, parts of Cilebar and Tempuran sub-regency. Total area loss along 73.65 km shoreline is approximately 404 ha. As for the rates, average abrasion rate is 4 m/yr or 15 ha/yr with 400 m retreat. In addition, accretion occurs in Cilamaya, Batujaya, and parts of Cilebar and Tempuran sub-regency. It gets additional land due to accretion about 874 ha. Accretion rate is 8 m/yr or 32 ha/yr with a maximum stride of 800 m.

This condition is worsened by land use and land use changes that occur continuously in the area. The classified features are categorized as settlement, agriculture land, and aquaculture pond, which cover almost 50% of the administrative area. Population growth of 6.85% over 2010-2015 [2] contributes to the coastal development. Thus, vast developed area has compacted soil with low infiltration rates and high runoff coefficient, which later lead to severe impacts of coastal flooding and inundation. Shoreline changes in accordance to inundation is the root of economic loss in Karawang in 2007, 2008, and 2013. Inundated aquaculture pond of about 4.760 Ha in 2007 caused a loss of 21 billion rupiah. In 2008, around 6.679 settlements were inundated by about 20-120 cm. Moreover, the latest inundation phenomenon in 2013 occur at wider area of 20 villages.

Based on the existing studies in a local scale, this study aimed to identify the shoreline position over a bigger scale area, which are Sungaibuntu and Cemarajaya village, at where the vast majority of fishermen community resides. Landsat images with temporal variation of 1999, 2002, 2007, 2012, and 2017 is used in this study. Those images processed through image classification technique of band rationing to identify shoreline position [4, 16, 27]. Besides, Digital Shoreline Analysis System (DSAS) is used to compute rate of changes. Shoreline change rates and its causes as the findings from this study will then employ as a variable in the development of a new assessment tool on economic and sanitation vulnerability within the local fishing community caused by shoreline changes.

2. STUDY AREA

This study was conducted in Sungaibuntu Village, Pedes District and Cemarajaya Village, Cibuaya District, Karawang Regency. Both villages are located along the shoreline where most of the fishermen live and work in either offshore or nearshore. This lowland area lies between 0-5 m above sea level on the slope of 0° - 2°, 2° - 15°, 15° - 40°, and >40°. Total area of Sungaibuntu is 1,022.59 Ha and Cemarajaya is 1,863.93 ha with approximately 12.6 km shoreline. Sungaibuntu Village comprises by 7 sub-village, which are Sungaibuntu 1, Sungaibuntu 2, Sugaisari, Sungaimanuk, Sungaitegal, Sungaibambu, and Krajan. As for Cemarajaya Village, it consists of 6 sub-villages, including Cemara 1, Cemara 2, Selong, Cemarajaya, Pisangan, and Muaralempeng. The area lies next to the Citarum River estuary. Figure 1 illustrates the site view of each village.

Figure 1. Site view of Sungaibuntu village (a) and Cemarajaya village (b).

3. DATA USED

Data used in this study are topography features of elevation and land cover. The source of elevation data is shuttle radar topography mission (SRTM) 2014 with 30 m resolution that available at http://srtm.csi.cgiar.org [24]. As for land cover, it is obtained from geospatial agency (BIG) at http://tanahair.indonesia.go.id/ [22]. Landsat-7 Enhanced Thematic Mapper Plus (ETM+) images with temporal variation of 1999, 2002, 2007, 2012, and Landsat-8 2017 at path 122 row 064 is main data that used in this study. Landsat images are obtained from earth explorer site and https://libra.developmentseed.org/ [12, 13]. Free cloud and free stripping image in the area of analysis is the important factor. A visualization of elevation over study area is shown in Fig. 2.

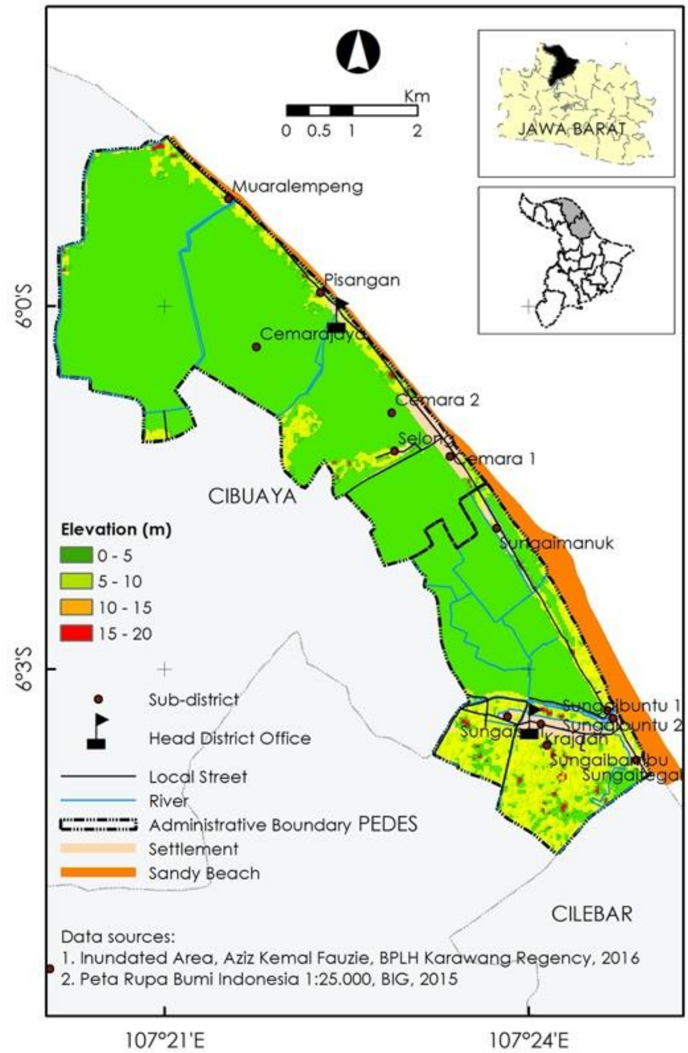


Figure 2. Land cover and elevation map over Sungaibuntu and Cemarajaya village.

4. METHODOLOGY

The software employed for analysis of shoreline changes was ArcGIS. The first step was to clip Landsat images to fit study area. Second was to build a composite image of 2-4-5 bands applied to Landsat-7 images [5, 16, 27] and 3-5-6 bands applied to Landsat-8 image [5]. Later a geometric correction or registering satellite images into object known on Google Earth and RBI map was employed. It was done by registering satellite images into at least 10 known objects on Google Earth and/or RBI map for a better resolution. It is required to select important landmarks such as river branches, river mouth to the sea or to the lakes, road branches, etc. This step is essentially important because a small misinterpretation might lead to shoreline displacement, which would create major errors on the shoreline extraction. Thus, the registration residual values or standard error was kept at maximum 0.5 pixels.

Residual values is calculated using eq. (1). The value represents the level of precision.

$$\sigma_{GCP} = \sqrt{\frac{\sum_{i=1}^{n} R_i^2}{m}} \quad (1)$$

with R_i^2 as residuals at each control points and m represent number of control points. Besides, root mean square error (RMSE) is also useful in determining precision level. Eq. (2) was used in calculating RMSE.

$$RMSE = \sqrt{\frac{(x' - x_{origin})^2 + (y' - y_{origin})^2}{n}} \quad (2)$$

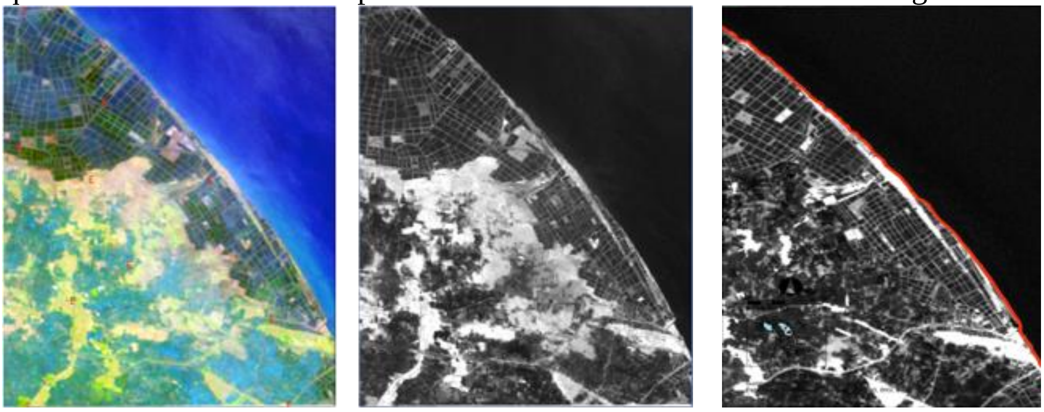
with x′, y′ represent coordinates at image, x_{origin}, y_{origin} represent the true coordinate obtained from Google Earth or topographic map, and n represents number of control points being used.

Table 1 summarizes residual values and RMSE of registered images in this study. Mean residual value is 0.293 pixels, which is approximately 8.88 m in the real world and not exceeding the image resolution of 30 m. In other words, geometric correction shows an agreement with precision criteria.

Table 1. Residual errors and RMSE

Year	Image Cycle path-122 row-064	
	Residual (pixels)	RMSE
1999	0,20	$1,76 \times 10^{-6}$
2002	0,16	$1,31 \times 10^{-6}$
2007	0,26	$2,34 \times 10^{-6}$
2012	0,37	$3,30 \times 10^{-6}$
2017	0,49	$4,45 \times 10^{-6}$

The next step is image classification using band rationing as the most common technique was processed. Band ratio operation Band2/Band5 employed to Landsat-7 and Band3/Band6 employed to Landsat-8. Image classification aimed to distinguish between land-soil (white) and water (black). Later digitizing procedures were taken to draw shoreline position over all the 5 images. Overlying topographic map and digitized shoreline have resulted in distinct features that can identify shoreline changes. Furthermore, Linear Regression Rates (LRR) were employed as an operation in shoreline change rates detection [3]. This process was done using DSAS as an add-on tool within ArcGIS software. LLR simply obtained by the means of fit least squares to all of the transect points. The extracted shoreline shown in Fig. 3.



(a) (b) (c)

Figure 3. Shoreline change extraction from satellite images.

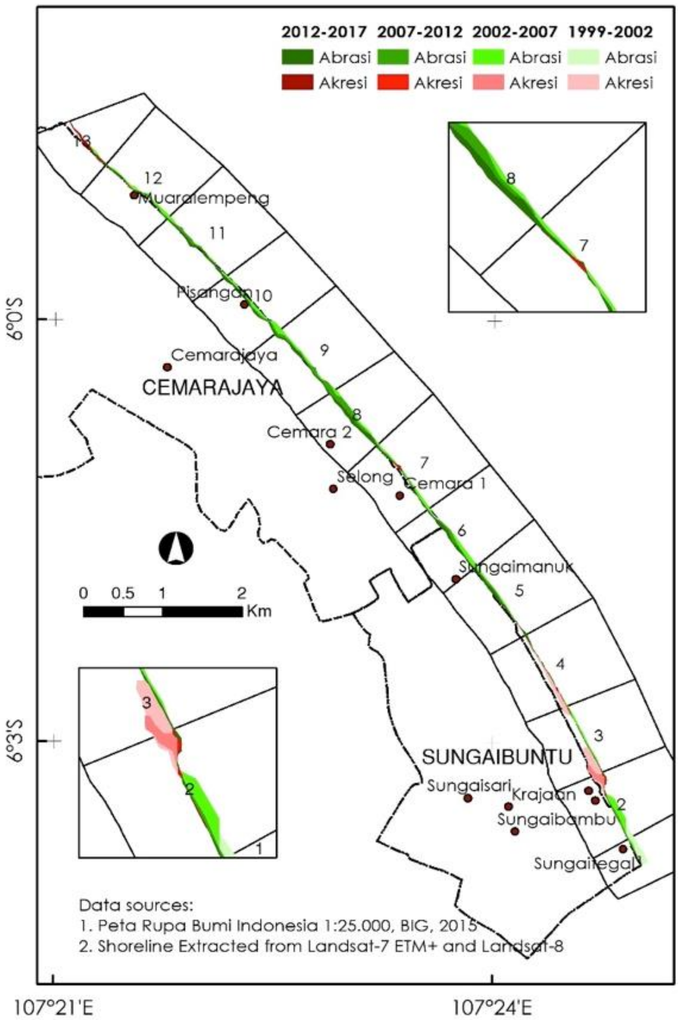


Figure 4. Shoreline changes along the shore of study area

5. RESULTS AND DISCUSSION

5.1. Identification of Shoreline Changes

Table 2. Area changes and its rate within 1999 – 2017.

Transect	1999-2002		2002-2007		2007-2012		2012-2017		Total 1999-2017		**Rate**
	+	-	+	-	+	-	+	-	+	-	
	(Ha)		(Ha)		(Ha)		(Ha)		(Ha)		**m/year**
1	0	3.365	0.009	0.435	0.262	0.216	0.008	0.480	0.279	4.496	**-3.8**
2	4.076	0.315	1.789	3.384	0.643	0.888	0.151	0.497	6.659	5.084	**+5.51**
3	5.817	0.352	0.445	0.147	0.211	0.380	0.019	0.874	6.492	1.753	**+2.19**
4	2.572	0.018	0.402	1.268	0.916	0.144	0.112	1.103	4.002	2.533	**+0.32**
5	1.092	0.033	0	2.505	0.332	0.720	0	2.392	1.424	5.650	**-3.04**
6	0.184	0.234	0.024	0.005	0.188	1.378	0	2.487	0.396	4.104	**-2.00**
7	0.503	0.026	0	2.982	1.079	0.042	0.002	1.389	1.584	4.439	**-2.78**
8	1.063	0.053	0	1.860	0.089	3.400	0	3.751	1.152	9.064	**-5.83**
9	0.304	0.195	0.077	0.351	0	2.643	0	2.209	0.381	5.398	**-6.48**
10	1.406	0.120	0.002	2.790	0.041	1.000	0	2.333	1.449	6.243	**-3.15**
11	0.368	0.060	0.378	0.788	0.140	1.180	0	2.751	0.886	4.779	**-2.93**
12	0.780	0.016	0	2.663	0.421	0.678	0.082	1.073	1.283	4.430	**-0.98**
13	0.442	0.047	0	2.021	0.975	0.425	1.218	0.690	2.635	3.183	**+1.20**
Total Area	**18.643**	**4.715**	**3.123**	**24.329**	**5.287**	**13.101**	**1.591**	**22.029**	**28.644**	**64.174**	

Notes: (+) Accretion as the shore advancing seaward (-) Abrasion as the shore retreating landward

In order to calculate the shoreline changes, 13 transect cells along the shore with a uniform interval of 1 km oriented perpendicular to the baseline were created. In addition, 1.5 km boundary drawn extending seaward from baseline [20]. The baseline defined as a minimum distance of onshore boundary, which is 100 m, in the coastal development as written in the Indonesian Law Number 27 of 2007. However, instead of 100 m, an advanced distance of 500 m landward from the defined shoreline in *Rupa Bumi Indonesia* (RBI) map [22] is used in this study.

Fig. 4 depicts the result of shoreline extraction, with a spontaneous position of shoreline. An accretion phenomenon occurs at Sungaibuntu and abrasion at Cemarajaya during 1999-2017. The shoreline was advancing seaward over transect 2 and 3 at Sungaibuntu. Sand deposited 6.659 ha and 6.492 ha, with the rate of 5.51 m/year and 2.19 m/year respectively. Table 2 shows a detailed affected area and the changes rate. An average rate of abrasion at Sungaibuntu is -0.15 m/year and -2.89 m/year at Cemarajaya. Significant abrasion occurred at transect cell 8 as the sand losses around 9.064 ha with the rate of -5.83 m/year.

5.2. Analysis of Shoreline Changes caused by Natural and Anthropogenic Factors

Mean Tidal Range. Water level or tide monitoring station around study area are not available, thus tide model from tides.big.go.id/ on Dec 2017 used to generate tide information. A point at 6°03’18”S and 107°24’52” E was chosen and it is identified that tide regime is mixed semidiurnal (Fig. 5). Both Sungaibuntu and Cemarajaya experiences two high and two low tides of a different tidal range every lunar day. A tidal range between -0.625 m and 0.528 m with a mean of 0.796 m. According to coastal vulnerability index (CVI) introduced by [10], mean tidal range over the study area classified as a very low vulnerable < 0.99 m.

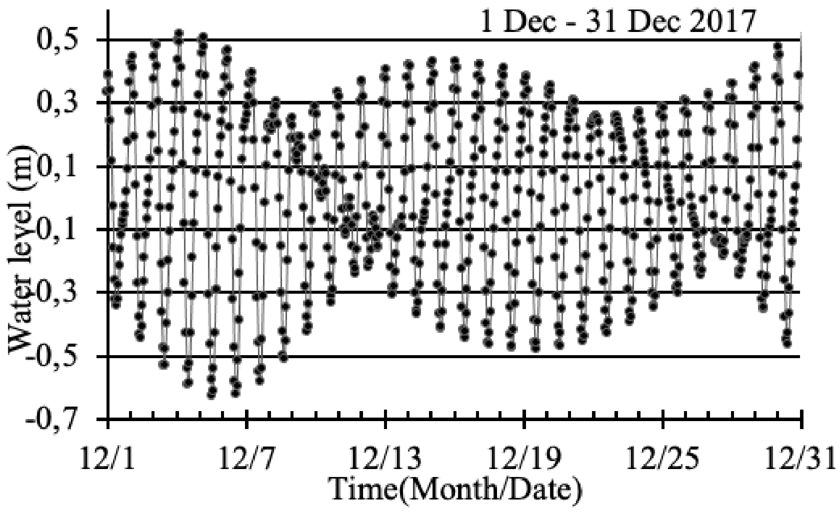


Figure 5. A month tidal range (data source: [22]).

Wind Wave. In terms of wind speed and direction analysis, wind data are collected from National Centre for Environmental Prediction (NCEP). Observation point used in wind analysis is the same with tide observation point. Wind components of u and v were converted into speed and direction (Fig. 6). As the two-study area is narrow, it is identified that the wind is coming from northwest over both locations.

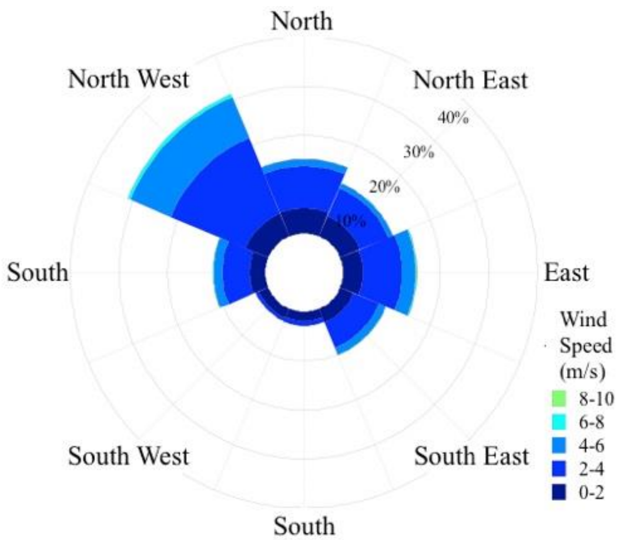


Figure 6. Wind speed and direction [28].

The significant wave height (Hs) model [24] ranged from 0.012 to 0.544 m with a mean of 0.214 m (Fig. 7). Wind and wave activity along the shore generated a longshore current, which moves parallel to the shore and sweeping the sand at an angle seaward. Periodic longshore current explains a dominant abrasion along the shore of Cemarajaya compare to that of Sungaibuntu. Nevertheless, a mean Hs which lies between 0-2.9 m is categorized as a very low vulnerable it is based on the CVI [10].

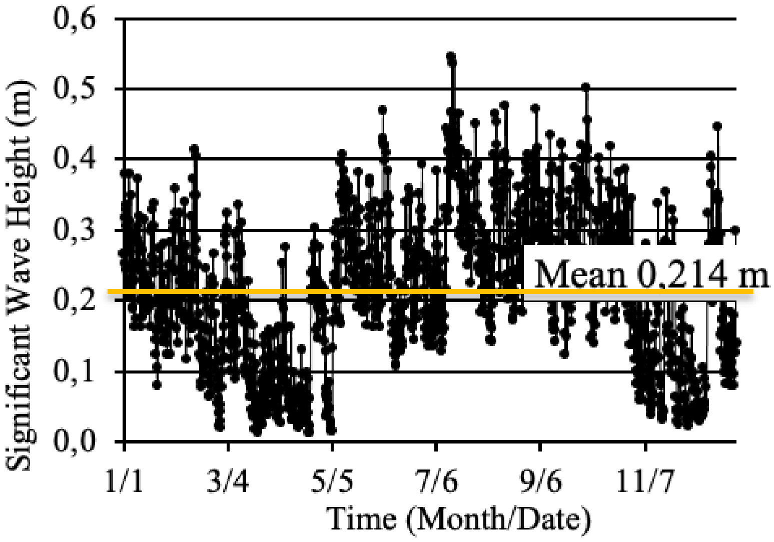


Figure 7. Significant wave height [21].

Sea Level Rise and Land Subsidence. Based on sea level rise (SLR) studies [17, 29], SLR rates over western part of Java Sea lies between 0.1-0.6 cm/yr to 0.73 cm/yr. Fig. 8 within supplementary document shows SLR rates in the means of sea surface height (SSH) during 22-year period. The value is higher that 4.1 mm and classified as a very high [10]. Besides, SLR rates is lower than subsidence rates along the northern Java island. Meanwhile, Andreas et al., [1] states that the range of subsidence rates is 1-20 cm/yr. Land subsidence, which caused by land cover changes and an excess groundwater extraction, raises the potential of inundation. It indicated that SLR is not significantly affected by coastal inundation and the shoreline changes effects. However, both SLR and land subsidence will later contribute to a long-term shoreline change.

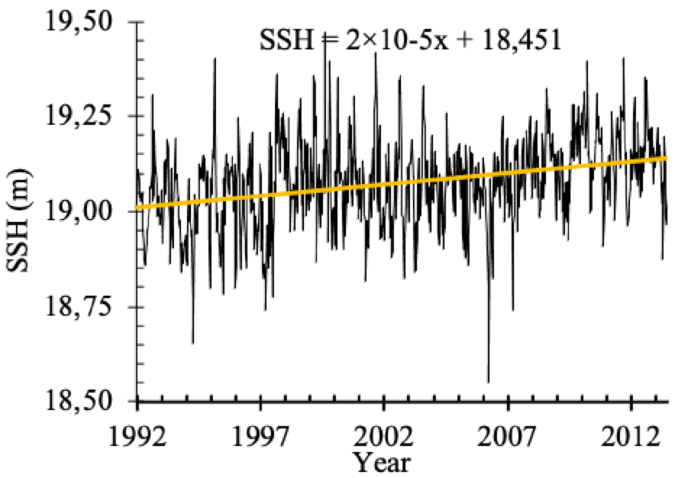


Figure 8. Trend of Sea Level Rise over Western Java Sea [29].

Anthropogenic Factor. Managed natural system within Sungaibuntu were mainly consist of farmland/paddy field/agriculture land, aquaculture pond, and residential area.

Managed area covers 1,010.03 ha out of 1,022.59 ha. As for Cemarajaya with 12.42 ha, or less than 1% from 1,863.93 ha, classified as swamp an unmanaged system. Even though it is mentioned in Indonesian Law No 26 2007 about spatial planning that an administrative area should have 20% green or blue space. In general, less open space in accordance to rapid coastal development causing soil compaction that reduces water infiltration along with increasing runoff. It leads to a growth in water demand either for agriculture or aquaculture to freshwater for human consumption. Such condition is linked to excessive groundwater extraction that led to land subsidence which later contributes to shoreline changes.

4. CONCLUSION

This study employed a common technique in extracting shoreline position of band rationing, that made it possible to identify shoreline change rates. Identified shoreline changes in the form of abrasion, as the shore retreating, at Sungaibuntu was not as significant as that of Cemarajaya. The rate over Sungaibuntu and Cemarajaya is -0.15 m/y and -2.89 m/y respectively. Longshore current associated with wind wave explained a high degree abrasion over Cemarajaya, as it is heading to the southeast.

Based on analysis of natural factors affecting shoreline changes, which are tidal range and significant wave height, area study was not vulnerable to coastal hazards including shoreline changes. In contrast, SLR results in a very high vulnerability. Shown a high rate (varies between 1 and 20 cm/y) on land subsidence along the northern part of Java. Such natural and human induced phenomenon within a longer period might contribute to severe shoreline changes. Following this study, the availability of information about shoreline change rates and its factors made it possible to develop a new economic and sanitation vulnerability assessment tool. The new vulnerability assessment tool is useful to ensure the environmental as well as economic and sanitation sustainability within fishermen system.

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REFERENCES

[1]. H. Andreas et al., Tidal inundation ("Rob") investigation using time series of high-resolution satellite image data and from institu measurements along northern coast of Java (Pantura), IOP Conference Series: Earth and Environmental Science, 71 (2017) 012005. https://iopscience.iop.org/article/10.1088/1755-1315/71/1/012005

[2]. Badan Pusat Statistik Kabupaten Karawang, Kabupaten Karawang dalam Angka 2016, Kabupaten Karawang: BPS Kabupaten Karawang, 2016.

[3]. A. BaMasoud, M. L. Byrne, The predictive accuracy of shoreline change rate methods in Point Pelee, Canada, Journal of Great Lakes Research, 39 (2013) 173-181. https://doi.org/10.1016/j.jglr.2012.12.010

[4]. N. Bushra, Detecting Changes of Shoreline at Kuakata Coast using RS-GIS Techniques and Participatory Approach, Bangladesh: Institute of Water and Flood Management, 2013. http://lib.buet.ac.bd:8080/xmlui/bitstream/handle/123456789/4186/Full%20Thesis.pdf?sequence=1&isAllowed=y

[5]. C. Chan, Portofolio GIS Products, Assessing Shoreline Change - Java, Indonesia, Retrieved May 27, 2017 from GIS Technologist. http://cherrychan.xyz/pdf/ChangeDetection.pdf (2017).

[6]. J. E. Cinner et al., Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries, Global Environmental Change, 22 (2012) 12-20. https://doi.org/10.1016/j.gloenvcha.2011.09.018

[7]. K. Damaywanti, Dampak Abrasi Pantai terhadap Lingkungan Sosial (Studi Kasus di Desa Bedono, Sayung Demak), Prosiding Seminar Nasional Pengelolaan Sumber daya Alam dan Lingkungan, (2013) 363-367. https://core.ac.uk/download/pdf/18605649.pdf

[8]. A. K. Fauzie, Assessment and management of coastal hazards due to flooding, abrasion and saltwater intrusion in Karawang, West Java, Indonesia. Coastal Sciences, 3 (2016) 8-12.

[9]. Google Earth v 7.1.8.3036, (2001, 12), Desa Sungaibuntu, Kabupaten Karawang, 06°02’40”S, 107°24’05”T, eye altitude 500 m, DigitalGlobe 2016, Landsat/Copernicus, Retrived March 13, 2017.

[10]. V. Gornitz, Global coastal hazards from future sea level rise, Global and Planetary Change, 3 (1991) 379-398. https://doi.org/10.1016/0921-8181(91)90118-G

[11]. W. Herdiyono et al., Modeling of Sediment Transport Affecting the Coastline Changes due to Infrastructures in Batang - Central Java, Procedia Earth and Planetary Science, 14 (2015) 166-178. https://doi.org/10.1016/j.proeps.2015.07.098

[12]. Landsat-7 ETM+ Images, retrived May 3, 2017. https://libra.developmentseed.org/

[13]. Landsat-8 Images, retrived May 3, 2017. https://earthexplorer.usgs.gov/

[14]. N. Lindawati, N. Kurniasari, Fish farmer perception on flood management over northern coast of West Java, Research Bulletin of Socio-Economic on Marine and Fisheries, 9 (2014) 59-64.

[15]. K. F. A. Lo et al., Impact of Coastal Land Use Change on Shoreline Dynamics in Yunlin County, Taiwan, Environments, 1 (2014) 124-136. https://doi.org/10.3390/environments1020124

[16]. A. Masria et al., Detection of Shoreline and Land Cover Changes around Rosetta Promontory, Egypt, Based on Remote Sensing Analysis, Land, 4 (2015) 216-230. https://doi.org/10.3390/land4010216

[17]. S. L. Nurmaulina et al., Long Term Sea Level Change from Satellite Altimetry and Tide Gauges in the indonesian Region, EGU General Assembly, 2010, pp. 1-7.

[18]. S. Paterson et al., The Human Dimension of Changing Shorelines Along the U.S. North Atlantic Coast, Coastal Management, 42 (2014) 17-35. https://doi.org/10.1080/08920753.2013.863724

[19]. S. K. Paterson et al., The social and economic effects of shoreline change: North Atlantic, South Atlantic, Gulf of Mexico and the Great Lakes Regional overview, University of Massachusetts Amherst, Department of Natural Resources Conservation, Lexington, MA: Eastern Research Group Inc, 2010. https://www.researchgate.net/publication/265631859_The_Social_and_Economic_Effects_of_Shoreline_Change_North_Atlantic_South_Atlantic_Gulf_of_Mexico_and_Great_Lakes_Regional_Overview

[20]. E. A. Pendleton et al., Coastal Vulnerability Assessment of Dry Tortugas National Park to Sea-Level Rise, Virgina: US Geological Survey, 2004. https://doi.org/10.3133/ofr20041416

[21]. I. Rudiarto et al., Socio-Economic Vulnerability to Flood Risk in Coastal Village within Demak Regency, Jurnal Wilayah dan Lingkungan, 4 (2016) 153-170.

[22]. Rupa Bumi Indonesia (RBI) Map, from Indonesian Geospatial Information Agency (BIG), 2017. http://tanahair.indonesia.go.id/

[23]. S. Supriharyono, A. Hartoko, An Examination of Shoreline Changes and Consequences using Multi-temporal Satellite Images over Semarang, East Java, Journal of Science and Technology in Fisheries, 8 (2013) 33-37.

[24]. Shuttle Radar Topography Mission (SRTM) of 2014, 2017. http://srtm.csi.cgiar.org

[25]. Significant Wave Height (Hs) of 2015 and Tide Data of December 2017 over Northern Java, retrived January 2, from Indonesian Geospatial Information Agency (BIG), 2018. http://tides.big.go.id/

[26]. A. Taofiqurohman, M. F. A. Ismail, Spatial Analysis on Shoreline Changes along the Coast of Subang Regency, West Java, Jurnal Ilmu dan Teknologi Kelautan Tropis, 4 (2012) 280-289. https://www.researchgate.net/publication/322231129_SPATIAL_ANALYSIS_OF_SHORELINE_CHANGES_IN_THE_COASTAL_OF_SUBANG_DISTRICT_WEST_JAVA

[27]. V. T. Tran, B. T. Trinh, Application Remote Sensing for Shoreline Change Detection in Cuu Long Estuary, VNU Journal of Science, 25 (2009) 217-222. https://js.vnu.edu.vn/EES/article/view/1879

[28]. Wind Gridded (reanalysis) Data 2013 - 2017 period, retrived January 2, 2018 from National Centre for Environmental Prediction (NCEP). https://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.pressure.html

[29]. W. Windupranata, A. Ikhsani, Physical Land Factors Analysis over Jakarta Bay for the Development of the Great Jakarta Sea Wall. In Dynamic Change over Jakarta Bay: Impacts Analysis of Sea Wall Construction (2014) 69-78. Bogor, West Java, Indonesia: IPB Press.