Impact of Land Subsidence and Sea Level Rise Influence Shoreline Change in The Coastal Area of Demak

Y Prasetyo1), N Bashit1), B Sasmito1) and W Setianingsih1)

1)Remote Sensing and Photogrammetry Lab, Geodesy Engineering Dept, Faculty of Engineering, Diponegoro University, Jl. Prof. Soedharto SH, Tembalang-Semarang, Central Java, Indonesia, 50277

Author email: yudo.prasetyo@ft.undip.ac.id 1)

Abstract. Climate change has a negative impact on the environment, one of which is the phenomenon of sea level rise. Sea level rise has a devastating effect on marine coastal areas such as shoreline abrasion. Sea level rise has caused a reduction in land, one area on the north coast of Java affected is located in Demak. Demak is a coastal area that has the potential for a shoreline abrasion because of sea level rise and a decrease in the land surface. Monitoring of shoreline changes needs to be monitored in order to find out the magnitude of the shoreline changes and the impact caused by reduced a mainland. One method that can be used to monitor shoreline changes is to use remote sensing technology. Satellite imagery can produce changes in shoreline abrasion without coming to the objects directly. This study aims to assess sea level rise and land subsidence resulting in changes in the shoreline in Demak. The data used are Jason-1 and Jason altimetry satellite data 2, Landsat 7 ETM + satellite imagery in 2011 and Landsat 8 in 2016. Altimetry satellite data is processed to obtain sea level rise on the coast of the Java Sea. Sea Level Anomaly (SLA) data processing uses Inverse Distance Weight (IDW) interpolation. The rise in sea level is determined by the analysis of linear trends from the processing of altimetry satellite data. The separation between water and land boundaries from Landsat satellite imagery uses the band ratio method on Green bands and NIR bands. shoreline changes are calculated using DSAS (Digital Shoreline Analysis System). The results of data processing obtained an average sea level rise in the Java Sea in 2011 to 2016 of + 6.80 mm/year. The highest increase was in Jakarta waters of +11.043 mm / year and the lowest was in Surabaya waters with an increase of +3.85 mm/year. The increase in Semarang waters was +5.52 mm/year which was used as validation with the tidal data of Semarang. The average change in coastline in the Demak region is -119.08 m. Demak experienced a land subsidence of +2,078 to -8,376 cm/years. The biggest abrasion occurred in Sayung Subdistrict of -691 m. The largest accretion occurred in the District of Wedung + 512.48 m. Based on the results of the increase in water level in the coastal areas of the island of Java and land subsidence that occurred in Demak caused a fairly wide shoreline abrasion.

Keywords: Shoreline, Land Subsidence, Altimetry Satellite, Sea Level Rise

1. Introduction
Climate change has a negative impact on the environment, one of which is the phenomenon of sea level rise which has a negative impact on coastal areas. Sea level rise has a bad impact on the coastal sea such as shoreline abrasion and can cause the sinking of small islands. If it happens for a long time,
Sea level rise will cause damage to the coastal area. The coast is a land area on the edge of the sea that still gets the influence of the sea including tides and sea breezes [9]. The area of the coastal area is influenced by the coastline in an area. The coastline is the boundary between mainland and seawater, where the position is not fixed and can move according to the tides and coastal erosion that occurs [13]. Sea Level Rise in a long period of time will result in increasing seawater so that it will increase the intensity and frequency of floods and can occur inundation of a land area. Sea level rise can cause a reduction in land area, one of the areas on the north coast of Java that is affected at Demak Regency. Demak Regency is a coastal area that has the potential for shoreline abrasion due to sea level rise and land subsidence. Coastal areas are also areas that are very susceptible to hazards such as inundation and land subsidence. The impact of the disaster will be greater if it is not handled properly. Since the 1980s, Demak District has become one of the areas that are often affected by floods. Residents living in the lowlands, port cities and river mouths are an area that can be affected due to global warming and climate change. Monitoring of shoreline changes needs to be monitored in order to find out the magnitude of the shoreline changes and the impacts. One method that can be used to monitor shoreline changes is to use remote sensing technology. This study aims to assess sea level rise and land subsidence resulting in changes in the coastline in Demak Regency.

2. Materials and Methods

2.1. Materials
In this paper using primary and secondary data as follows:

| NO | Data                      | Data Source                        | Type Of Data |
|----|--------------------------|------------------------------------|--------------|
| 1  | Jason-1 altimeter data   | Download data on http://rads.tudelft.nl/rads/rads.shtml | 2006-2008    |
| 2  | Jason-2 altimeter data   | Download data on http://rads.tudelft.nl/rads/rads.shtml | 2009-2016    |
| 3  | Landsat 7 Satellite Images | Download data on USGS              | 2006,2011    |
| 4  | Landsat 8 Satellite Images | Download data on USGS              | 2016         |
| 5  | QuickBird Satellite Images | BPN Kabupaten Demak                | 2015         |
| 6  | Tidal data on Semarang   | Badan Informasi Geospasial         | 2012-2016    |
| 7  | coastline                | Field Survey                       | 2017         |

2.2. Methods

2.2.1 Remote Sensing. Remote sensing is a science, technique, art to get information about an object, area or phenomenon through analysis of data obtained without direct contact with the object [7]. Simple sense of remote sensing is a person doing the process of reading the text on the book to get the information contained in the text [7]. The process of acquiring remote sensing data using sensors placed on satellite. Remote sensing data has resolution on remote sensing data depending on satellite. Resolution on satellite imagery is very important to be understood by the user of the image to know the data to be used as needed. The condition and quality of the image can be viewed based on image resolution information such as spatial resolution, spectral resolution, temporal resolution and radiometric resolution. The resolution contained in satellite imagery has characteristics generated by
the sensor system on the satellites [11]. Remote sensing satellites experience the development of sensor capability in obtaining high resolution image data. High resolution satellite imagery is an image to obtain information of object detailed on the earth’s surface. High resolution image can be used to classify land use from the process of visual interpretation and classification image. Visual interpretation and classification image of high resolution image can produce good classification accuracy [12].

2.2.2 **Altimetry satellite systems.** Altimetry satellite systems have been developing since 1975. At present, altimetry satellite systems generally have three long-term scientific objectives, among others observing global ocean circulation, monitoring volumes, and polar ice sheets, and observing global average sea level changes. The use of altimetry satellites is intended to understand more deeply the global climate system and the role played by the oceans [1]. Altimetry satellites are equipped with several devices such as radar pulse transmitters, radar pulse receivers, and high accuracy clocks. A radar altimeter carried by a satellite emits pulses of electromagnetic waves to the surface of the sea. The pulses are reflected back by the sea surface and received again by satellite. The main information to be determined by the altimetry satellite is the topography of the sea level. This is done by measuring satellite altitude above sea level by using the travel time from radar pulses sent to sea level and reflected back to the satellite [1]. The data is downloaded from the RADS website (Radar Altimeter Database System, http://rads.tudelft.nl/rads/data/radsdata1.cgi), with a 10-day temporal resolution (1 cycle). Please note that the RADS data acquisition website provides a wide selection of types of data that can be downloaded, so that this study is limited to using only SLA data with RADS standard correction [4].

2.2.3 **Sea Level Rise.** Sea Level Rise is a phenomenon of sea level rise which is generally always associated with global warming. Sea level has experienced a rise of 120 meters since the peak of the ice age 18,000 years ago. The highest sea level rise occurred before 6,000 years ago. From 3,000 years ago to the beginning of the 19th century, sea level almost remained only increased by 0.1 to 0.2 mm / year, until 1900, sea level rose by 1 to 3 mm / year. since 1992, the TOPEX / Poseidon Altimetry satellite has indicated a rate of sea level rise of 3 mm/year. Global temperatures are increasing, causing ice near the poles to melt at an ever increasing speed. Both land and water have the ability to reflect light less when compared to ice and consequently, absorb more solar radiation. This adds to the warming of global temperatures and gives rise to more melting ice, then becomes a continuous cycle that causes the Sea Level Rise phenomenon.

Sea level rise was initially seen as a series of tidal processes. At present, sea level rise is allegedly caused by the effects of global warming. The relative increase in sea level can change for several reasons and over a range of time [14]. Increased sea level can be caused by the phenomenon of climate change due to melting ice conditions so that there is an increase in the volume of seawater. Water mass in Indonesia can be affected by the characteristics of the water mass and the monsoons system [6]. The causes of sea level rise are classified into three factors, that is:

1. Global factors. The main cause of sea level rise which is a global factor is the thermal expansion of the sea surface layer and the melting of polar ice caps and global climate change.
2. Regional factors. Regional factors are generally caused by tectonic activity in a region that covers a relatively wide area, for example, the shift of tectonic plates.
3. Local factors. Local factors are much influenced by the process of subsidence due to changes in land time due to human activities and changes in the underground fluid.

2.2.4 **Coastline.** The coastline is the boundary between land and sea water, where the position is not fixed and can move according to the tides and coastal erosion that occur [13]. The coastline has varying properties according to the periodic tide conditions. Although certain fixed and periodic sea level surfaces must be chosen to explain the position of the coastline. In areas affected by tides, the coastline is approximated as the Mean High Water Line (MHWL). Areas that are not affected by tidal
fluctuations, the coastline used is the Mean Water Level Line (MWL) or Mean Sea Level (MSL). On the sea, the map is usually used a high water line (High Water Line) as a coastline. The coastal area is an area that is very dynamic towards change, as well as changes in the coastline. Shoreline changes are a continuous process through various natural processes on the coast which include sediment movement, longshore current, wave action and land use [2]. Shoreline changes can occur due to land subsidence or erosion and the addition of mainland [9]. Addition of land is one of the factors in the change of coastline influenced by the construction of ports, infrastructure development, industrial areas, and beach tourism. While the shoreline changes due to land subsidence can be caused by abrasion estimated due to an erosion of ocean wave energy.

2.2.5 Band Ratio. Band ratio or rationing is done to compare an image with another image. Sometimes, the difference in the value of Brightness Value (BV) or the degree of brightness of an image from the same surface material can be caused by topography, shadow, or seasonal changes. Normalized images with a digital value range of 0 to 1 [5]. The band ratio equation [5] can be seen in formula 1.

$$\text{BV}_{ijr} = \frac{\text{BV}_{ijk}}{\text{BV}_{ijl}}$$ ...........................................(1)

$\text{BV}_{ijr}$ = ratio of output in row i and column j
$\text{BV}_{ijk}$ = reflectance k
$\text{BV}_{ijl}$ = reflectance l

The ratio between band 2 on Landsat 7 and band 3 on Landsat 8 with band 4 on Landsat 7 and band 5 on Landsat 8 will produce the best image ratio for extracting shoreline, especially for muddy beaches which are found in mangroves. The choice of band 4 / band 5 and band 2 / band 3 is based on the function of each of the different wavelengths. According to the FAQ on the official website of the USGS (United States Geological Survey), band 2 on Landsat 5 has a wavelength of 0.52 µm -0.60 µm and band 3 on Landsat 8 has a wavelength of 0.53 µm -0.59 µm, both have the same advantages for analysis that emphasizes peak vegetation, it serves to assess the density of plants in an area. Whereas, band 4 on Landsat 5 has a wavelength of 0.77 µm-0.90 µm and band 5 on Landsat 8 has a wavelength of 0.85 µm-0.88 µm, both of which are suitable for analyzing surface biomass levels and shoreline extraction [10].

2.2.6 Land subsidence. Land subsidence is a phenomenon that often occurs in big cities in Indonesia. Land subsidence can cause huge losses because it can cause flooding [3]. Land subsidence can be caused by a number of things including underground water subsidence, solidification of clays in aquifers, mining and sediment compaction, compression of alluvial deposits naturally, landfill and loading of buildings [8]. Land subsidence can be interpreted as a decrease in land relative to a particular reference field that is considered stable. In this case, changes occur in the vertical direction in an area. Land subsidence can occur slowly, or also occur suddenly in an area depending on the symptoms experienced. There are many land subsidence events in a few centimeters per year. Sudden changes in the land surface are usually followed by real physical changes and can be known directly large and the speed of decline. However, for land subsidence which is slowly known after a long event, the magnitude of the decline can be determined periodically. Slow land subsidence can be caused by increased population density and groundwater extraction. Excessive groundwater removal causes an empty space under the ground which can lead to land subsidence. Identification of land subsidence can be seen from the rate of land subsidence.

3. Results and Discussion

3.1. Sea Level Rise Analysis
Altimetry satellite data used to calculate the sea level rise is ascending pass 051 for the period 2006-2016 and descending pass 064 for the period 2006-2016. The use of ascending pass 051 and descending pass 064 because it is close to the research area in Demak Regency.

Based on the graph in Figure 1 the value of the linear trend is:
\[ y = 0.0002x + 0.0544 \]

The results of the linear trend above are still in units of meters/cycle, it needs to be changed in units of millimeters/year to get the Sea Level Rise value. Calculations for obtaining Sea Level Rise values are:

\[ \text{SLR value} = (0.0002 \times 1000) / (9.9156 / 365) = 7.362 \text{ millimeters/year}. \]

The increase in sea level in the ascending pass 051 in 2006-2016 was 7.362 millimeters/year.

Based on the graph in Figure 2 the value of the linear trend is:
\[ y = 0.0001x + 0.0605 \]

The results of the linear trend above are still in units of meters/cycle, it needs to be changed in units of millimeters/year to get the Sea Level Rise value. Calculations for obtaining Sea Level Rise values are:

\[ \text{SLR value} = (0.0001 \times 1000) / (9.9156 / 365) = 3.681 \text{ millimeters/year}. \]

The rise in sea level in descending pass 064 in 2006-2016 was 3.681 millimeters/year.

### 3.2. Sea Level Rise and Observation of Tides Analysis

The SLA altimetry chart of the ascending pass 051 is compared with tidal observation data from the Semarang tidal station. The selection of tidal stations in Semarang because Semarang is the closest area to the Demak Regency and in the area, there are tidal data which are used as validation results of processing water level rise from satellite altimetry data.
Figure 3. Graph SLA pass 051 with graph tidal data Semarang

Table 2 shows that the significance value of SLA and tidal data is > 0.05, the data is normally distributed.

|                  | Kolmogoror-Smirnov | Shapiro-Wilk |
|------------------|--------------------|--------------|
|                  | Statistic          | df | Sig. | Statistic | Df | Sig.    |
| SLA              | 0.046              | 111 | 0.200      | 0.995     | 111 | 0.960   |
| Pasang Surut     | 0.044              | 111 | 0.200      | 0.991     | 111 | 0.648   |

Table 3 shows that the correlation test between tide and SLA is 0.488, so it can be concluded that the SLA data on the 051 pass and the tidal data have sufficient correlation.

|                  | SLA     | Tidal data |
|------------------|---------|------------|
| SLA              | Pearson Correlation | 1 | 0.488 |
|                  | Sig. (2-tailed)      | 0.000     |
|                  | N                  | 111 | 111 |
| Tidal data       | Pearson Correlation | 0.488 | 1 |
|                  | Sig. (2-tailed)      | 0.000     |
|                  | N                  | 111 | 111 |

The SLA altimetry graph descending pass 064 is compared to tidal observation data from the Semarang tidal station.

Figure 4. Graph SLA pass 064 with graphs of tidal data Semarang
Table 4 shows that the significance value of the SLA is > 0.05, the data is normally distributed, while the significance value of the tide is < 0.05, the data is not normally distributed. Data that is not normally distributed are caused by the time interval of data used is 9.9156 days and there is a data vacuum at a certain time. Because of the data vacuum, the time interval between one data and the next data is more than 9.9156 days.

**Table 4. Test results for normality in descending pass 064**

|                | Kolmogorov-Smirnov | Shapiro-Wilk |
|----------------|--------------------|--------------|
|                | Statistic | df  | Sig.  | Statistic | df  | Sig.  |
| SLA            | 0.053     | 141 | 0.200 | 0.995     | 141 | 0.395 |
| Pasang Surut   | 0.082     | 141 | 0.023 | 0.981     | 141 | 0.046 |

Table 5 shows the results of the correlation test between tides and SLAs of 0.557 so that it can be concluded that the SLA data on the pass 064 and Semarang tidal data have a strong correlation.

**Table 5. Test results for correlation descending pass 064**

|                   | SLA        | Tidal Data     |
|-------------------|------------|----------------|
| Spearman’s rho    | SLA        | Correlation Coefficient |
|                   |            | 1.000          | 0.557           |
| Sig. (2-tailed)   |            | 0.000          |                  |
| N                 | 141        | 141            |
| Tidal Correlation Coefficient | 0.557 | 1.000 |
| Sig. (2-tailed)   |            | 0.000          |                  |
| N                 | 141        | 141            |
3.3. Land Subsidence and Sea Level Rise cause Shoreline changes Analysis

Point A in Figure 5 shows the smallest abrasion in Wedung District of -0.3 m. Point B shows the largest abrasion in Wedung District at -571.08 m. Point C shows the largest abrasion in Bonang District of -434.49 m. Point D shows the smallest abrasion in Bonang District of -0.33 m. Point E shows the largest abrasion in Karangtengah District of -156.63 m. Point F shows the smallest abrasion in Karangtengah District of -0.17 m. G point shows the greatest abrasion in Sayung District of -691 m. Point H shows the smallest abrasion in Sayung District of -2.23 m. The point I show the smallest accretion in Wedung District of +1.5 m. Point J shows the largest accretion in Wedung District of +512.48 m. Point K shows the largest accretion in Bonang District of +268.97 m. Point L shows the smallest accretion in Bonang District of +12.2 m. Titik M shows the largest accretion in Karangtengah District at +68.48 m.

Point A is the largest abrasion in Wedung District. B is the biggest abrasion in Bonang District. C is the biggest abrasion in Karangtengah District. D is the biggest abrasion in Sayung District. SLR values increase from 2006 to 2011, but from 2011 to 2016 decreased compared to 2006 to 2011. Changes in shoreline abrasion occur at points A, B, C, and D. Relationship between SLRs and shoreline changes in 2006 until 2011, which can be seen from SLR charts and changes in coastlines that have increased. Points A, B, and D in 2011 to 2016 experienced a higher increase than point C. The SLR chart from 2011 to 2016 decreased. SLR graphs and shoreline changes from 2011 to 2016 have their respective patterns of increase, this is due to the lack of shoreline change data so that no changes can be detected every year.
Sea level rise is not a major factor in changes in coastline in Demak Regency. According to Komariah Ervita (2015) in his research stated that the erosion process occurred a lot in Sayung Subdistrict which caused several hamlets to sink and the community relocated to other hamlets. Erosion Processes also occur in Karangtengah and Bonang Subdistricts, but the extent and impact are not too large as happened in Sayung District. The Erosion Process that occurred in Wedung Subdistrict was mostly located in the northern part of Delta Wulan, while in the southern part it was more dominated by the accretion process caused by sedimentation from upstream material carried by the Wulan River. The accretion process that occurs mostly is in upstream of the river which indicates the deposition of upstream material carried by the river flow which is then deposited in the downstream part of the coastal area.

Erosion in Sayung District was caused by land subsidence. Lutfi Eka Rahmawan (2016) in his research stated that the land subsidence rate in Sayung District was between +2.078 to -8.376 cm/year with IGS net processing method. The CSEM local net method produces a high change of +1.341 to -5.822 cm/year. While the radial method ranges from +0.130 to -8.546 cm/year. The pattern of land subsidence (PMT) in Sayung has spatially varying characteristics, with several processing methods found the tendency of land subsidence is getting closer to the western northern coast of Sayung with the largest decrease in Sidogemah and Bedono villages. In line with these results, these two villages suffered the worst impact from PMT in the form of rob floods and infrastructure damage.

4. Conclusion
1. Altimetry satellite observations for the period 2006-2016 show the phenomenon of Sea Level Rise in the North Sea of Java with an average increase of +6.80 mm/year. Sea level rise in the average study area is equal to ±5.52 mm/year.
2. The results of the Digital Analysis Shoreline System (DSAS) calculation show the occurrence of abrasion and accretion of coastlines in the Demak region in 2006-2016. Almost every area in the Demak coast experiences abrasion. The average abrasion occurred in Demak Regency was -119.08 m. The biggest abrasion that occurred in Wedung District was -571.08 m. The biggest abrasion in Bonang District -434.49 m. The biggest abrasion in Karangtengah District is -156.63 m. The biggest abrasion in Sayung District is -691 m. The biggest accretion in Wedung District is +512.48 m. The biggest accretion occurred in Bonang District of +268.97 m. The largest accretion in Karangtengah District is +68.48 m.
3. Sea level rise in 2006 to 2011 and shoreline changes from 2006 to 2011 have the same increase in graphs, which shows the relationship between sea level rise and shoreline changes. Sea level rise and shoreline changes from 2011 to 2016 have their respective chart increases. Sea level rise is not a major factor in shoreline changes. The abrasion process in Sayung District is caused by...
the rate of land subsidence. Abrasion process which occurs in the Wedung District mostly located in the north, while the southern part is dominated by the accretion process caused by sedimentation from upstream material carried by the river. The accretion process that occurs mostly is at the mouth of the river which indicates the deposition of upstream material carried by the river flow which is then deposited in the downstream part of the coastal area. The process of abrasion and accretion in the Karangtengah and Bonang Districts extends and the impact is not too large as happened in Sayung and Wedung Districts.

References
[1] Abidin H Z 2001 Geodesi Satelit Jakarta: PT. Pradnya Paramita
[2] Arief M, Winarso G, and Prayogo T 2011 Kajian Perubahan Garis Pantai Menggunakan Data Satelit Landsat Di Kabupaten Kendal 71–80
[3] Gumilar I, Abidin H Z, Hutasoit L M, Hakim D M, Andreas H, Sidiq T P, and Gamal M 2012 Pemetaan Karakteristik Penurunan Muka Tanah (Mapping Of Land Subsidence Characteristic Using Geodetic Methods) 17–27
[4] Hartanto P, Prijatna K, and Nurmaulita S L 2014 Perubahan Muka Air Laut Berdasarkan Data Satelit Altimetri Dan Data Argo Pada Rentang 1992-2012 Di Wilayah Samudera Pasifik Bagian Barat (The Sea Level Change of the Western Pacific Ocean Based on Altimetry and Argo Floats 17–24
[5] Istriqomah F 2016 Pemantauan Perubahan Garis Pantai Menggunakan Aplikasi Digital Shoreline Analysis System (Dss) Studi Kasus : Pesisir Kabupaten Demak. Undergraduate Thesis Teknik Geodesi Universitas Diponegoro Semarang.
[6] Khasanah I U and Yenni J N 2017 Kenaikan Muka Air Laut Perairan Sumatera Barat Berdasarkan Data Satelit Altimetri JASON-2 2 1–8
[7] Lillesand T M, Kiefer R W and Chipman J W 2004 Remote Sensing and Image Interpretation (USA: John Wiley and Sons)
[8] Phien-wej N, Giao P H, and Nutalaya P 2017 Land subsidence in Bangkok, Thailand, (December). https://doi.org/10.1016/j.enggeo.2005.10.004
[9] Roziqin A and Gustin O 2011 Pemetaan Perubahan Garis Pantai Menggunakan Citra Penginderaan Jauh di Pulau Batam, 295–299
[10] Septiangga B 2017 Penginderaan Jauh Untuk Pemantauan Dinamika Batas Daerah Darat di Sebagian Kawasan Pesisir Demak-Jepara Departemen Geografi Lingkungan Universitas Gadjah Mada
[11] Smith R B 2012 Introduction to Remote Sensing (Nebraska: Microimages.inc.)
[12] Sudaryanto 2013 Studi Penggunaan Lahan Di Kecamatan Umbulharjo Kota Yogyakarta Berdasarkan Interpretasi Citra Quickbird Magistra 86 Th. XXV 112–118
[13] Triatmodjo B 1999 Teknik Pantai Beta Offset Yogyakarta
[14] Yoskowitz D W, Gibeaut J, and McKenzie A 2009 The Socio-Economic Impact of Sea Level Rise in the Galveston Bay Region