Automatic Detection of Decadal Shoreline Change on Northern Coastal of Gresik, East Java –Indonesia

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\textbf{Abstract.} The Coastal zone is a dynamic region that has high environmental and economic values. This present research focuses on the analyzing the rate of shoreline change using multi-temporal Landsat Imagery and Digital Shoreline Analysis Systems (DSAS) along the northern part of Gresik coastal area, East Java Indonesia. Five village were selected for analysis; Campurejo, Dalegan, Prupuh, Ngemboh, and Banyuurip. Erosion and Accretion were observed and detected on Multi-temporal satellite Images along the area of interest from 1972 – 2016. Landsat Images were radiometrically and geometrically corrected before using for analysis. Coastline delineation for each Landsat image was performed by MNDWI method before digitized for quantitative shoreline change analysis. DSAS was performed for quantitative analysis of Net Shoreline Movement (NSM) and End Point Rate (EPR). The results indicate that in the study area accretion and abrasion was occurred, but overall abrasion was dominated than accretion. The remarkable shoreline changes were observed in the entire region. The highest abrasion area was occurred in Ngemboh village. From 1972 to 2016, coastline was retreat 242.56 meter to the land and the rate of movement was -5.54m/yr. In contrast, Campurejo area was relatively stable due to the introduction of manmade structure, i.e. Jetty and Groin. The Shoreline movement and the rate of movement in this area were -6.11 m and -0.12 m/yr respectively. The research represents an important step in understanding the dynamics of coastal area in this area. By identification and analysis of coastline evolution, the stake holder could perform a scenario for reducing the risk of coastal erosion and minimize the social and economic lost.

\textbf{Keywords:} Shoreline Change, DSAS, Landsat Imagery, Gresik Coast

\section{1. Introduction}

Coastal areas are in one of the most area with highest economical values. In developing countries, 60\% of population lives in coastal areas [1]. Coastal erosion in a severe problem, especially for a country facing highly population growth in coastal area [2]. A shoreline is defined as the line of contact between land and a water body [3] and subjected to continually change over time [4].Its considered as one of the most dynamic process in coastal areas [4][5]. Shoreline generally subjected to change due to coastal process, which are controlled by hydrodynamic characteristics, sediment characteristics, beach form, etc. [6]. In addition, the economic and social development also induce the change of coastal area.
Northern coastal area of Gresik, East Java is one of the area that severe from coastal erosion in the past years. Coastal abrasion is a major crisis and it potentially impacts the coastal population and natural environment. The science of shoreline mapping a monitoring has developed significant over the past 70 years [7] and those technique have progressed by automation with technological advance in order to reduce uncertainty. In addition, remotely sensed data combined with GIS technique can provides valuable result of coastline change mapping and monitoring. Monitoring of coastline areas is needed over time and can detect some change of the coastal area includes land-use /cover change and shoreline/coastline change using some statistical approach. Those approach including End point rate, Net Shoreline Movement, and Linear Regression Rate. The variability of such approach depend significantly on the methodology used to derive them [8][9].

The objectives of this study were to detect the abrasion/erosion and accretion areas and determine the rate of shoreline change in the Northern coastal area of Gresik, East Java in the periods of 44 years.

2. Study Area
The Study area (Fig 1) is the northern coast of Gresik regency, East Java Province- Indonesia. Spreads between with the length about 10 km and consist of 5 coastal village, i.e. Campurrejo, Dalegan, Ngemboh, Prupuh and Banyu Urip Villages. The coast is bordered by Java sea in the north and Bengawan Solo delta in the east. As well as northern coast of Java Island, the area of study is exposed to the seasonally reversing monsoon wind. The wet season occurs during October – February, while dry season is facing during April- August. The dominated wind (46%) blows from west in the wet season with the velocity 1-21 knot, in contrast in the dry season wind blows from Southeast with the velocity 1-11 Knot [10].

Coastal setting determines both sea and swell waves generally approach the coast from North west in the wet season and North East direction in the dry season. Although generally NW waves greater importance than any other approaching waves. The tidal type of the study area are diurnal and the tidal ranges varies from 1.2 – 1.5 m [11][12].

![Figure 1. Study area](image)

3. Methodology
The shoreline change in the study area was analyzed for periods of 44 years (1972-2014), which is classified as long term analysis [13][14] An ortho rectified Landsat satellites imagery from first
generation of landsat (landsat 1) to the latest generation (Landsat 8) were used to delineation of shoreline at designated time. The Landsat systems have been widely used in remote sensing application for coastal environment changes monitoring and other related studies [15][16]. The landsat images used for this research were downloaded from USGS Earth Explore web tool. The details information for each images and corresponding band is given in Table 1. The satellites images were geo-referenced separately using selected control points from topographic map published by Geo-spatial Information Agency, Indonesia. More over some controls points also recognized from fields survey using a Differential –Global Positioning Systems (D-GPS). Image rectification was implemented using WGS 84 datum and its referenced ellipsoid. Radiometric calibration was applied to minimized the the possible negative effect of inconsistency of solar irradiance, atmospheric effect, earth-sun distance, and solar zenith angle [17].

Table 1. Details of Landsat Images for Shoreline delineation

| Acquisition date | Satellites | Sensor | Band       | Resolution (meter) |
|------------------|------------|--------|------------|--------------------|
| 27/09/1972       | Landsat 1  | MSS    | 4 (Green)  | 60                 |
|                  |            |        | 7 (Near IR)| 60                 |
| 11/09/1982       | Landsat 3  | MSS    | 4 (Green)  | 60                 |
|                  |            |        | 7 (Near IR)| 60                 |
|                  |            |        | 2 (Green)  | 30                 |
| 08/07/1994       | Landsat 5  | TM     | 5 (Medium IR) | 30               |
|                  |            |        | 2 (Green)  | 30                 |
| 23/08/2002       | Landsat 7  | ETM+   | 5 (Medium IR) | 30               |
|                  |            |        | 3 (Green)  | 30                 |
| 04/07/2016       | Landsat 8  | OLI    | 3 (Green)  | 30                 |
|                  |            |        | 6 (SWIR 1) | 30                 |

Automatic shoreline extraction were applied to all multi temporal satellites images following the Normalized Difference Water Index (MNDWI) method was proposed by [18] which is based on [19] and [20] for Landsat TM and ETM and landsat 8 OLI, respectively. Shoreline produced by this step which is in raster format then converted to vector file using automatic threshold method.

MNDWI transformation for Landsat TM and ETM [18]:

$$MNDWI = \frac{\text{Green} - \text{NIR}}{\text{Green} + \text{NIR}}$$ (1)

MNDWI transformation for Landsat 8 OLI [20]:

$$MNDWI = \frac{\text{Green} - \text{SWIR 1}}{\text{Green} + \text{SWIR 1}}$$ (2)

Shoreline for each images produced by previous step then used as input in Digital Shoreline Analysis System (DSAS), an ArcGIS extension for quantifying shoreline change in the terms of erosion or accretion [21]. DSAS is an widely used technique for quantitavive methodology for coastal morphology research [16]. In order to extract historical changes of the shoreline, an orthogonal transects with the length of 1.5 km and with interval of 60 m and perpendicular to shoreline were automatically created. In this study, a total of 170 transect were identified along the northern coastal area of Gresik. Each transect then used to measure the position of shoreline overtime from the baseline. The end point rate (EPR) was chosen as the rate change statistic. The EPR is a ratio between the shoreline movement along each transect and time span between them. In order to quantify the length of shoreline movement, the Net Shoreline Movement (NSM) approach was used in this research. This method calculate the distance of coastline from the first year to the last year of observation.
4. Results and Discussion

4.1. Decadal Shoreline Evolution

1972-1982

The map of shoreline movement and corresponding table for shoreline dynamics from 1972 to 1982 can be seen in figure 2 and table 2. Negative values in the table indicate the erosion while positive values represent accretions. In 1972-1982 most of the area of observations was severe from abrasion. Based on the analysis (table 2), Ngemboh village has the highest average abrasion rate ie EPR -21.18 m/year and NSM -210.81 m. During this first period of detection, there was also an accretion phenomenon. The highest rate of accretion was in Dalegan Village with the average of EPR value 4.84 m/year and NSM 48.14 m.

![Figure 2. Map of Shoreline change 1972-1982](image)

| Village      | EPR (m/yr)    | NSM (m)    | Remarks       |
|--------------|---------------|------------|---------------|
|              | Average       | Average    |               |
| Campurrejo   | 3.12          | -6.58      | -65.47        | Abrasion      |
| Dalegan      | 4.84          | -13.79     | -137.24       | Abrasion      |
| Ngemboh      | -             | -21.179    | -210.81       | Abrasion      |
| Prupuh       | 2.35          | -12.85     | -127.88       | Abrasion      |
| Banyu Urip   | 3.26          | -5.27      | -52.49        | Abrasion      |

1982-1994

In the second period of observation of coastline changes that is 1982-1994, the major phenomenon that occurs was still the same as the previous period of observation. In the research area is still dominated by the event of abrasion (Figure 3 and table 3). When compared to the previous period of observation, the abrasion rate in this period was lower than in 1972-1982. Dalegan Village which in the previous period had the highest level of accretion, but in this period has the highest abrasion rate with average EPR -8.29 m/year and with average NSM -98.01 m. Campurrejo village in this period had the highest level of accretion with the average of EPR is 2.92 m/year and a NSM an average NSM of 34.55 m. Ngemboh village which in the previous period was detected to have the highest abrasion average in this
period began to decline, as well as the Village Prupuh which in the previous period experienced the highest abrasion rate in this period experienced a similar thing with Ngemboh Village.

![Figure 3. Map of Shoreline change 1982-1994](image)

**Table 3.** The rate and the net movement of shoreline in 1982-1994

| Village    | EPR (m/yr) | NSM (m) |
|------------|------------|---------|
|            | Average    | Average | Remarks   |
|            | +          | -       |           |
| Campurrejo | 2.92       | -3.22   | 34.55     | -38.01     | Abrasion |
| Dalegan    | 0.24       | -8.29   | -8.29     | -98.01     | Abrasion |
| Ngemboh    | -          | -8.01   | -         | -94.73     | Abrasion |
| Prupuh     | -          | -4.66   | -         | -55.06     | Abrasion |
| Banyu Urip | 1.28       | -4.50   | 15.15     | -53.21     | Abrasion |

1994-2002

In the periods of 1994-2002, the shoreline at the most of the region began to experience accretion phenomenon while in the previous periods severe from abrasion (fig.4 table 4). The highest average accretion was found in Ngemboh Village with average EPR 12.18 m / year and mean NSM 98.95 m. Ngemboh village which in the previous period tends to experience abrasion, at those periods begins to decrease and reach a peak in 2004. After this year, abrasion was undetected and the shoreline has been stable. As well as Ngemboh village, Dalegan Village also experiencing an accretion process. Moreover, accretion occurred in this village was higher compared to previous periods.

The highest rate of abrasion during this period was found in Camprurrejo 1 village, EPR -4.31 m / year with EPR -9.86 m / year and NSM -80.16 m with NSM -35.01 m average. Camprurrejo village in the previous period had the highest level of accretion in this period began to experience abrasion, but the abrasion rate occurring in this period was not as high as the abrasion rate detected in 1972-1982.
Figure 4. Map of Shoreline change 1994-2002

Table 4. The rate and the net movement of shoreline in 1994-2002

| Village   | EPR (m/yr) | NSM (m) | Remarks  |
|-----------|------------|---------|----------|
|           | Average    | Average |          |
| Campurrejo| + 4.56     | -4.31   | 37.06    | -35.01   | Accretion |
| Dalegan   | + 9.31     | -3.90   | 75.65    | -31.65   | Accretion |
| Ngemboh   | + 12.18    | -       | 98.95    | -        | Accretion |
| Prupuh    | + 4.06     | -2.90   | 32.98    | -23.53   | Accretion |
| Banyu Urip| + 3.71     | -       | 18.54    | -        | Accretion |

2002-2016

In the last decade of shoreline analysis, all of the study area except Ngemboh village dominated by accretion process. The highest average of accretion was in the Dalegan Village with the movement of shoreline more than 107 m in the 14 years. In contrast, ngemboh was facing abrasion for approximately 42 meters in average for this period. The rate of shoreline movement also follows those shoreline change indication, ie. Abrasion. Ngemboh village facing abrasion for more than 3 m per year. This phenomenon is mainly caused by different landuse that exist in those area. Ngemboh village formerly was dominated by natural coastal type, ie. sandy coast without any protection structure, was vulnerable from coastal erosion. In addition another area of the research study was introduced by traditional man made structure such as traditional fish pond and seawall made from rocks.
Figure 5. Shoreline change 2002-2016

Table 5. The rate and the net movement of shoreline in 2002-2016

| Village      | EPR (m/yr) | NSM (m) | Remarks |
|--------------|------------|---------|---------|
|              | Average    | Average |         |
| Campurrejo   | 4.11       | -2.74   | 56.95   | -37.94 | Accretion   |
| Dalegan      | 7.75       | -0.89   | 107.53  | -31.58 | Accretion   |
| Ngemboh      | 2.29       | -3.04   | 31.76   | -42.13 | Abrasion    |
| Prupuh       | 6.64       | -       | 76.02   | -      | Accretion   |
| Banyu Urip   | 5.92       | -2.17   | 82.05   | -30.04 | Accretion   |

4.2. Long term Shoreline Evolution (1972-2016)

The longterm shoreline change in the different village in the study area had several characteristics of abrasion. In Dalegan, Prupuh, and Ngemboh village shoreline tend to extremely retreat due to abrasion phenomenon. Figure 6 and table 6 revealed that in those area abrasion process was eradicate the coast for more than 240 m for 44 years. In the other hand the abrasion process in Banyuurip and Campurrejo village is not as extremely as other area. This is might be caused by the introduction of man made structure such as Sea wall, groin, and fish pond structure. From the google image (fig. 6), several man made structure also can be identified such as jetty and reclamation area.
5. Conclusions
The aims of this study were to identify and characterize shoreline dynamics during long term periods from 1972-2016 in the region of Northern coastal area of Gresik. The change of shoreline overtime is in response to environmental, economic, and social forces. There were 3 abrasion and accretion regime during this periods. Between 1972-1994, a clear and notable abrasion trend was detected. The average rate of abrasion for this periods is more than 21m/yr caused the shoreline retreat for almost 210 m for 22 yr. In contrast, in the year of 1994-2002, the research area mostly facing accretion phenomenon. Moreover, in the last periods (2002-2016) of analysis, there were accretion as well as abrasion which identified in the study area.

The present study suggest that multi-temporal satellites data along with GIS and statistical techniques can be effectively used for detection of shoreline change in the study area. But the major driving factor for this phenomenon remains unclear. Forecast for the future evolution of coastline is somewhat tricky works because of the economics development in the area.
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