ASSESSMENT OF THE COASTAL CHANGE METHODOLOGY: A CASE STUDY OF THE COASTAL RECESSION AS THE IMPACT OF HIGH TIDE

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ABSTRACT: Climate change has directly impacted the dynamics changed of oceanographical parameters. One of the significant impacts of this climate change is a change in the tidal wave. The effect of tidal changes combined with human activities on exploited the coastal ecosystem will cause a decrease in the coastal area and its related ecosystem. Various Remote Sensing methods have been implemented to assess changes in the coastal area due to these tides' influence. However, the accuracy of this method leaves many questions. This study intends to evaluate and combine the methods commonly used to analyze changes in coastal areas, including water change detection, normalized difference water index (NDWI), and a selected image transformation method. The coastal area of Pekalongan, Java - Indonesia, which has experienced a significant change in the coastline, is used as the study area. The assessment results indicate that the band selection, either for solely method or the combined ones, is the key to the accuracy approach of the findings. Moreover, the combined methods, which apply NDWIs, have higher accuracy in identifying water features to assess coastal changes.

1. INTRODUCTION

1.1 Background

Climate change has a significant impact on the rising sea level worldwide. As a consequence, it will affect the dynamic changes of oceanographical parameters, such as tidal wave. Green berg et al. (2012) said that the high water would affect the existing trend in changing tides, contributing to the coastal area's rising tides. In some cases, land-use conversion causes environmental degradation, which increases vulnerability to tidal flooding, land subsidence, and changes in coastlines. The effect of tidal changes in combined with human activities on exploiting the coastal ecosystem, will decrease coastal areas and their related ecosystem. Remote sensing has proven to be a powerful tool for monitoring the spatio-temporal of coastal changes (Jiang et al., 2015). Thus, it offers a comprehensive approach to understanding the variable forces that shape the dynamic changes of the coastal environment (Ramsey, 2019). Various Remote Sensing methods have been implemented to assess changes in the coastal area due to the influence of tidal change, from simple ecosystem change detection, water indexing to pixel-based, and object-based classification methods. However, which method supposes to be the fastest and the accurate ones require further assessment.

This study intends to evaluate and combine the methods commonly used to analyze changes in coastal areas, including water change detection, normalized difference water index (NDWI), and a selected image transformation method. The change detection following the pixel-based and object-based are not assessed in this study since many previous scientists have done the research. For this purpose, the coastal area of Pekalongan, either administratively part of the city or district on the north coast of Java island – Indonesia, was selected as a study area. Like other coastal cities and districts in the north Java island, Pekalongan has been impacted by the high tide, the local name is rob, for quite a long time. The coastal environment condition would be getting worsen if not any mitigation action is implemented in the area. The fastest and simple remote sensing method to study the coastal change will hopefully assist the monitoring of the inundation pattern for any mitigation and adaptation program. The Landsat data, which can be freely downloaded from The USGS website, were used as the source of data, as one of the remote sensing data that can be quickly obtained and further used for environmental changes studies.

1.2 Problems in the study area

Both Pekalongan City and Pekalongan district, located on the north coast of Java island (Figure 1), experience tidal flooding problems, locally called rob. Locate in the coastal plain area with flat topography; this area is vulnerable to global warming impacts, such as the sea-level rise and tidal wave (Saudah et al., 2019). The rapid growth of development within this area has also contributed to the inundation, and the need for groundwater for industries and households have a significant impact on land subsidence. This land subsidence will exaggerate the tidal flooding and inundation within the coastal area. The findings from Nasrullah et al. (2013) showed that the average of land subsidence rate in Pekalongan city was 3 cm/year. Meanwhile, Pratama (2019) found that the inundation height across the Pekalongan coastal area will increase to about 11, 36, and 132 cm in 2019, 2025, and 2050, respectively. Therefore, the research needs to be further developed to assess the best method for monitoring, evaluating the coastal area's pattern and changes in which a remote sensing technique can assist.

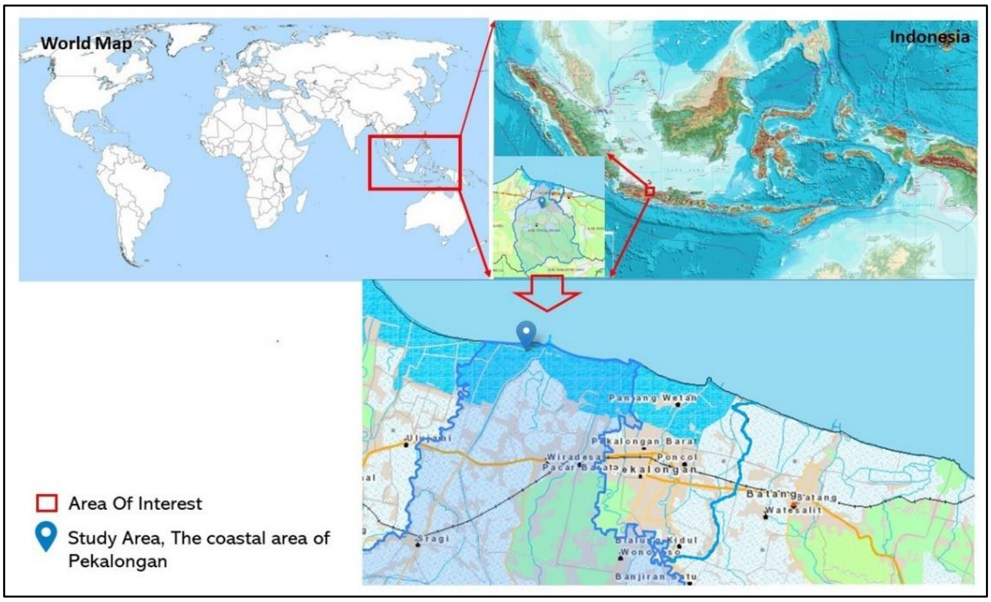

Figure 1. illustration of study area (world map, 2020; Peta NKRI, 2020)

2. METHODs

2.1 Data and Method

Landsat Enhanced Thematic Mapper Plus (ETM^+) data obtained on December, 5^{th} 2000, and Landsat 8 Operational Land Imager (OLI) acquired on October, 1^{st} 2020 was used for assessment (downloaded from http://earthexplorer.usgs.gov/). Figure-2 shows the Landsat Imageries that are used for coastal change assessment. The assessment steps included the development of the Normalized Difference Water Index (NDWI) for each image, the statistical change detection method using image differencing, and principal component analysis (PCA).

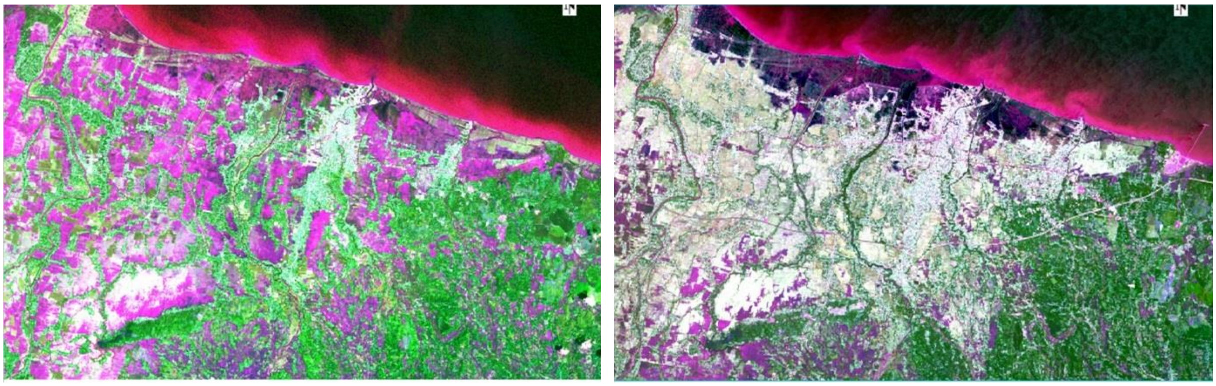

Figure 2. Landsat ETM$^+$ acquired on Dec,15th 2000 (a) and Landsat 8 OLI acquired on Oct, 01st 2020

The flow of the assessment is explained in Figure-3.

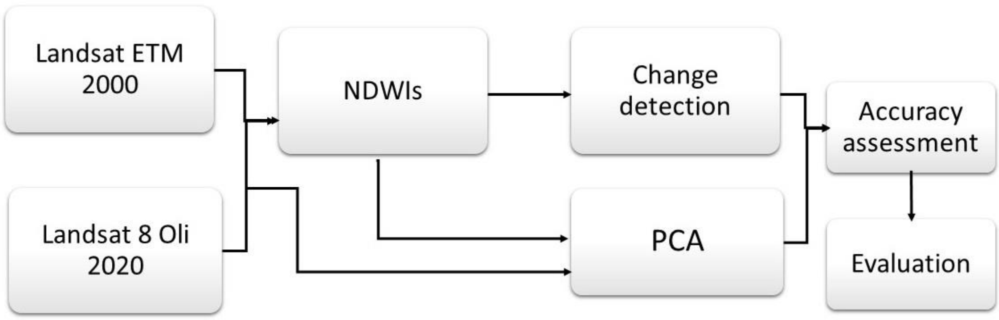

Figure 3. Flowchart of the assessment

NDWI method is commonly utilized in surface water body detection and mapping (Özelkan, 2020). The common band used for this method is NDWI$_{(Green,\ SWIR)}$ (Özelkan, 2020). Landsat 8 OLI has two Short-wave infrared (SWIR) band, SWIR1 with 1.560 – 1.660 µm wavelength, and SWIR2 with wavelength of 2.100 – 2.300 µm. For this assessment, we used SWIR1 since it is similar to the SWIR band of Landsat ETM$^+$, there is 1.55-1.75 um. The algorithm can be explained as follow

$$NDWI_{green,SWIR} = (V_g - SWIR) / (V_g + SWIR) \quad \cdots\cdots\cdots \ (1)$$

$$NDWI_{green,SWIR1} = (V_g - SWIR_1) / (V_g + SWIR_1) \quad \cdots\cdots\cdots (2)$$

whereas, $NDWI_{green,SWIR}$ is the NDWI for Landsat ETM$^+$ image, $NDWI_{green,SWIR1}$ is the NDWI for Landsat 8 OLI, V_g is visible green band, *SWIR* is near infrared band, $SWIR_1$ is the shortwave infrared band-1 of Landsat 8 OLI.

These both NDWIs become input for change detection assessment by using image differencing method. Image differencing change-detection method is performed by subtracting the digital number (DN) value of a pixel at one date for a given band from the DN value of the same pixel at another date for the same band (Afify, 2011). We modify the formula by using the NDWI images to replace the two raw image of the year 2000 and 2020 and can be illustrated in the following algorithm

$$CD_{NDWI} = NDWI_{green,SWIR1_i} - NDWI_{green,SWIR} \text{...............(3)}$$

whereas CD_{NDWI} is the changes in the coastal area using *NDWI* images

As a comparison, a PCA method was also applied to the two images. Due to its simplicity, the PCA is commonly used in change detection (Wu, et al., 2015). The concept is where the eigen vectors of the variance – covariance matrix of the merged data set are linearly transformed to provide the eigen-structure, which specifies the band variance loaded or involved in each PCA (Afify, 2011). In this case, the unchanged areas with a high correlation between the two images, can be explained by the first PCs. Meanwhile, the change areas or features that not are present or uncorrelated will be present in the later order of the PCA (Afify, 2011). This assessment is used the band 1 of each image that represents the water bodies for PCA analysis. Besides that, the PCA of NDWI images was also being assessed by using band 2 ($NDWI_{green,SWIR}$).

2.2 Accuracy Assessment

The accuracy assessment was employed by using Sutrisno et al. (2020) algorithm, which was described in the following equations:

$$Ev = \frac{\sum t_1 + t_n}{\sum (P)_{ref}} \, x\ 100\ \% \text{ .... (4)}$$

$$if (x, y)_1 = (x, y)_n \quad then\ (x, y)_1\ is\ true \text{ ....(5)}$$

$$if\ (x, y)_1 \neq (x, y)_n\ then\ (x, y)_1\ is\ false \text{..................(6)}$$

where *Ev* is the result of the evaluation (%), based on *t* = a true value, *1…n* are the points from the studied images, and P_{ref} is the total point of reference image and $(x, y)_n$ is a reference point object within the studied images.

After that, the evaluation will be employed to assess the faster and more precise method in providing information related to changes in the coastal environment and its distribution patterns

3. RESULT AND DISCUSSION

3.1 NDWIs and Image differencing method

The result of the NDWI for both images, $NDWI_{green,SWIR}$ and $NDWI_{green,SWIR}$, and the change detection of both NDWI images (CD_{NDWI}) on given dates can be seen in Figure-3. The green and near-infrared (NIR) spectral bands of Landsat TM were first formed of the most widely used water indices to detect open bodies of surface water (McFeeters, 1996). Then a modified NDWI (MNDWI) was promoted by Xu (2006) applying the green and Short-wave infrared band (SWIR) to the algorithm by using Landsat TM images. The implementation of the $NDWI_{green,SWIR}$ indicates the more advantages of this algorithm in detecting water bodies in the Landsat ETM and Landsat 8 OLI, as shown in Figure-3 and Figure 4. The histogram of $NDWI_{ETM}$ (Figure 4-a) and histogram of $NDWI_{OLI}$ (Figure 4-b) shows the distribution of water bodies detection, which higher in the $NDWI_{OLI}$ compare to $NDWI_{ETM}$ caused by the seawater inundation. NDWI provides better separation among land-use features, from water bodies to others. Gürso, (2015) support through his findings that the NDWI (Green, SWIR) provided better result compare to previous NDWI (Green, NIR).

The change detection of both NDWI images (CD_{NDWI}) emphasize the change of north coastal area to water bodies, which identifies a shoreline retreat due to seawater inundation. The change detection using band-differencing method is usually applied to a selected band of a given image. However, in this assessment, we modify the previous band differencing method by combining it with the NDWI method.

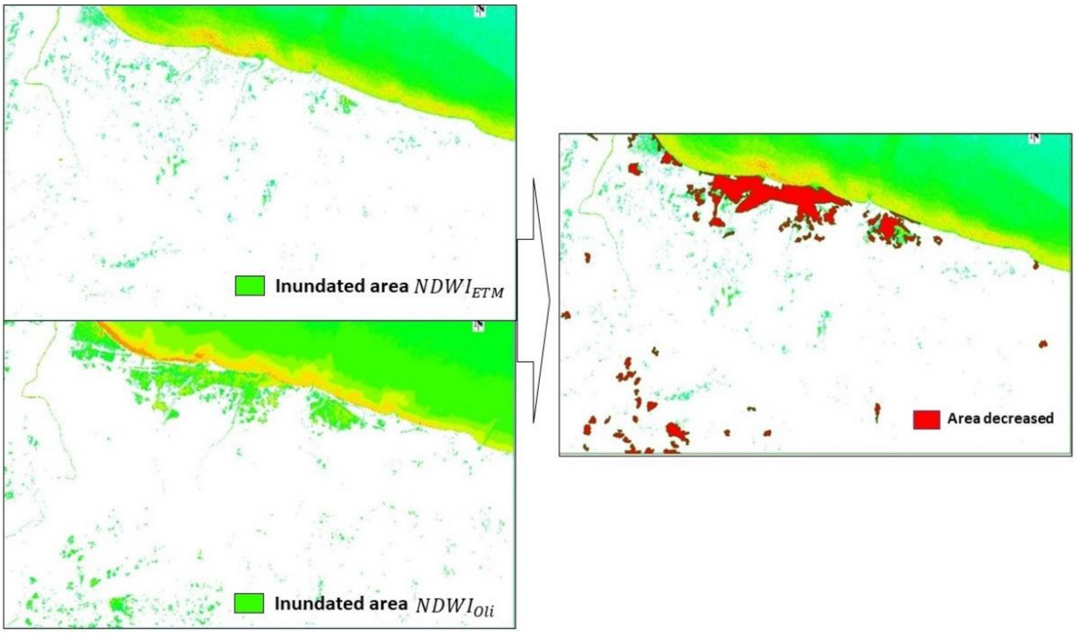

Figure 3. Assessment of $NDWI_{green,SWIR}$ and $NDWI_{green,SWIR1}$ and Change detection CD_{NDWI}

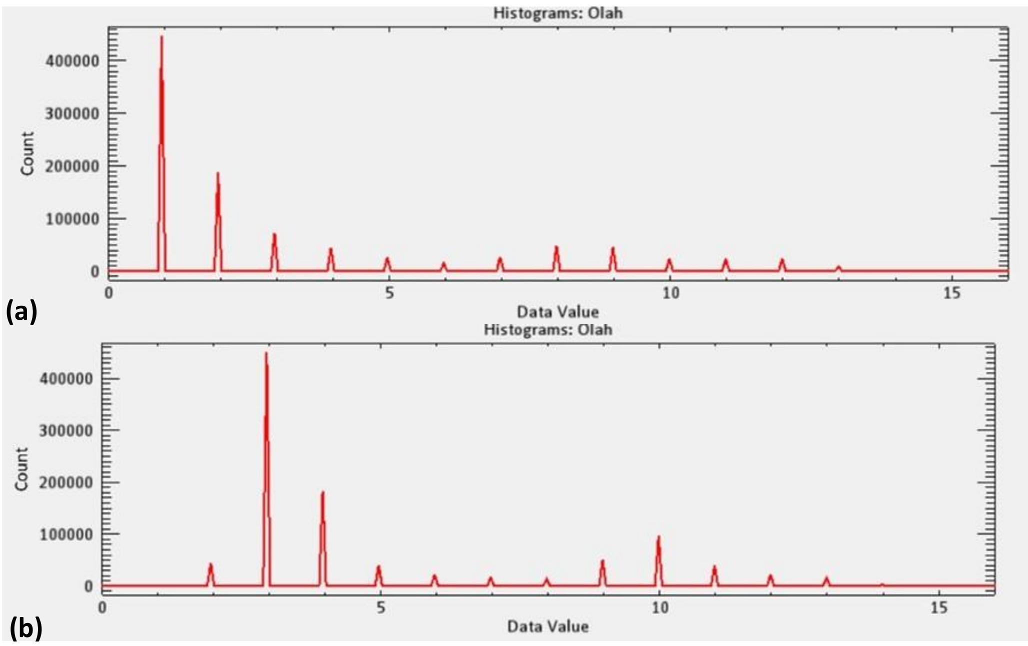

Figure 4. Histogram of $NDWI_{green,SWIR}$ (a) and $NDWI_{green,SWIR1}$ (b)

Another method of change detection using PCA (CD_{PCA}) can be seen in Figure-5. This method is able to identify the water bodies of both Landsat images in the given year of 2000 (Landsat ETM$^+$) and in 2020 (Landsat OLI) by using PCA-1. The histogram of CD_{PCA} (Figure 5-b) shows a more precise distribution of water bodies compared to CD_{NDWI}. Besides that, a PCA based on NDWIs ($CD_{NDWI-PCA}$) has also been implemented. The result can be seen in Figure 6.

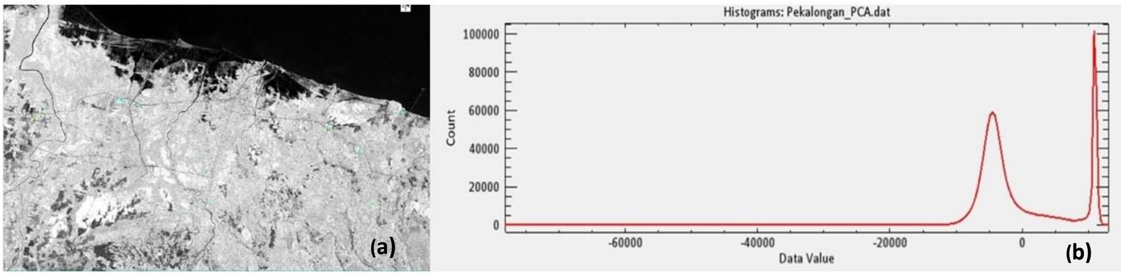

Figure 5. PCA Method result (a), histogram of PCA (b)

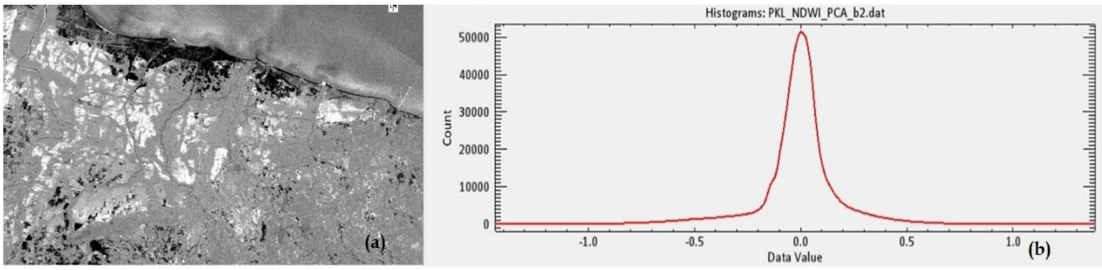

Figure 6. $CD_{NDWI-PCA}$ method result (a), histogram of $CD_{NDWI-PCA}$ (b)

$CD_{NDWI-PCA}$ can separate the features of water bodies, sedimentation, and objects under or on the water more clearly than CD_{PCA}. Meanwhile, CD_{PCA} can identify the water feature better compare with $CD_{NDWI-PCA}$. In contrast to the previous study by Rokni et al. (2014) shows that the method of $CD_{NDWI-PCA}$ was found inappropriate for surface water change detection by using Landsat ETM$^+$ data. However, this study shows different results, where the $CD_{NDWI-PCA}$ can distinguish between water bodies, objects contained therein and other land features. The input NDWIs image can higher the image performance compared with other indexes used for this purpose.

A comparative analysis and validation were performed to assess the performances of different methods adopted in this study to detect the coastal changed (Figure 7). The finding among CD_{NDWI}, CD_{PCA} and $CD_{NDWI-PCA}$ illustrated that the accuracy of CD_{NDWI} is 72%, CD_{PCA} is 89 % and $CD_{NDWI-PCA}$ is 81%.

CD_{PCA} is capable of assessing the extent of the inundation landward, which can be used as a reference for assessing coastal changes. However, to know better the depth of the inundation $CD_{NDWI-PCA}$ was better. These findings indicate the superiority and higher performance of the NDWI for surface water change detection and the PCAs by using band-1 or visible blue wavelength. Both methods either combine of NDWI and change detection ($CD_{NDWI-PCA}$) and PCA (CD_{PCA}) are the fastest coastal changed detection methods to identify the coastal changes and coastal recession pattern.

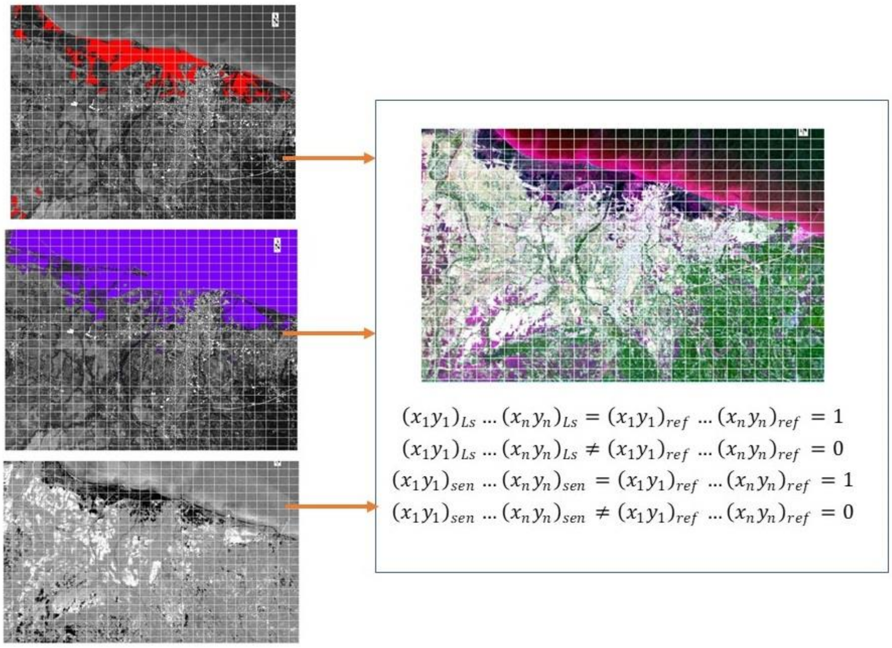

Figure 7. Evaluation matrix analysis of CD_{NDWI}, CD_{PCA}, and $CD_{NDWI-PCA}$ for accuracy assessment of SW to reference image of 2020.

4. CONCLUSION

This study aimed to evaluate the spatiotemporal coastal change method by using Pekalongan coast as an example. A comparative analysis of NDWIs of each given date, combines the NDWI and Change detection method, combines the PCA and NDWI method, and the PCA method were being implemented. The findings describe faster and accurate information for coastal change detection by the combined of PCA and NDWI method and a solely PCA method, which have accuracy assessment > 80 %, respectively. The assessment has been proven the effectiveness of both methods in detecting the water surface changes within the coastal area. Not less important is the band selection, either for solely method or the combined ones, is the key to the accuracy approach of the findings. Accordingly, the methods may be used to identify the coastal recession, flood monitoring and spatial planning.

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CONTRIBUTION

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