JOURNAL OF APPLIED GEOSPATIAL INFORMATION

Vol 2 No 2 2018

http://jurnal.polibatam.ac.id/index.php/JAGI
ISSN Online: 2579-3608

Tidal Correction Effects Analysis on Shoreline Mapping in Jepara Regency

Arief Wicaksono [1,*], Pramaditya Wicaksono[1], Nurul Khakhim[1], Nur Mohammad Farda[1], Muh Aris Marfai[1]

[1] Department of Geographic Information Science, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia.
*Corresponding author e-mail: wicaksono.arief08@gmail.com

Received: October 11, 2018
Accepted: December 18, 2018
Published: December 19, 2018

Abstract

The existence of high-spatial resolution imagery that are now available free by Planet Labs opens up opportunities in detailed scale mapping research, both as basic data and as reference data for geometry accuracy assessment. However, the use of several satellite sensors types with different recording times is the biggest obstacle in the use of high spatial resolution imagery as reference data because the shoreline instantaneous imaging at the data acquisition time does not consider the spatial and temporal variability of the shoreline boundaries. The purpose of this study was to analyze the effect of tidal correction on shoreline mapping in Jepara Regency using Landsat 8 OLI imagery in 2018.

The effect of tidal correction analysis is done by comparing the position of the shoreline corrected by tides with the shoreline that is not corrected for tides. The influence of tidal correction is marked by differences in the position of the two shorelines. Shoreline shift calculation when there is a difference in tidal conditions between the test shoreline and the reference shoreline is carried out using the theory of right triangle (also called as one-line shift method).

Based on the analysis of tidal correction effects, it is known that the shift in shoreline position after tidal correction varies from 0.21 m to 1.8 m, the value does not exceed one pixel of the PlanetScope image (3 m) so that tidal correction does not needs to be done because the effect is insignificant and undetectable on PlanetScope imagery.

Keywords: tidal correction, shoreline, Planetscope, Landsat 8 OLI, Jepara

1. Introduction

Coastal zone is an area with dynamic processes, both due to natural processes and accelerated by human activities (Sunarto, 2004). One example of dynamics in coastal areas is the change in shoreline. Shoreline changes occur in a short or long term depending on the balance between sediment movement near the coast by waves and currents (Triatmodjo, 2008), topography (Sinaga and Susiati, 2007), coastal material, tides, and wind (Dulbahri, 1983).

Landsat imagery is an example of an image with a multispectral sensor that is widely used in Indonesia. In addition to being available for free, Landsat imagery has other advantages as stated by Tucker et al. (2004). Landsat imagery is suitable for monitoring shoreline changes because it is the only data that records global land-sea conditions, multispectral characteristics, and easy acquisition at a spatial scale of 15 – 30 meters for the past 37 years. With these advantages, Landsat imagery provides a great opportunity for researchers to be able to map and monitor changes in natural and human phenomena that occur in coastal areas. Even so, Liu et al. (2017) stated that the biggest challenge in utilizing Landsat imagery for shoreline acquisition and monitoring is the limited image spatial resolution of 30 m so that the minimum shoreline change that can be detected by Landsat imagery is a change in the size of its spatial resolution. Various studies have presented the use of Landsat imagery to map shorelines, including Rokni et al. (2014), Yang et al. (2015), Ji et al. (2015), Li and Gong (2016), as well as Sarp and Ozcelik (2017).

The existence of high-spatial resolution remote sensing imagery that are now available free of charge by Planet Labs opens up opportunities in detailed scale mapping research, both as basic data and as reference data for assessing geometry accuracy. In shoreline research, research by Sarp and Ozcelik (2017) and Elfatma (2017) provides examples of the use of high spatial resolution remote sensing imagery as a reference data for geometry accuracy assessment. The high spatial resolution imagery was chosen as an alternative comparison in testing shoreline geometry accuracy on a regional scale map from Landsat imagery replacing the base map (RBI and LPI) because they were irrelevant as a comparison of shoreline data over the 2000s, field surveys with GPS requires big time and money, and compressed Quickbird imagery from Google Earth with low data quality.

However, the use of several types of satellite sensors with different recording times according to Kelly and Gontz (2018) is the biggest obstacle in the use of high spatial resolution images as reference data because the shoreline instantaneous imaging at the time of data acquisition does not consider the spatial and temporal variability of the shoreline boundaries. Through certain tidal cycles and depending on the coastal geometry the shoreline can change from centimeters to hundreds of meters horizontally. However, according to Boak and Turner (2005) the consideration when going to tidal correction is the tidal variation and the slope of the beach. Image spatial resolution also needs to be considered because it affects the minimum area of the object that can be detected from the image. Therefore, further research is needed on how much influence the tidal correction has on the shoreline mapping in Jepara Regency.

The shoreline positions used on each map may differ depending on the purpose of mapping and selecting the sea level position. The sea level position refers to Jaring Kontrol Vertikal Nasional (JKVN). Law No. 4 of 2011 concerning Geospatial Information states that the shoreline of the Indonesian Base Map (RBI) is determined based on the average sea level position, while the shoreline on the Indonesian Coast Environmental Map (LPI) and the National Marine Environment Map (LLN) is determined based on the lowest low tide sea level. RBI is used for the purpose of terrestrial topography mapping so that the shoreline is selected between the average sea level position of the highest tide and the lowest ebb average, while LPI and LLN are used for the purpose of mapping the aquatic environment, withdrawal of territorial boundaries, and navigation so that the shoreline is selected at the lowest low tide level. Meanwhile, in Act No. 23 of 2014 concerning Regional Government, what is meant by the shoreline is the boundary of the meeting between the sea and the land when the highest tide sea water occurs, which is intended for the determination of the administrative area in the management of the sea area. The choice of the definition of a shoreline must consider spatial and temporal notions, and must consider the dependence of variability on the time scale when examined (Boak and Turner, 2005). The shoreline obtained from the remote sensing image is an instantaneous shoreline, which is defined as the position of a land-sea meeting at one time.

The purpose of this study was to analyze the effect of tidal correction on shoreline mapping in Jepara District using Landsat 8 OLI imagery in 2018. By analyzing the effect of tidal correction in shoreline mapping in Jepara District using 2018 Landsat 8 OLI imagery, it can be seen how large difference in influence when making tidal corrections and not, and when tidal correction needs to be done so that the data processing stage becomes more efficient.

2. Research Methods

2.1 Study Area

Jepara Regency is located between 5^{0}43'20.93 "SL and 6^{0}47'25.81" SL, and between 110^{0}9'48.81 "EL and 110^{0}9'48.04" EL is one of the districts in the northern part of Central Java Province which bordering the Java Sea, with a shoreline of 82.73 km, including the Karimunjawa (Pemerintah Kabupaten Jepara, 2012). Some causes of shoreline dynamics in Jepara Regency are oceanographic conditions (currents, winds, waves and tides), physical development (reclamation and embankments), cultivation (mangroves and ponds), and sedimentation in river estuaries. The damage problem of mangrove ecosystems on the west coast of Jepara Regency and sand mining on the north coast of Jepara Regency is also the cause of shoreline dynamics due to changes in coastal morphology conditions that affect the direction and speed of ocean currents. Factors from the sea greatly influence the coastal land area of Jepara Regency (Marfai and Permana, 2014).

2.2 Data

The data used in this study are as follows:

1. Landsat 8 OLI imagery path 120 / row 64 recorded on March 18, 2018 at 09:47:16, used to obtain shoreline data. Obtained by accessing www.earthexplorer.usgs.gov.
2. SRTM imagery 1 Arc-Second Global Coverage recorded on September 23, 2014, used to obtain elevation data and make slope maps. Obtained by accessing www.earthexplorer.usgs.gov.
3. PlanetScope imagery in Jepara Regency recorded on March 18, 2018 at 09:20:29 and 09:21:45, and March 19, 2018 at 10:30:45, used as reference data for assessing the geometry accuracy of shoreline. Obtained by accessing www.planet.com.
4. Tidal prediction data in Jepara District in 2018 issued by the Geospatial Information Agency (BIG, for tidal correction. Obtained by accessing www.tides.big.go.id.

PlanetScope imagery is one of the products from Planet Labs, which consists of 120 CubeSat 3U satellites measuring 10 x 10 x 30 cm or known as dove. The PlanetScope imagery used in the study is at the level of Ortho Tile Product Analytic products or 3A, which has done a mosaic between the recording images in the same area so that the image coverage area becomes a 25 x 25 km uniform. This product has been projected to UTM coordinates and is orthorectified using GCP and DEM detailed with RMSE position accuracy <10 m (Planet Labs, 2018). The PlanetScope image characteristics can be seen in Table 1.

Table 1. Characteristics of PlanetScope imagery

Image Characteristics	PlanetScope
Inclination	98º
Orbit height	475 km
Area coverage	24.6 x 16.4 km
Orbit	Sun-synchronous
Spatial resolution	3 x 3 m
Temporal resolution	Daily (since 2017)
Radiometric resolution	16 bit
Band and wavelength (µm)	Band 1 (Blue): 0.45 - 0.51 Band 2 (Green): 0.50 - 0.59 Band 3 (Red): 0.59 - 0.67 Band 4 (NIR): 0.78 - 0.86
Time through the equator	9.30-11.30 local time

Source: Planet Labs (2018)

2.3 Tidal Correction Method

Tidal correction begins with seeing the tide height between the image recording date and the date of tidal predictions. The need for tidal correction takes into account the magnitude of the effect of sea level height variations during highs and lows which are affected by the slope of the coast and the spatial resolution of the image. The assumption used in tidal correction is a measurement of shifts in the image as a flat plane (Bachrodin, 2012). This tidal correction method approach can be explained based on the assumption that the delineation stage of the image will obtain the position of the sea-land boundary that will follow the coastal slope type accretion or erosion as shown in Figure 1.

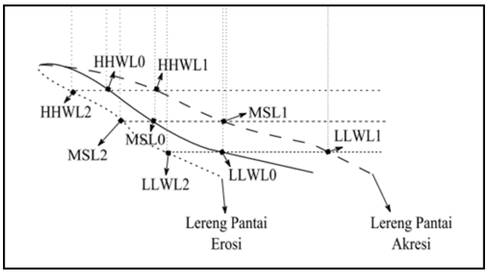
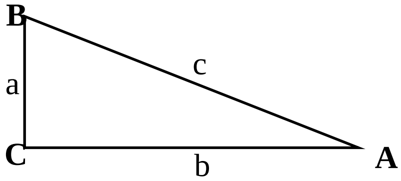


Figure 1. Cross section of a coastal area diagram along with water level points on normal coastal slopes, accretion and erosion (Kasim, 2011)

The method for shifting waterlines to the tidal-datum-based shoreline position on HWL is based on the concept of one-line model for shoreline evolution and is called one-line shift method (Chen and Chang, 2009). It is assumed that the beach moves offshore or onshore with one bottom profiles. Analysis of the tidal correction effect is done by comparing the position of the shoreline corrected by tides with the shoreline that is not corrected for tides. The influence of tidal correction is marked by differences in the position of the two shorelines. Shoreline shift calculation when there are differences in tidal conditions between the test shoreline and the shoreline reference is done using the following right triangle theory.



$$\text{Tan A} = \frac{a}{b} \quad (1)$$

Information:
a = tidal difference between the highest pairs (Landsat imagery) minus the water level at PlanetScope image recording
b = the value of shoreline shift at the highest tide (Landsat imagery)
A = the slope angle of the beach measured in the field

3. Result and Discussion

Tidal correction calculations carried out in five tidal measurement stations found in Kedung, Jepara, Bangsri, Keling, and Donorojo Subdistricts with station distribution shown in Figure 3. Tidal data at this measurement station are tidal prediction data obtained through harmonic analysis from the measurement station in Jepara District by BIG. The distribution of the five tidal measurement stations is considered to represent the shoreline which is presented based on the beach orientation. Thus, the magnitude of shoreline shift can be calculated due to the influence of tides on each shoreline in each beach orientation. The average value of the five tidal measurement stations was also calculated to generalize the tidal conditions at the study site so that it could be seen the general effect of tidal correction in shoreline mapping in Jepara Regency.

Figure 2. Distribution of tidal measurement stations, measurement of slope in the field, and slope conditions of the study area of SRTM

Figure 2 also presents a measurement point of the slope in the field which amounted to 14 points with uneven distribution because there were no measurements carried out in Kembang and Keling Districts. The reason for not being measured in the two sub-districts is the limited access to the coast in both sub-districts because it is located on the plantation land owned by PT Perkebunan Nusantara IX. Field measurements were carried out to see the comparison between the slope obtained from direct field measurements, RBI maps, and SRTM images, which are presented in Table 2. This was done to find data sources that were able to complete the slope data deficiencies from field measurements so tidal correction can be carried out on all shorelines in the study area, not limited to the location of the slope measurement points in the field.

Table 2. Comparison of slopes (in degrees) from field measurements, RBI maps, and SRTM images

No	Sub-district	Field	RBI	SRTM
1	Jepara	3	0,20	7,25
2	Jepara	2	0,17	1,68
3	Jepara	1	0,21	1,04
4	Jepara	2	0,27	3,36
5	Mlonggo	5	0,08	3,97
6	Kedung	0	0,22	2,00
7	Kedung	0	0,32	1,92
8	Mlonggo	6	0,39	2,37
9	Mlonggo	5	0,39	3,36
10	Donorojo	9	0,58	15,3
11	Bangsri	6	0,12	1,36
12	Donorojo	5	1,63	1,98
13	Jepara	3	0,18	2,51
14	Donorojo	11	0,44	0

However, from these comparisons it is known that there are differences in values between the three slope data that have different data sources. This is caused by differences in the accuracy of the data source so that the coverage area considered in calculating the slope is different and this is also influenced by the type of land cover around. Due to the absence of slope data that has similarities with the results of field measurement data, the limited field measurement data is used in the calculation of tidal correction. In general, the slope conditions on the coast of Jepara Regency are in the flat class (0-2%) and gentle slope (2.1-14%) and only in a few locations have a rather steep slope to very steep slope, especially in Donorojo District . The slope condition is obtained from the results of SRTM image processing with a spatial resolution of 30 m. SRTM imagery has limitations in the presentation of detailed slope data because it has a horizontal accuracy of 8.8 m and an absolute vertical accuracy of 6.2 m (Rodriguez, 2005). The slope condition from the results of RBI contour processing with 12.5 m interval contour also shows slope conditions which are generally similar to the results of SRTM image processing.

Tidal height graph at Jepara station on the recording date of Landsat 8 OLI imagery and PlanetScope imagery as presented in Figure 3 shows the tidal conditions when image recording is going to tide. From the tidal data, it was noted that the highest tide on March 18 and 19 2018 occurred at 12.00. This condition is in accordance with the definition of the shoreline used so that the shoreline obtained from the processing of Landsat 8 OLI images is the shoreline at high tide. If it is associated with tidal data for a month in March 2018, the tidal conditions that occur on March 18 and 19 2018 are not the highest pairs.

The type of ups and downs in Jepara Regency according to the tidal data at Jepara station for a month is a single daily (diurnal tide), which means that in one day there is one tide and one ebb. Conditions and tidal times are important to know in shoreline research when using multi-temporal and multi-source data so that the analysis of changes made is not wrong. Although it did not do the change analysis, but this study used multi-temporal and multi-source data so that the tidal conditions on PlanetScope imagery and Landsat 8 OLI images need to be considered.

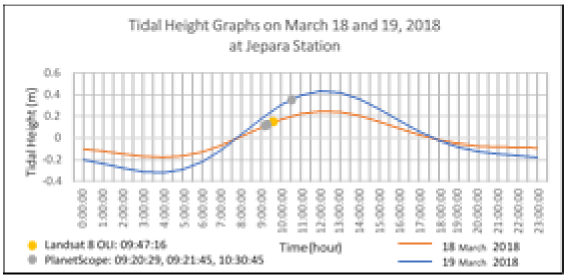


Figure 3. Tidal altitude graphs on March 18 and 19, 2018 at Jepara station

Tidal rise simulation is carried out to determine the land cover class which is prone to shoreline changes due to the influence of tides. Tidal increase of 1 m is chosen by considering the tidal range in the study area and because the value is a minimum elevation that is able to be distinguished by the SRTM imagery. From the simulation results shown in Figure 4, land cover classes that are susceptible to tidal changes include ponds, rice fields, residential buildings, non-volcanic sand beach, non-residential buildings, and volcanic sand beach. Ponds is the most vulnerable land cover to change with the greatest difference in distance when there is a change in tidal height.

The position of the shoreline used in each map may differ depending on the purpose of mapping and selecting the sea level position. The shoreline has its own uses and its properties are complementary. This study uses operational definition of the shoreline as the highest tide sea level because the shoreline data obtained is intended for the management of coastal areas and small islands so that it refers to Law No. 23 of 2014 concerning Regional Government. In order that the shoreline data in this study can be integrated with other maps that use the shoreline with different sea level positions, besides needing to pay attention to the projection and datum systems used, tidal correction should also be carried out by referring to a certain sea level position. This also requires information on beach slope and sea level position in the study area.

The selection of the shoreline definition in this study that looked at the highest tide sea level position line actually had little effect when using Landsat 8 OLI imagery as a data source. This is due to a spatial resolution of 30 m so that the difference in tides less than 30 m cannot be distinguished. Therefore, whatever definition of shoreline is used, the existence of the shoreline will remain at the same pixel. However, this is different if the tidal variations occur on the shoreline near the ponds.

Anticipation that can be done so that the shoreline position near the ponds can be obtained correctly is adjusting the recording time of the image data used in processing, namely using the image recorded at the same tidal position. However, if this step is still not capable, then another adjustment that must be done is with tidal correction. The shoreline near the pond land is most susceptible to experiencing the largest shoreline changes if there is a change in tidal height is due to the slope of the coast. So, it is necessary to know the slope information on the land cover class, both through field measurements and DEM data with high spatial resolution and good accuracy. Thus, simulation of shoreline changes due to changes in tidal height and tidal correction can be done so that the shoreline is obtained with the position of the shoreline in accordance with the operational definition of the shoreline used.

Table 3 presents the parameter values needed in tidal correction so that the information can already be known how much the impact is when making tidal corrections. From as many as 14 slope measurement points in the field with tidal conditions represented by five tidal measurement stations as shown in Figure 3, apparently none of the points experienced a shift in shoreline position due to tidal influences exceeding one pixel of PlanetScope imagery. The magnitude of the shift in the position of the shoreline starts from 0.21 m to 1.8 m. Thus, it was concluded that the tidal correction in this study did not need to be carried out because the shift in shoreline position due to tidal influences was not detected in PlanetScope imagery because the shift in distance was less than 3 m. If tidal correction is still done, it will not change geometry accuracy significantly so that the tidal correction stage can be passed.

One example of shoreline that has carried out tidal correction is shown in Figure 5. The shoreline is located in Jepara Subdistrict and is on the coast with a slope of 1^0, which is the beach with the most distant shoreline shift between the other shoreline samples measured the beach slope. The difference in the position of the shoreline between before (red) and after (blue) tidal correction is clearly visible when enlarged to the 1: 250 display scale, while when displayed on a scale of 1: 100,000, which is the result map presentation scale, the two lines the beach is indistinguishable. As a result, the difference in shoreline position between before and after tidal correction can be ignored because visually the difference is not significant.

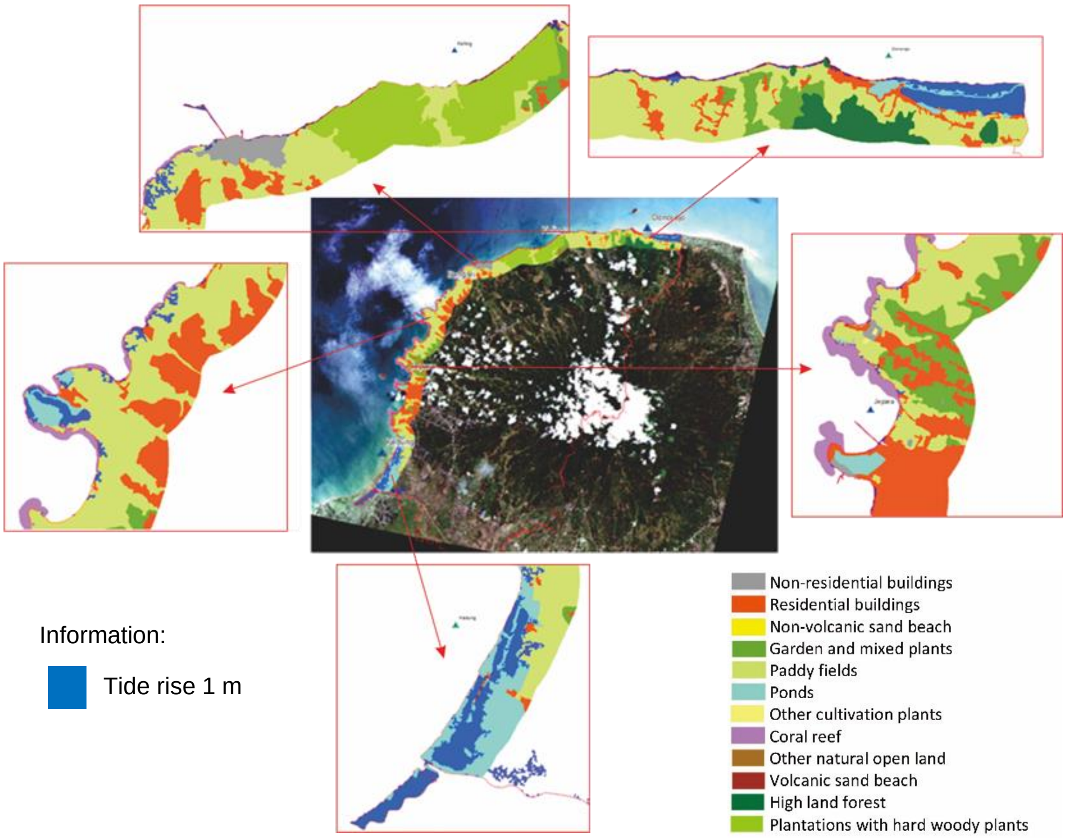


Figure 4. Shoreline on land cover which is susceptible to change when the tides rise 1 m

Table 3. Analysis of the effects of tidal correction in shoreline mapping in Jepara District

Station	a (m)	A (^{0})	Tan A	b (m)
Bangsri	0,039	5	0,0874	0,45
		5	0,0874	0,45
		6	0,1051	0,37
Jepara	0,031	1	0,0175	1,80
		2	0,0349	0,90
		2	0,0349	0,90
		3	0,0524	0,60
		3	0,0524	0,60
		5	0,0875	0,36
Kedung	0,031	0	0	-
		0	0	-
Donorojo	0,033	9	0,1584	0,21
		5	0,0875	0,38
Keling	0,033	11	0,1944	0,17
Mean	**0,033**	**4,07**	**0.0712**	**0,46**

information: a = value of tidal height difference between PlanetScope image and Landsat 8 OLI image, A = coast slope angle in the field, b = information on shoreline shift value.

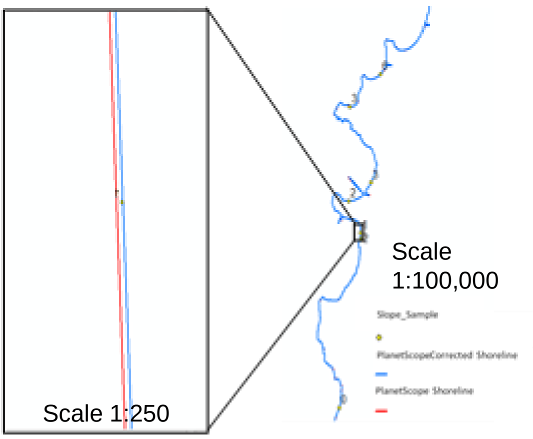


Figure 5. Differences in the position of the shoreline before (in red) and after (in blue) carried out tidal correction

Although the size of the slope measured in the closing class of the pond land in Kedung District is 0^0, but after fieldwork it is known that the traditional ponds has a quite high embankment, which does not allow tidal sea water to propagate further so the shoreline position did not shift as far as shown in tidal rise simulation. This condition is found in the existing ponds in Donorojo Sub-district as in Figure 6.

Figure 6. Condition of traditional ponds with high embankment in Donorojo District

4. Conclusion

Based on the analysis of tidal correction effects, it is known that the shift in shoreline position after tidal correction varies from 0.21 m to 1.8 m, the value does not exceed one pixel of the PlanetScope image (3 m spatial resolution) so that tidal correction does not need to be done because the effect is insignificant and undetectable on PlanetScope imagery. Based on some of the results above, the following information is obtained: (1) based on the simulation of the tidal rise of 1 m, the most susceptible shoreline to shifting position due to tidal influences is the shoreline near the ponds. However, this needs to be re-checked in the field regarding the condition of the dividing embankment between the ponds, whether it is high enough to block sea water from passing or not, (2) the slope which has a large influence on the shifting of shoreline due to tidal influences is when valuable > 0^0 and <1^0, (3) based on tidal data analysis at 09.00 and 10.00 (assuming the recording time of Landsat 8 OLI and PlanetScope imagery) in March 2018 then the maximum tidal range is 0.4 m so that the tidal range is that large and the slope slope 1^0 then tidal correction needs to be done for the shoreline from PlanetScope imagery, while for shorelines from Landsat 8 OLI imagery is not necessary, and (4) with such tidal conditions (always rise), it means that shoreline obtained from Landsat 8 OLI Imagery will always meet the operational definition of the shoreline used.

Acknowledgements

The author would like to thank the faculty for all the support.

References

Abidin, H.Z., 2000. Penentuan Posisi dengan GPS dan Aplikasinya. Pradnya Paramita, Jakarta.

Bachrodin, I., 2012. Penggunaan citra landsat multi-temporal untuk kajian perubahan garis pantai di Jawa (thesis).

Boak, E.H., & Turner, I.L., 2005. Shoreline Definition and Detection: A Review. Journal of Coastal Research, 21(4), 688-703.

Dulbahri., 1983. Aplikasi citra landsat skala 1:250.000 untuk studi perubahan garis pantai di daerah Jawa Tengah dan Jawa Timur (rep.). aplikasi citra landsat skala 1:250.000

untuk studi perubahan garis pantai di daerah Jawa Tengah dan Jawa Timur

Elfatma, O., 2017. Sistem informasi geografi dan penginderaan jauh untuk studi pesisir: perubahan garis pantai multi-proxy di Kepesisiran DIY dan prediksi garis pantai tahun 2026 (thesis).

Ji, L., Geng, X., Sun, K., Zhao, Y., & Gong, P., 2015. Target Detection Method for Water Mapping Using Landsat 8 OLI/TIRS Imagery. Water, 7(2), 794-817.

Kasim, F. 2011. Koreksi Pasang Surut dalam Pemetaan Perubahan Garis Pantai Menggunakan Data Inderaja dan SIG. Jurnal Ilmiah Agrosains Tropis 6, 180-188.

Kelly, J.T., & Gontz, A.M. 2018. Using GPS-surveyed Intertidal Zones to Determine The Validity of Shorelines Automatically Mapped by Landsat Water Indices. International Journal of Applied Earth Observation and Geoinformation, 65, 92-104.

Li, W., & Gong, P., 2016. Continuous Monitoring of Shoreline Dynamics in Western Florida with A 30-year Time Series of Landsat Imagery. Remote Sensing of Environment, 179, 196-209.

Liu, Y., Wang, X., Ling, F., Xu, S., & Wang, C., 2017. Analysis of Shoreline Extraction from Landsat 8 OLI Imagery. Water, 9(11), 1-26.

Marfai, M.A., & Permana, K., 2014. Erosi dan Sedimentasi Kawasan Pesisir Jepara. in Sunarto, Marfai, M.A., & Setiawan, M.A., Geomorfologi dan Dinamika Pesisir Jepara (pp. 39-76). Gadjah Mada University Press, Yogyakarta.

Pemerintah Kabupaten Jepara., 2012. Rencana Pembangunan Jangka Menengah Daerah Kabupaten Jepara Tahun 2012 - 2017. Pemerintah Kabupaten Jepara, Jepara.

Planet Labs., 2018. Planet Imagery Product Specifications.Planet Labs, California.

Rodriguez, E., 2005. A Global Assessment of the SRTM Accuracy. in National Geospatial-Intelligence Agency., The Shuttle Radar Topography Mission: Data Validation and Application (p. 12). National Geospatial-Intelligence Agency, Virginia.

Sarp, G., & Ozcelik, M., 2017. Water Body Extraction and Change Detection Using Time Series: A Case Study of Lake Burdur, Turkey. Journal of Taibah University for Science, 11, 381-391.

Sinaga, T.P., Susiati, H., 2007. Studi Pemodelan Perubahan Garis Pantai di Sekitar Perairan Tapak PLTN Semenanjung Muria. Jurnal Pengembangan Energi Nuklir, 9(2), 1-10.

Sunarto., 2004. Perubahan fenomena geomorfik daerah kepesisiran di sekeliling Gunungapi Muria Jawa Tengah: kajian paleogeomorfologi (dissertation).

Triatmodjo, B., 2008. Teknik Pantai. Beta Offset, Yogyakarta.

Tucker, C.J., Grant, D.M., & Dykstra, J.D., 2004. NASA's Global Orthorectified Landsat Data Set. Photogrammetric Engineering and Remote Sensing, 70(3), 313-322.

Undang-Undang Republik Indonesia Nomor 23 Tahun 2014 tentang Pemerintah Daerah.

Undang-Undang Republik Indonesia Nomor 4 Tahun 2011 tentang Informasi Geospasial.

Yang, Y., Liu, Y., Zhou, M., Zhang, S., Zhan, W., Sun, C., & Duan, Y., 2015. Landsat 8 OLI Image Based Terrestrial Water Extraction from Heterogeneous Backgrounds Using A Reflectance Homogenization Approach. Remote Sensing of Environment, 171, 14-32.