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Physical and Social Factors of Shoreline Change in Gebang, Cirebon Regency 1915 – 2019

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Abstract

Shoreline changes are the main concern for coastal management. In Indonesia coastal zone is the populated region for marine and fishery economic sectors. Dynamic of the region shown by shoreline change. This study aims to explain the dynamics of shoreline change in Gebang, Cirebon Regency from 1915 to 2019, and several factors that influence. This research using overlay intersections to know shoreline change from 1915-2019 and multiple linear regression to determine several factors that influence the shoreline change. The shoreline increased 992.99 meters caused by accretion. Physical factors that influence shoreline changes include total suspended solids, bathymetry, wind, and tides, whereas social factors include the presence of beach building, population density, building density, and distance from the built-up area. The most influential factor in increased shoreline is bathymetry. Based on the results of statistical tests known that physical and social factors are influence significantly on the dynamics of shoreline changes. The correlation between the actual and the predicted value reached 0.97 with p-value 0.001.

Keywords: Abration, Accretion, Physical and social factors, Gebang, Shoreline

1. Introduction

Shoreline change is a dynamic that occurs between land and sea area marked by coastal abrasion and accretion, physical and social factors influence the dynamic coastline (Srivastava, et al, 2005). Indonesia has approximately 95,180 km shoreline length dan ranks four of 182 countries after Canada, the United States, and Russia Federation (Ministry of Marine and Fishery, 2018; Luijendijk, *et al.,* 2018). Shoreline change is a problem that concerns most coastal managers, coastal populated by 60 percent of the world's population. Coastal has several benefits for development because the region is the transitional area between terrestrial and marine ecosystems that influence each other, coastal region suitable for agriculture, fisheries, transportations, and other human-based activities (Dahuri, et al., 2013). The existence of biological and non-biological natural resources contained therein can be optimized to sustain the community's economy. Communities around the coast in Indonesia generally work as fishermen who exploit this potential, where the national fish catch reaches 12.5 tons per year (Ministry of Marine and Fishery, 2015). In addition, salt ponds or embankments, tourist attractions and nature reserves are main land use in coastal area.

Cirebon Regency is a coastal region in West Java, Indonesia. Cirebon divided into two region area are separated by Cirebon City namely West and East Cirebon. Some sub-district in East Cirebon have directly bordered the Java Sea in the north and forms a coastal area includes Mundu, Astanajapura, Pangenan, Losari, and Gebang (Anshari, et al, 2016). The East Cirebon coast is the estuary of large rivers from Pantura-Ciayu watershed (1820 km^2) and Cisanggarung watershed (1325 km^2). The abundance of fluvial material coupled with sea currents along the coast causes sediment accumulation and accretion (Faturachman, et al., 2004; Warman, 2015). Efforts to optimize coastal resources often negative impacts, some constructions installation such as breakwaters can inhibit litoral flow. This condition can cause erosion and also trigger sedimentation in another area (Dahuri, 2013; Nandi, 2018).

Over the past 20 years since 1998, the coastal region of East Cirebon has a change in shoreline due to abrasion and accretion reaching 500 Ha (Widiawaty, 2018). Abrasion causes a decrease, but accretion increases the shoreline due to the process of river sedimentation which brings additional material to the coast. Poor management in upper watersheds exacerbates sedimentation in rivers estuary of East Cirebon, the reduced vegetated area in upstream has an impact on erosion and triggers sedimentation – accretion in downstream. Rapid development in the upstream by large conversion of forest areas into agriculture, plantations, and settlements. A significant coastal dynamic by the process is located in Gebang, wherein a 2013 accretion increase of 260 Ha and erosion decrease of 120 Ha – addition land with a gain of 140 Ha.

Land accretion is more dominant than land erosion in Gebang by material accumulation from the Ciberes river. Muddy coast types of the region have material characteristics that are easily transported by currents (Heriati & Husrin, 2017). Based on the background, this article has the purpose to examine the dynamics of shoreline changes in Gebang and its several factors that influence. The study of the shoreline dynamic takes various physical and social environmental factors, physical factors such as total suspended solids (TSS), ocean's depth or bathymetry, wind, and tides, whereas social factors include coastal construction presence, population density, building density, and distance from the built-up area.

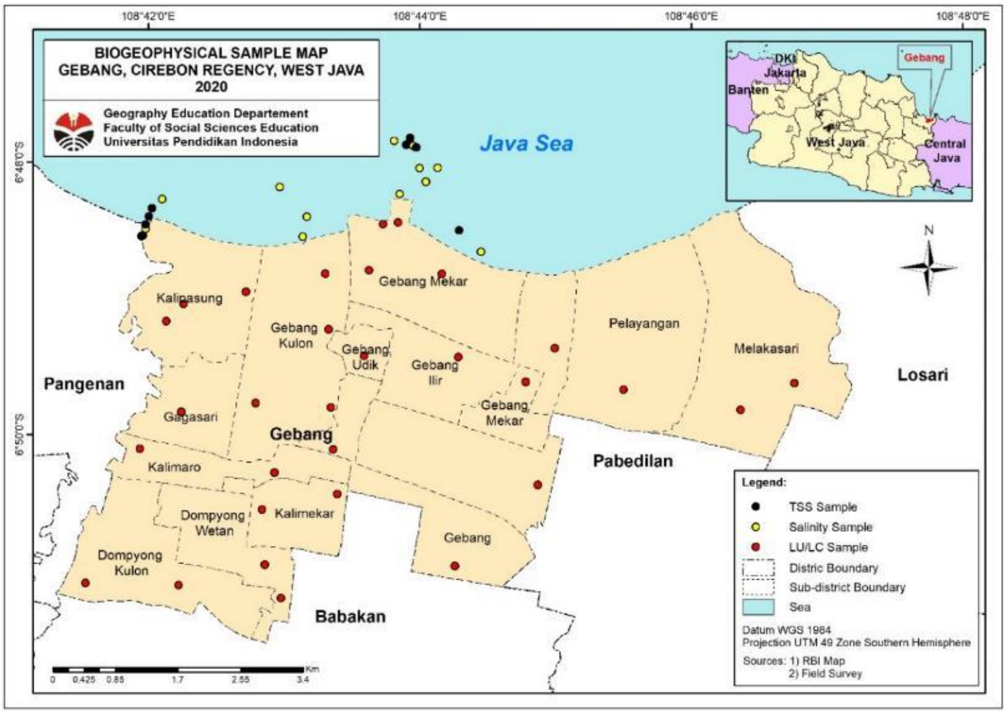

Fig. 1. Research Location and Samples Distributions.

2. Methodology

2.1 Research Location

This research located in the Gebang sub-district, Cirebon Regency, West Java, Indonesia. Gebang borders to other sub-district in the East Cirebon such as Babakan, Pabedilan, Losari, and Pangenan. In the north, Gebang directly bordering with the Java Sea (see **Figure 1**). Gebang is relatively flat with an average height of 7.5 meters above sea level. The lowest elevation located in the north, while the highest point in the south. Gebang has 35.97 km^2 of total area and 61,342 population with annual growth rate reaches 0.7 percent arithmetic density level of 17.02 person per hectare.

2.2 Data Acquisition

This study uses primary and secondary data for the shoreline changes analysis and its influencing factors. Shoreline changes data were obtained from topographic maps (Topografische Dients) in 1915, topographic maps (AMS) in 1940, and Landsat series (USGS) in 1972, 1988, 1999, 2005, and 2019. For physical factors data including TSS were obtained from Landsat and Sentinel imagery, while data on wind speed, current, and tide are obtained from data providers such as BMKG, MetOcean Hindiacast, and INDESO. Especially for bathymetry data, ocean depths from topographic maps (Topografische Dients) was interpolated using Kriging method cause has the minimum error (Widiawaty, *et al.,* 2017). For related social factors data such as the existence of coastal buildings, population density, building density, and distance from built-up were obtained from high-resolution imageries, official monographs of Gebang, statistics data of BPS, interviews, and questionnaires by residents, and field observation.

2.3 Data Analysis

The analysis using vector data from maps and imageries digitalization with intersecting overlay. Before performing imageries analysis, it is necessary to need geometric, radiometric, and atmospheric corrections to perform RGB composites (431 Landsat-1 MSS, 432 Landsat-5 TM, or Landsat-7 ETM, and 567 Landsat-8). Furthermore, shoreline changes analysis was carried out within a predetermined time span so that the extent and length of abrasion and accretion were known. In this part, there is some algorithm to determine physical and social factors are influence shoreline change based satellite imageries data. TSS measurements are carried out using secondary data which include Landsat-8 OLI (USS) and Sentinel-2 (ESA) imageries in the same period which validated using primary data – in-situ measurements, the following equation is used based on Parwati algorithm (2017) as **Equation 1**. Whereas building density analysis is performed using the Normalized Difference Built-up Index (NDBI) as an algorithmic that uses short infrared waves (SWIR) and near-infrared (NIR) (As-Syakur, 2012), NDBI is formulated with **Equation 2**.

$$TSS_{(mg/l)} = 0{,}621 \times (7{,}904 \times \mathrm{Exp}(23{,}942 \times \text{red band}))^{0.9645} \qquad (1)$$

$$\mathrm{NDBI} = \frac{\mathrm{SWIR} - \mathrm{NIR}}{\mathrm{SWIR} + \mathrm{NIR}} \qquad (2)$$

Where SWIR is short wave infrared, NIR is near infrared, and red band is electromagnetic wave on 0,64 – 0,67 µm length.

Many factors that influence the shoreline change in Gebang can be determined using a multiple regression model as **Equation 3**. According to Dede et al (2018), multiple regression is parametric statistics that need some classical assumption test to fulfillment best linear unbiased estimator (BLUE) and ordinary least square (OLS) model. Detail elaboration about multiple regression models and its independent variables show in the results and discussion part.

$$Y = a + b1X1 + b2X2 \ldots, + bnXn \qquad (3)$$

Where Y is dependent variable (shoreline change), X is independent variables (physical and social factors), a is konstanta, and b is regression coefficient.

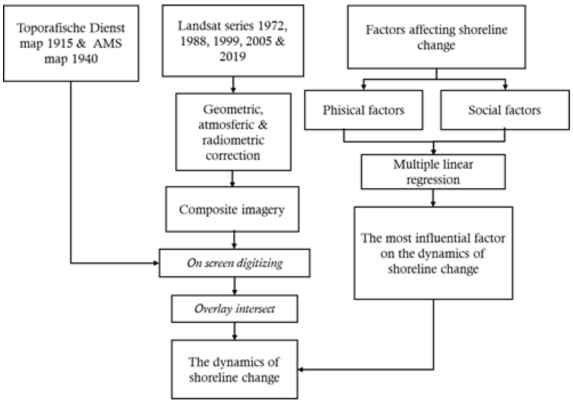

Fig. 2. Research Flow Chart.

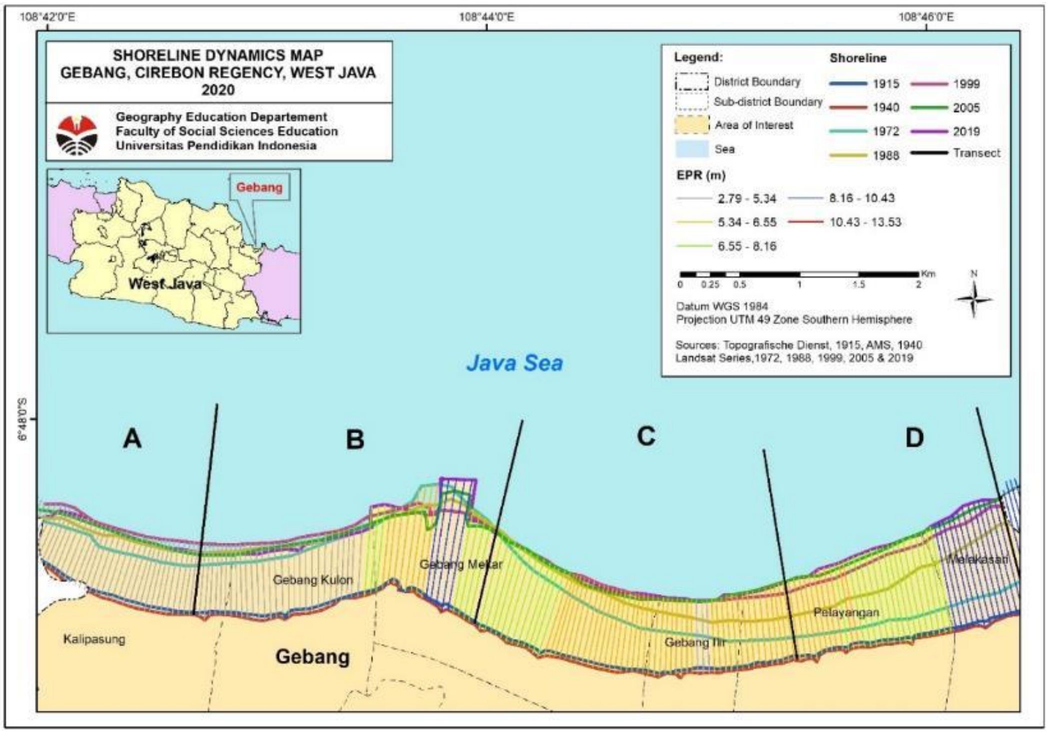

Fig. 3. Shoreline Dynamics Map.

3. Results and Discussion

3.1 Shoreline and Coastal Dynamics

The results show that in 1915 the north coast of Gebang had an area of 1604.6 Ha, while in 1940 the area was reduced to 1576.32 Ha. This indicates that there had been a large phenomenon of abrasion. The abrasion in 1940 reached 28.28 Ha, whereas in 1972 the land expanded to 1967.59 Ha. The expansion was caused by the accretion of 391.27 Ha. Likewise in 1988, the land expanded due to accretion from 1967.59 to 2090.79 Ha, it was increased to 130.27 Ha. Abrasion also occurs in some segments reach of 7,07 Ha. To measuring the area of accretion and abrasion, shoreline changes measurement (gain and loss) from 1915 to 2019 see Table 1.

From these results, it is known that the maximum change from 1915 – 2019 reached 1,07 km. The first measurement is in 1940 with 1915 as a baseline. In 1940 there was no accretion, abrasions occurred and reached of 30.26 meters. Whereas in 1972 the accretion reached 429.14 meters with a maximum length of 992,99 meters, the period 1940 – 1972 was maximum increased shoreline in Gebang. In 1988, accretion occurred with an average length of 176,09 meters, and abrasion reached of 80.92 meters. Start from 1999, accretion value was decreased below 100 meters, wherein 2005 shoreline in Gebang was decreased and loss of -5.69 meter. Therefore, in 2019 abrasion and accretion will continue with an average of 32.8 meters and 14.84 meters as shown on **Table 2**. Shoreline change was a very significant condition at point 61 to 68 (see **Figure 3**). The changes as a result of coastal engineering which began construction since the 2000s to the present – there are three jetties as shown by **Figure 5** social Factors maps on distance from beach building.

Table 1. Abrasion and Accretion Extent.

Year	Area Extent (ha)	Accretion (Ha)	Abrasion (Ha)	Gain/ Loss (Ha)
1915	1604.60	0	0	0
1940	1576.32	0	28.28	-28.28
1972	1967.59	391.27	0	391.26
1988	2090.79	130.27	7.07	123.2
1999	2176.22	89.09	3.66	85.43
2005	2170.53	19.16	24.85	-5.69
2019	2186.33	19.75	3.95	15.8

3.2 Factors are Affecting the Dynamics of Shoreline Change

The average TSS concentration in 2019 was 19.49 mg/liter, high TSS levels are in estuary areas. Whereas the sample point with a low TSS value is in the north of Gebang Mekar, coastal constructions affect sediment from the river to trapped in the vicinity and made the north water body have very low TSS levels. High TSS level areas are characterized by turbid water, while low TSS level areas are characterized by clear water conditions. Estuary areas that are relatively turbid have TSS levels between 19 mg/liter to 331 mg/liter. Meanwhile, the area blocked by beach buildings has 0 mg/liter TSS value. TSS testing of in-situ results with Sentinel-2 MSI and Landsat-8 OLI images was carried out in the same season period in 2020 and shows a similar trend. According to Nurdian *et al.,* (2020), a similar and significant trend between in-situ and remote sensing value show the imageries data result can be determined as a dataset for spatial analysis.

Beside TSS, depth of the sea in Gebang is relatively shallow with ranging from 0 to 5,5 meters. From 1915 to 2019, accreted land occurs in tidal flat areas or tidal plains with a depth of 0 to 0,2 meters. This area is deposited by sediment loads from rivers which empties into the sea. Shallow depth has the potential area for new material to be deposited, where wind as a potential factor in shoreline changes being able to generate currents and waves. The wind is able to erode and move material found around the coast. Wind speed data obtained from MetOcean Hindacast is processed by extracting contour values (isotach) with 0.2 meters per second as the interval. Wind speed patterns in the Gebang vary greatly with ranging from 5,9 to 6.08 meters per second. Another physical factor for shoreline change analysis is tides. The highest tides occur in the south, while the lowest tide pattern is getting smaller into northwards with an average of 1.811 meters. Detail distribution for the physical factors shown in **Figure 4**.

Social factors related to human-based activities also influence shoreline changes. Development activities have begun since 2002 until now (Hartanti, 2018). The several buildings erected around the coast, the presence of jetty gives enough attention because it keeps extending into northwards. There are three jetties with a total length reaching 2,31 km. The jetties result in the trapping of sediment loads from the river around the area. Sediment concentration is only centered near the Ciberes River estuary adjacent to the coastal structure so that the waters tend to be free of river sediment loads. The influence of the jetties in the study was analysed through the buffering method, thus the distance from them is known with ranging from 0 to > 6.5 km (see **Figure 5**). Another factor that contributes to the dynamics of shoreline changes is population increasing. Population density on the north coast of Gebang shows a non-uniform pattern. Melakasari and Gebang Ilir have a low population density because the populations who inhabit the area is relatively smaller. Melakasari has the lowest population density, in contrast to Pelayangan, Kalipasung, Gebang Kulon, and Gebang Mekar which have high population density. In addition to population density which refers to the area of built-up area and population, information related to the tendency to increase the built-up area can also be known by measuring building density using the normalized difference built index (NDBI) algorithm.

The results NDBI analysis indicates that high building densities are marked with positive. Six villages in Gebang have a similar pattern of developed land density ranging from -0.30 to 0.27. In addition, social factors that affect shoreline changes are population behavior such as distance from settlements in mangrove planting as conservation and rehabilitation effort, conversion of mangrove land to embankments/salt ponds, construction of new built-up or settlement area, beach abolition activities, and garbage disposal around the coast. The distance from the built-up area can explain the intervention of the population towards changes in the shoreline and the existence of community patterns to utilize marginal land is also a consideration.

3.3 Shoreline Change Model in Gebang

Before starting the classic assumption requirement, each independent variable that has the potential to influence shoreline change must have correlation value to result in a fit model. In this case, the partial correlation between independent and dependent variables tested using the Spearman-Rank correlation method. The result shows that independent variables have a positive value from 0.051 to 0.841 and negative value from -0.915 to -0.193. The highest partial correlation is the depth of the sea with -0.915, its sign that accretion occurs in shallow water bodies. To generate the regression model, the first stage of the classic assumption requirement is data normality. Generally, normality is an absolute requirement and can be obtained from a residual value distribution analysis and can know using the normal distribution curve, but to obtain a more valid normality verdict, the Kolmogorov-Smirnov (KS) and Shapiro-Wilk (SW) methods are also used.

Table 2. Length of Abrasion and Accretion.

Year	Accretion dynamics (m)			Abrasion dynamics (m)			Changes per year (m)
	Max.	Min.	Average	Max.	Min.	Average	
1915	-	-	-	-	-	-	-
1940	0	0	0	57,98	0,77	30,26	-1,21
1972	992.99	148,44	429,14	0	0	0	13,56
1988	518.61	2,22	176,09	182,86	3,39	80,92	9,31
1999	272.48	5,22	118,90	89,15	4,84	43,66	9,41
2005	170.34	1,59	60,20	158,92	0,32	48,23	-1,15
2019	343.30	1,13	32,80	50,98	0,15	14,84	1,31

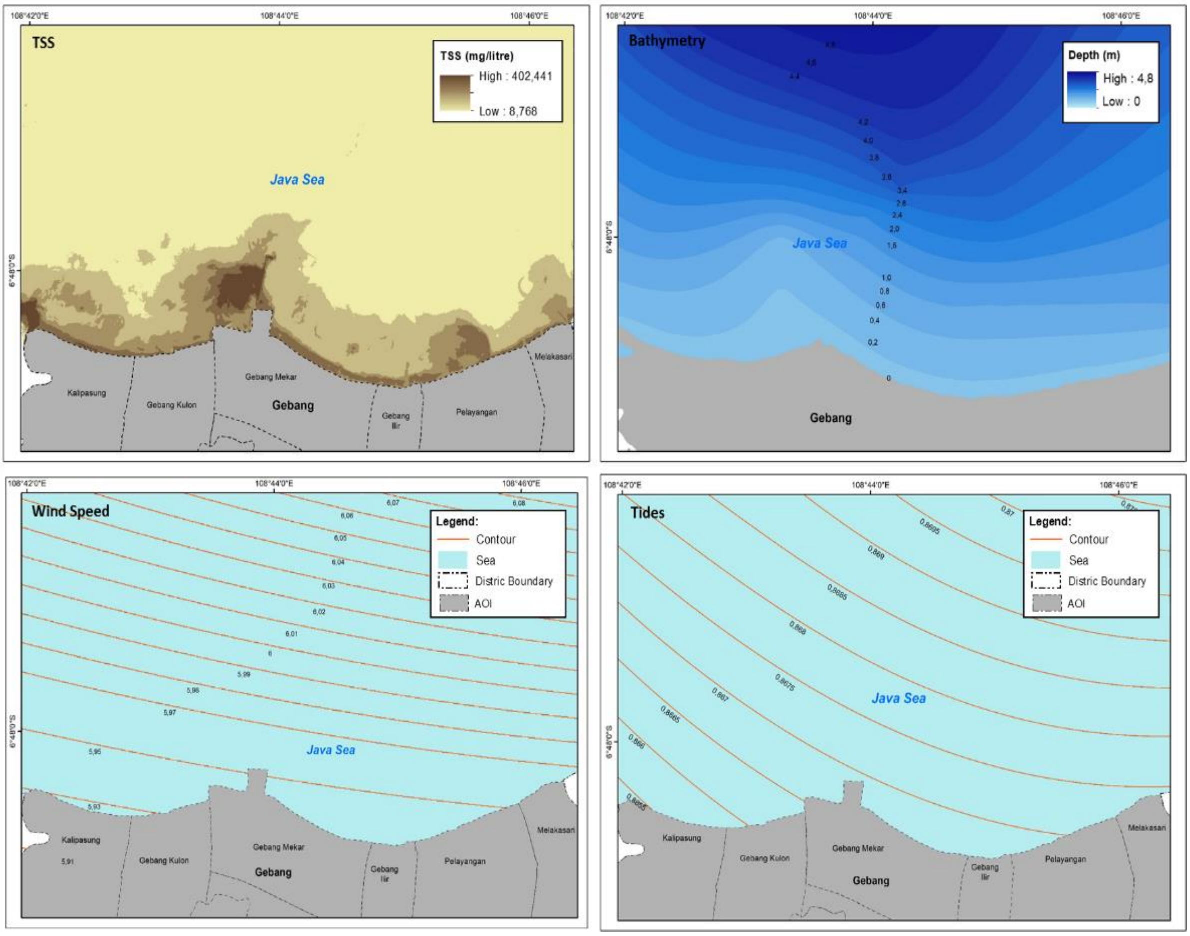

Fig. 4. Physical Factors Map.

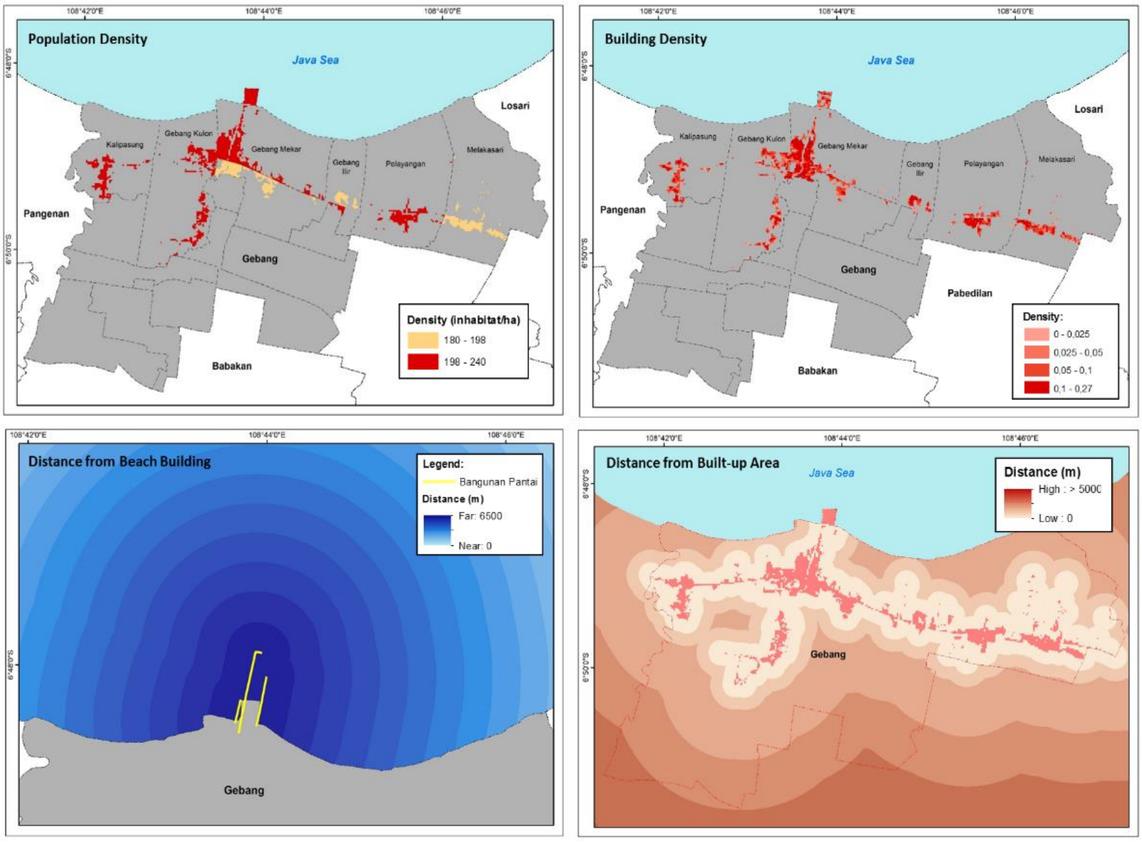

Fig. 5. Social Factors Map.

Table 3. Variable Coefficient of Multiple Regression Test Result.

Variable		B	t-count	Sig.
Constant		1805093	14.730	0.000
TSS	X_1	237.273	9.737	0.000
Ocean's depth (bathymetry)	X_2	-251.669	-17.321	0.000
Wind speed	X_3	-75.071	20.646	0.000
Tides	X_4	-1390220	-14.978	0.000
Distance from beach building	X_5	11.381	2.099	0.037
Population density	X_6	44.918	0.979	0.328
Built-up density	X_7	140.824	1.366	0.173
Distance from built-up area	X_8	8409.884	-16.156	0.000

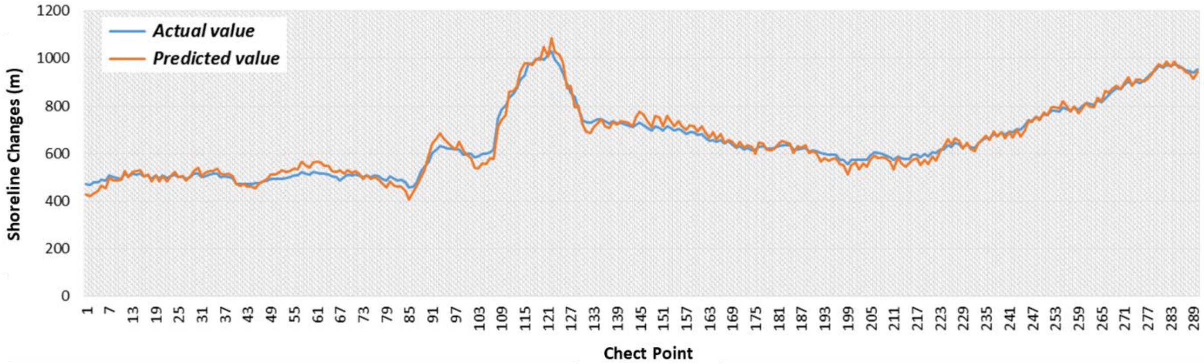

Fig. 6. Comparison of Shoreline Change Actual and Predicted Value.

$$Y = 1805093 + 237.273 (X_1) - 251.669 (X_2) - 75.071 (X_3) - 1390220 (X_4) + 11.381 (X_5) + 44.918 (X_6) + 140.824 (X_7) + 8409.884 (X_8) \quad (4)$$

The residual data has a normal distribution with a curve shape resembling a perfect bell and a significant value of more than 0.05. Therefore the data in this study were declared normal and continued in the multicollinearity test to find out intercorrelation, collinearity between independent variables, and heteroscedasticity. From these results, eight independent variables used were declared feasible with tolerance below 1, VIF below 10, and a random pattern of the standardized predicted value. The multiple regression model shows eight independent variables that have a significant collective influence on shoreline change in the Gebang with r-square values reaching 0.977 and F-count 1473.911 with p-value of less than 0.01. When referring to the r-square value, mathematically that produces **Equation 4** has an epsilon of 0.023 and a standard estimated error of 22.83. The partial effect of each independent variable on the dependent variable as linear regression models known by Student's T-Test is presented in the following **Table 3**.

Five dependent variables which include TSS (X1), beach buildings (X5), population density (X6), building density (X7), and distance from the built-up area (X8) have positive coefficients. According to Park et al. (2012), TSS is a major factor in the formation of land rising rapidly in inter-tidal areas with the shape of waters in the form of bays. On the beach building variable, population density and distance from the built-up area show a tendency of human-based activities to cause greater accretion. This is similar to the results of Seenipendi *et al.,* (2015) study that human intervention on the coastal environment also accelerates the accretion rate, even the existence of artificial buildings such as jetty, groin, seawall, revetment, etc. Thus the change of coastal landscape is the dominant factor that drives accretion on a sloping beach.

Three variables namely bathymetry (X2), wind speed (X3), and tides (X6) have a negative coefficient, these meaning that the value opposite for coastal accretion. This condition is common in shallow and gentle slopes close to shore, where accumulation occurs due to backwash sediment (Emran *et al.,* 2017; Inman *et al.,* 2005). Accretion generally occurs in calm waters, where low wind speeds and non-extreme tidal dynamics cause sediment displacement to follow only longshore current and tend to be deposited along the coast (Weitzner, 2015). From this model, it is known that physical and social factors also have a significant influence on the process of shoreline change in Gebang. The regression model in Equation 4 provides accurate results for modeling shoreline changes with prediction value is close to the real-world as shown in Figure 6. Thus, the potential for land formation arising on the coast of Gebang in the future can be well predicted if the dataset of independent variables is met.

4. Conclusion

Gebang has addition the longest coastline to reach 992.99 meters during 104 years which occurred in segment B, the biggest gain was occurred in 1972 and reached 391.26 Ha. The maximum abrasion occurred in 1988 with a length of 182.86 meters. Physical and social factors that affect shoreline changes include TSS, ocean's depth, wind, tides, the existence of beach buildings, population density, building density, and distance from built-up area. Based on the results of the statistical test is known that physical and social environmental variables have a simultaneous, strong, and significant effect on the shoreline change in Gebang. The resulting correlation between the actual value and the predicted results reached 0.977, where the ocean's depth is the most influential factor of the accretion phenomenon.

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