Study on shoreline changes using Landsat imagery in Sangsit Region, Bali Province

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Abstract. This study was conducted to observe the dynamic of shoreline changes in Sangsit Region, Bali Province using multi-temporal remote sensing datasets. The remote sensing data were acquired from several Landsat images in the period of 2000-2019 (20 years) with 30-meter spatial resolution. Digital Shoreline Analysis System (DSAS) method was used to analyse data images to determine the shoreline changes. Prior to the analysis, the images were corrected by ground check data. It revealed that the shoreline changes has occur in Sangsit Region for period of 20 years (2000-2019). The results obtained indicate that there is a change in shoreline with mild accretion to less extreme abrasion categories which occurred in the Sangsit Region in that period. From 2000-2005 it shows an accretion of 221.03 m which is categorized as mild accretion and from 2005-2019 the shoreline changes that occur is only an abrasion its categorized as mild to less extreme abrasion. The highest abrasion occurred in the period of 2010-2015 which the abrasion is around 49.65 m.

1. Introduction
Sangsit Region is a region located on that north side of Bali Province, part of Buleleng Regency. Due to the development in the coastal area causes the shoreline to changes and affect changes in land use, the phenomena of shoreline changes are accretion and abrasion. Accretion is the condition of the beach advancing due to the addition material from the results of river sedimentation, type of beaches or other physical factors, while abrasion is damage to the beach which results in the erosion of the beach caused by waves and current [1]. Abrasion and accretion processes that occur along the coast also influences change in land use [2]. Due to urban development the research on shoreline changes is needed for planning coastal management [3]. The process of shoreline changes in the form of abrasion and accretion is a natural process, there are three important dynamics process (waves, wind and tides) causes the shapes of shoreline changes [4].

Research on shoreline changes has been carried out using several methods, some of it using mathematical model and the others are using remote sensing – Geographic Information System (GIS) based method [5]. Remote sensing technology can be an effective and efficient for mapping and measuring shoreline changes. Shoreline changes can be described using spatial data in the form of satellite imagery. Satellite images with high resolution can illustrate shoreline change in more detail and with the temporal resolution of satellite it can detect these changes easily [6]. Usage of remote sensing data is very helpful to determine shoreline changes, we can calculate the change by temporal resolution mean that we will get the information from other years before and we can study large area using this...
method. The use of satellite images with medium spatial resolution such as Landsat is suitable for spatial dynamics monitoring of shoreline [7].

This study was conducted to observe the dynamic of shoreline changes in Sangsit Region from 2000-2019 (20 years) by using Landsat images with Digital Shoreline Analysis System (DSAS) method. The main objective of this study is to mapping shoreline changes by spatial and temporal resolution using satellite imageries. This study uses a remote sensing technique approach.

2. Methods
Data used for this study are from various Landsat images (2000-2019) and Ground Control Points (GCP) that will be obtained through field observations in 2019 for a geometric correction. The data that we used for interpret the shoreline changes are shown in Table 1 and for the study area can be seen in Figure 1.

Table 1. Data image that used.

| Image       | Spatial resolution | Acquisition date | Path/Row |
|-------------|--------------------|------------------|----------|
| Landsat 5 TM| 30 x 30 m          | 2000-07-10       | 117/066  |
| Landsat 7 ETM+| 30 x 30 m        | 2005-03-17       | 117/066  |
| Landsat 7 ETM+| 30 x 30 m        | 2010-03-15       | 117/066  |
| Landsat 8 OLI| 30 x 30 m         | 2015-05-17       | 117/066  |
| Landsat 8 OLI| 30 x 30 m         | 2019-05-07       | 117/066  |

Figure 1. Study area.

2.1. Images pre-processing
We are using 5 images from three different satellites but same spatial resolution which is 30 x 30 m. To start the images processing, first we do geometric correction using polynomial method with nearest neighbor resampling type. This method is used to fix the object position so that the coordinates on the images match the geographic coordinates. Furthermore, radiometric correction is performed to reduce the influence of the atmospheric which can reduce image quality using Dark Object Subtraction (DOS) [8]. The formula can be seen as follows:

Corrected Digital Number = Digital Number – Bias (minimum value) \hspace{1cm} (1)

In this correction it is assumed that the lowest pixel value in a scene it should be zero, if the lowest value is not zero then the addition value is considered as noise. The bias value is obtained from each band using the histogram adjustment method.
2.2. Shoreline Extraction
Determination of the shoreline on Landsat images using the shoreline extraction technique [9]. After doing the first step, the boundaries of the study area are made by cropping the Landsat images. Determining the Normalized Difference Vegetation Index (NDVI) in this technique uses a composite red band and Near Infrared (NIR) to determine the level of greenness and classification of vegetation areas. The next step uses Tasseled Cap to convert band channel into a new band set with clear interpretation for vegetation mapping, this transformation already proven fit for shoreline extraction [10]. Tasseled Cap process are using composite bands of red, green, blue, NIR, short wave infrared-1 (SWIR-1) and short wave infrared-2 (SWIR-2) to find out the level of brightness, greenness and wetness of an object. The mathematical equation of the three components of the Tasseled Cap is as follows [11]:

\[
\begin{align*}
\text{Brightness} & = 0.3037B1 + 0.2793B2 + 0.4743B3 + 0.5585B4 + 0.5082B5 + 0.1863B7 \\
\text{Greenness} & = -0.2848B1 - 0.2435B2 - 0.5436B3 + 0.7243B4 + 0.0840B5 - 0.1800B7 \\
\text{Wetness} & = 0.1509B1 + 0.19731B2 + 0.3279B3 + 0.3406B4 - 0.7112B5 - 0.4572B7 \\
B1 &= \text{Blue}, B2 = \text{Green}, B3 = \text{Red}, B4 = \text{NIR}, B5 = \text{SWIR-1}, B7 = \text{SWIR-2}
\end{align*}
\]

At the classify stage to separate land and sea used NDVI values, brightness, greenness and wetness, in this stage pixel value are classified into two classes namely land class with value 0 and sea with value 10. The next step is shore boundary, which is to make a shoreline from two classes of data using majority filtering, contours and smooth line command [12]. The last step is overlaying the shoreline that extracted from the images then used for Digital Shoreline Analysis System (DSAS). The study area is divided into two zones (A and B) with an area of each zone is 1.295 x 1.295 km and each divided into two parts (A1, A2, B1 and B2) with an area of each zone is 0.32 x 0.32 km. Measurement of shoreline changes is done by extracting 2000 shoreline as a baseline data that will be compared with other images. The abrasion are symbolized by a sign (-) while the accretion are symbolized by a sign (+) as shown in Figure 2.

2.3. Digital Shoreline Analysis System (DSAS)
Temporal shoreline change analysis is performed using the DSAS method which calculates the level of statistical change for shoreline time series vector data and analysis of each shoreline distance are using the net shoreline movement (NSM) method, which is by measuring the shoreline distance change between the longest shoreline and the most recent shoreline [9]. The next step is to do a statistical calculation to show the phenomenon of abrasion and accretion rate from multi temporal data (2000-2019) at several valuation locations using the End Point Rate (EPR) method. Mathematically the EPR method can be measured as follows [13]:

\[
RSe = \frac{Xo}{t}
\]

\(RSe\) is End Point Rate shift (m/year)
\(Xo\) is measured horizontal offset between wet/dry and MHW shorelines (m)
\(t\) is time span between the shoreline positions used to calculate the end point shoreline change rate
In this study the change rate is divided into 8 classes, which is 4 abrasion classes and 4 accretion classes as follows [14]:

| No | Change rate (m/yr) | Category             |
|----|-------------------|----------------------|
| 1  | > -10             | Very extreme abrasion|
| 2  | -9.99 - -5        | Extreme abrasion     |
| 3  | -4.99 - -2        | Less extreme abrasion|
| 4  | -1.99 – 0         | Mild abrasion        |
| 5  | 0 – 2             | Mild accretion       |
| 6  | 2 – 5             | Less extreme accretion|
| 7  | 5 – 10            | Extreme accretion    |
| 8  | > 10              | Very extreme accretion|

3. Results and Discussion

In Figure 3 can be seen the area of interest conducted in this study, shoreline changes that occur in the study area include three locations (Sangsit, Kerobokan and Penarukan). In that pictures, it can be seen the shoreline changes that occurred in these three areas over a period of 20 years (2000-2019). Table 3 shows the changes that occur in total to these three areas. Although this study in only limited to the Sangsit Region, the remote sensing data used can cover up to three areas.

Table 3. The results of shoreline changes in all of area (zone A and B).

| Year       | Min (m) | Max (m) | Average (m) | EPR (m/yr) | Category            |
|------------|---------|---------|-------------|------------|---------------------|
| 2000-2005  | -44.93  | 580.56  | 267.82      | 0.21       | Mild Accretion      |
| 2005-2010  | -140.54 | 529.44  | 194.45      | 0.62       | Mild Accretion      |
| 2010-2015  | -441.48 | 36      | -202.74     | -4.47      | Less Extreme Abrasion|
| 2015-2019  | -104.08 | 33.71   | -35.19      | -2.76      | Less Extreme Abrasion|

Note: (-) landward and (+) seaward

In all three areas, periodic changes in shoreline can be seen every 5 years between 2000-2019 (Table 3), the result obtained for shoreline changes in every five years period along the all study areas in 2000-2005 there was an accretion of 267.82 m which is categorized as mild accretion. In 2005-2010 there was an accretion of 194.45 m which is categorized as mild accretion and in the next period (2010-2015) an abrasion of 202.74 m occurred which is categorized as less extreme abrasion. Then in the last period (2015-2019) a less extreme abrasion of 35.19 m occurred.

Figure 3. Changes shoreline in all of area (zone A and B) and every 5 years.
On the map shown in Figure 4, we can see the shoreline changes in Zone A which includes Sangsit Region. In the table 4, it can be seen that shoreline changes that was occur only in the Sangsit Region, the model applied is calculate the shoreline changes data in every 5 years period start from 2000 to 2019. From 2000-2005 it shows an accretion of 221.03 m which is categorized as mild accretion. From 2005-2019 the shoreline changes that occur is only an abrasion its categorized as mild to less extreme abrasion. The highest abrasion occurred in the period of 2010-2015 which the abrasion is around 49.65 m and it was categorized as less extreme abrasion.

![Figure 4. Changes shoreline for 2000-2019 in Sangsit area.](image)

| Year     | Min (m) | Max (m) | Average (m) | EPR (m/yr) | Category               |
|----------|---------|---------|-------------|------------|------------------------|
| 2000-2005| 0       | 442.05  | 221.03      | 0          | Mild Accretion         |
| 2005-2010| -140.54 | 83.17   | -28.69      | -2.4       | Less Extreme Abrasion  |
| 2010-2015| -133.98 | 34.69   | -49.65      | -2.7       | Less Extreme Abrasion  |
| 2015-2019| -74.83  | 32.24   | -21.30      | -0.97      | Mild Abrasion          |

Note: (-) landward and (+) seaward

The shoreline changes that occur in the Sangsit Region are categorized from mild accretion to less extreme abrasion which is ranging from 0 - 3 m/year. The results are not very clearly seen, because some of the data that shown the shoreline changes are around 30 m or less than 3 m / year, it is very difficult to see the changes in one pixel of Landsat imagery. Therefore it is necessary to use high resolution imagery to improve the accuracy of the data generated.

4. Conclusion
The use of remote sensing technology can predict shoreline changes that occur in Sangsit Region within a period of 20 years (2000-2019). The results obtained indicate that there is a change in shoreline with mild accretion to less extreme abrasion categories which occurred in the Sangsit Region in that period. From 2000-2005 it shows an accretion of 221.03 m which is categorized as mild accretion and from 2005-2019 the shoreline changes that occur is only an abrasion its categorized as mild to less extreme abrasion. The highest abrasion occurred in the period of 2010-2015 which the abrasion is around 49.65 m. This research can be continued by adding oceanographic data so that more information about the source of shoreline changes and the impact of land changes that occur in the area. Also for further research it is necessary to use high resolution imagery data so the results obtained will be more detailed.
5. References

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