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# Monitoring Shoreline Changes for Evaluation of Regional Spatial Plans Using Google Earth Engine in West Wawonii District

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## Abstract

Abrasion is a natural phenomenon that usually occurs in coastal areas. This phenomenon becomes serious when it continues to experience a downward trend and disrupts residential areas on the coast. Wawonii Barat District is one of the sub-districts whose coastal areas are experiencing abrasion and accretion. However, studies on shoreline changes have not yet been reviewed based on the Regional Spatial Plan. The purpose of this study is to monitor, analyze and evaluate the rate of shoreline change in accordance with the spatial plan for the Wawonii Barat District as stated in the spatial pattern of Konawe Kepulauan Regency in 2021-2040. The method used is a qualitative method with the Digital Shoreline Analysis System (DSAS) technique which is integrated with the Google Earth Engine (GEE) for the identification of abrasion and accretion. The analysis of causes, impacts and recommendations was carried out in a qualitative descriptive manner. Overall Accuracy and Kappa Coefficient for each map, namely 2013 = 0.93 and 0.86; 2015 = 1 and 1; 2017 = 0.93 and 0.86; 2019 = 0.94 and 0.89; and 2021 = 1 and 1. The average abrasion is -10.58 m/year with the highest abrasion reaching -264.2 m/year. The recommendation is to re-evaluate the RTRW, especially regarding the plan for the road infrastructure network system and mangrove ecosystem areas, making bays and breakwater bays. in coastal areas that are directly related to settlements and mangrove planting along the coast.

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## INTRODUCTION

Coastal areas are defined by the International Geographic Data Commission (IGDC) as one of 27 important features in the world that should receive more attention because there is an intensification of human and natural activities (Wang et al., 2017; Qiao et al., 2018; Emami & Zarei, 2021; Ranjbar et al., 2021). The average sea level has risen by about 210 mm between the 19th and early 21st centuries and is expected to continue to rise by 450-820 mm by the end of the 21st century (Le Cozannet et al., 2014; Qiao et al., 2018). Large constructions such as harbors have a major impact on the shape of the coast, so it is necessary to understand the interaction between sea level and human activities on shoreline changes (Wang et al., 2017; Do et al., 2019).

The coastline of Wawonii Barat District continues to change. During the east monsoon season, the soil in several residential areas on the coast experiences abrasion (Agus, 2016; Heeryl, 2020). In addition, no mangrove habitat is found, large sea waves reaching Hs> 2.5, and having a flowing or parallel current type (longshore current) can also cause changes in the coastline in Wawonii and its surroundings (Hartomo et al., 2022). Shoreline accretion and abrasion can be caused by beach erosion, beach waves or human activities such as reclamation, *shore protection*, deforestation and planting of coastal forests to river flow patterns that carry material from the mainland (Bird & Ongkosongo, 1980; Nybekken, 1992).

Google Earth Engine (GEE) is a cloud base platform which provides the algorithm machine learning for geospatial analysis of raster data (Tamiminia et al., 2020). Shorelines can be extracted through GEE using the EVI, LSWI algorithms (Wang et al., 2020), ANN, KNN, SVM (Kumar et al., 2020) NDWI (Wang et al., 2017) or through algorithm modifications such as MNDWI (Wang et al., 2017; Vos et al., 2019; Wang et al., 2020) by classifying the appearance of satellite imagery into two classes, namely water and non-water (Ngowo et al., 2021). A modified NDWI can increase sensitivity to open water features while efficiently suppressing and even separating built-up areas, vegetation and soil (Hu, 2006). To measure the distance of the shoreline change can use the Digital Shoreline Analysis System (DSAS). The DSAS is a useful software in analyzing the rate of change of the shoreline over time (Hakim et al., 2014).

GEE-based shoreline changes analysis and evaluating the Regional Spatial Plan (RTRW) have never been carried out in Wawonii Barat District. The RTRW has just been enacted into a Regional Regulation on June 27 2021, so an initial evaluation needs to be carried out to avoid problems in the future. The purpose of this study is to monitor, analyze and evaluate changes in the coastline according to the spatial plan for the Wawonii Barat District as contained in the Konawe Kepulauan Regency Spatial Pattern for 2021-2040.

## METHOD

### Studies Area

The research location is in the coastal area of Wawonii Barat District, Konawe Kepulauan Regency, Southeast Sulawesi which is located at coordinate 3°68'30" – 4°6' South Latitude and 122°67' – 123°4'30" E with the Banda Sea on the North and West sides, Wawonii Tengah District on the South side and Wawonii Utara District on the East side. The research location can be seen in Figure 1.

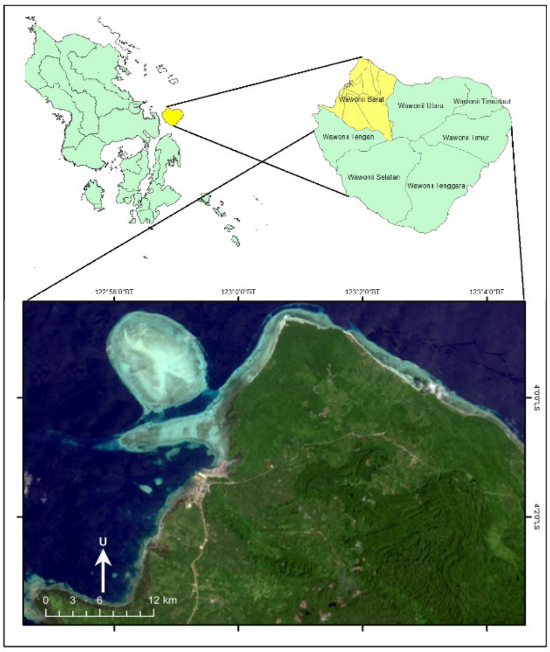


**Figure 1.** Studies Area

According to BPS (2021), Wawonii Barat District is inhabited by 8,746 people with an area of 91.21 km2. There are 16 Villages in the study area, with 10 Villages directly adjacent to the coast. The sub-districts/villages directly adjacent to the coast are the villages of Langgara Tanjung Batu, Langgaro Bajo, Langgara Iwawo, Mata Langgara, Langgara Indah, Pasir Putih, Kawa-Kawali, Wawobili, Wawolaa and Langgara Laut Village.

**Data Collection and Acquisition**

This study used Landsat 8 time series image with less than 10% cloud cover (Danoeder0, 2012). The number of images used is 5, i.e. from 29/09/2013 to 02/07/2021 with intervals of ±2 years called from the GEE platform. The 2013 image is used as the baseline in this study because it is located on the mainland (*onshore*) so as to clarify the boundary between waters and land where the position of the shoreline from the image can be seen clearly. Low cloud cover is required to get good classification results. The presence of clouds and cloud shadows can cause problems in separating pixel values in satellite images and extracting coastlines. *Cloud Removal* (Scaramuzza et al., 2011; Aldiansyah et al., 2021; Aldiansyah & Saputra, 2022) is used to get cloud-free images. The shoreline was extracted using the MNDWI algorithm (Xu, 2006) to classify built-up land, vegetation and soil and separate them from water. The MNDWI algorithm can be expressed by the following formula:

$$((Green-SWIR1))/((Green+SWIR1))$$

Classification process was done using *Supervised Classification*. *Support Vector Machine* (SVM) method is an effective learning machine algorithm to solve regression and classification problems. The number of classes used consists of water and land classes. The results of the classification can be seen in Figure 2.

**Shoreline Shift**

The shoreline change rate was processed using the DSAS toolbox in ArcMap 10.4.1 software. Shoreline changes are obtained by digitizing the SVM classification results from time to time for each map. The transect is made perpendicular to the shoreline. The distance between transects is 100 meters as suggested by Rostami et al. (2022). By using the intersection of the transects with each shoreline, the rate of change between shorelines can be determined. Statistical analysis of shoreline movement rates is performed automatically by DSAS including values of *Net Shoreline Movement* (NSM) and *End Point Rate* (EPR). Information regarding the statistics of shoreline changes can be seen in Table 1.

**Evaluation of Regional Spatial Planning**

The evaluation was carried out with reference to the Spatial Pattern of the Wawonii Barat District as contained in the Konawe Kepulauan RTRW for 2021-2040. The results of the evaluation are related to accretion and abrasion phenomena, impacts, recommendations using qualitative descriptive methods from similar studies, spatial pattern maps and laws and regulations.

**Table 1.** Statistical description of shoreline changes

| Statistics | Information | Unit |
|---|---|---|
| NSM | The distance between the initial and final shorelines. | m |
| EPR | Analyzed by dividing the NSM by the value between the initial and last shorelines. | m/year |

Source: Ngawo et al. (2021)

## RESULTS AND DISCUSSION

Support Vector Machine Classification

The classification results of the SVM method have good accuracy. The value of the resulting *kappa coefficient* > 0,8 with an overall accuracy of > 0,9. This shows that the MNDWI algorithm can classify certain types of land cover and land use as 1 class, making it easier to classify land and water using SVM. According to Rostami et al. (2022) the MNDWI algorithm is very good at classifying land cover between land and water. The MNDWI algorithm can extract water bodies area in the surrounding land cover in the form of non-developed land and waters with low sediment concentrations (Xu, 2006). Map of the classification results can be seen in Figure 2. The accuracy value of the classification results can be seen in Table 2.

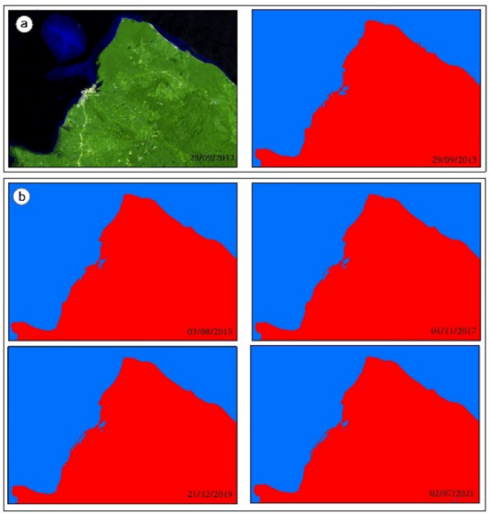


**Figure 2.** (a) *False color* from Landsat 8 imagery, (b) Classification from SVM by recording date

**Table 2.** The SVM Classification accuracy

| Year | Overall Accuracy | Kappa |
|---|---|---|
| 29/09/2013 | 0,93 | 0,86 |
| 03/08/2015 | 1 | 1 |
| 01/11/2017 | 0,93 | 0,86 |
| 21/12/2019 | 0,94 | 0,89 |
| 02/07/2021 | 1 | 1 |

Each map features diverse shoreline changes. The initial shoreline is 32.65 km and the final shoreline is 30.46 km. The long and winding shoreline is caused by the many shorelines forming bays, straits, capes and peninsulas. Shoreline changes can be seen in Figure 3.

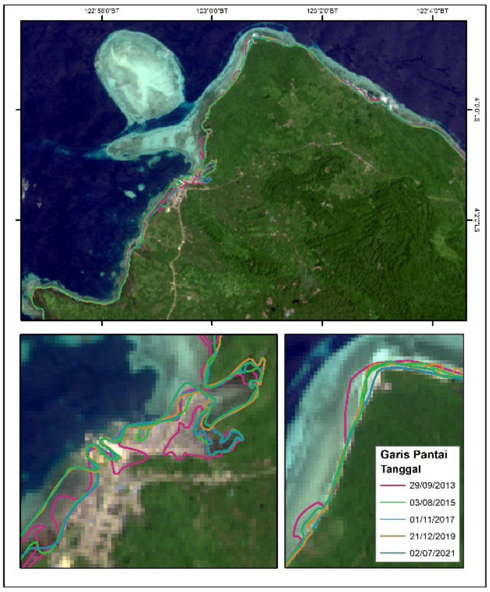


**Figure 3.** Wawonii Barat District's Shoreline changes

## Shoreline Shift

Shoreline changes were calculated by laying 288 transects, the distance of each transect was 100 meters. Based on NSM calculations, 48.96% of the transect experienced sedimentation and 51.04% experienced shoreline erosion. At 7.29%, the erosion rate is above 100 meters. In addition, 28.82% of the transects had erosion rates above 10 meters. Figure 4 shows the shoreline movement rate through the graph and Figure 5 shows the shoreline movement rate based on NSM analysis.

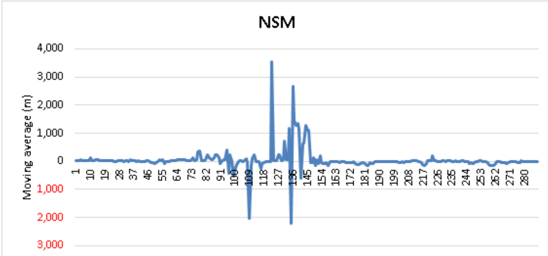


**Figure 4.** Shoreline movement rate (NSM)

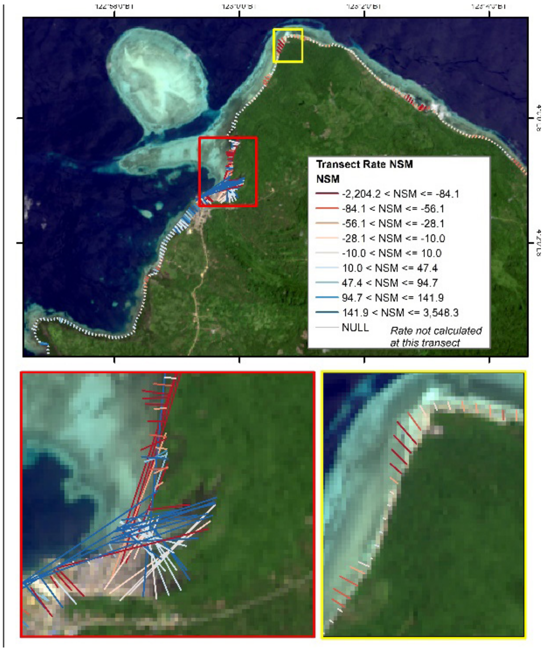


**Figure 5.** Initial and final shoreline movementrates were measured by NSM

## End Point Rate

End Point Rate (EPR) shows that most of the study area experienced abrasion. The average coastline has experienced abrasion of up to -10.58 m/year with the highest abrasion of -264.2 m/year. The coast of Langara Tanjung Batu village (yellow box) and the coast of Langaro Bajo village (red box) are showing the abrasion occurrences. The coast of Pasir Putih village shows that the shoreline is moving forward due to the presence of mangrove forests along the coast. Mangrove forests function were to maintain shoreline stability, protect beaches and rivers from erosion and abrasion, block storms/strong winds, hold material from the mainland and create new land (Riyawati, 2014).

 5

Abrasion on the western and northern sides of Wawonii Barat is caused by strong current from the Banda Sea (Agus, 2016). Sea current variations are closely related to seasonal wind patterns that occur in Indonesia (Kurniawan et al., 2011). The wave pattern in the waters of Sulawesi and the Banda Sea that blows in the east monsoon is dominantly derived from southeastern winds with an average speed of 2-10 knots and the characteristic wave pattern during the east monsoon reaches an average height of -0.25-2.5 meters (Istiyono et al., 2017). Villages experiencing abrasion and accretion can be seen in Figure 6 and Table 3.

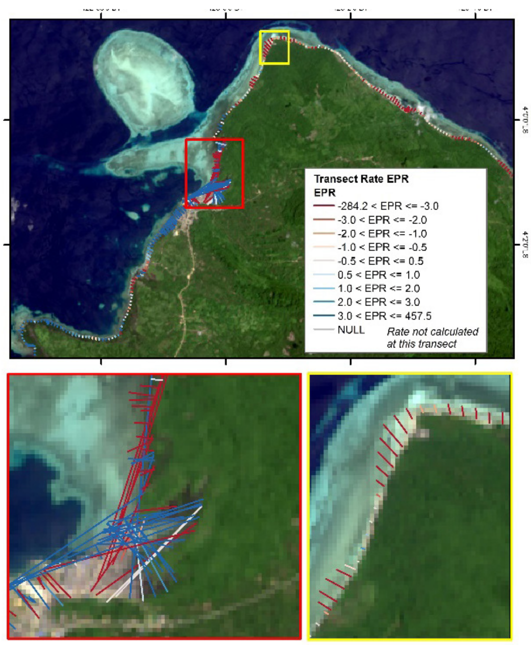


**Figure 6.** The average shoreline movement is measured by the EPR

**Table 3.** Abrasion and Accretion per Sub-district/ Village in the shoreline of Wawonii Barat District

| Sub-district/Village | Movement rate (m/year) | |
|---|---|---|
| | Abrasion | Accretion |
| Langgara Tanjung Batu | -17,59 | 48,37 |
| Langgaro Bajo | -11,81 | 32,93 |
| Langgara Laut | -32,95 | 11,63 |
| Langgara Iwawo | -8,82 | 19,16 |
| Mata Langgara | - | 10 |
| Langgara Indah | - | 10 |
| Pasir Putih | -3,45 | 3,47 |
| Kawa-Kawali | -0,68 | 0,18 |
| Wawobili | -4,58 | - |
| Wawolaa | -4,75 | 0,83 |
| Amounts | -84,62 | 136,55 |
| Average | -10,58 | 13,66 |

## RTRW Evaluation

The road construction plan on the coast is not suitable due to the movement of the shoreline (Figure 7). The shoreline has experienced abrasion to the extent that it has passed the planned road network system on most of the coast in Pasir Putih and Mata Langgara Villages.

Figure 8 shows that the Mangrove forest along the coast of Pasir Putih Village has decreased from what was planned with reference to the current shoreline. The existence of this protected area plan has been regulated based on Regional Regulation of the Konawe Kepulauan Regency No. 2 of 2021 in the form of a mangrove ecosystem area of 781 ha spread over 6 subdistricts including Wawonii Barat District. This area is designated for plant cultivation, environmental service utilization activities, non-timber forest product (HHBK) collection activities.

Shoreline degradation due to abrasion can cause conflict. The radius for the coastal border has been determined by Presidential Decree No. 32 of 1990 concerning the Management of Protected Areas, namely a minimum of 100m from the highest tide point towards the land. Regional Regulation No. 13 of 2011 clearly states the activities that are permissible for beach recreation, coastal protection, fishing activities, fishing boat moorings, port activities,*landing point cable* and/or underwater pipelines, national defense and security interests, beacon towers, activities related to water quality control, coastal environmental conservation, development of natural and artificial structures to prevent abrasion on the coastal border, safeguarding the coastal border for public spaces, weather observation activities and climate change and similar activities provided they do not disturb, damage and change the function of the coastal border. This shows that abrasion can lead to land conflicts. Abrasion has the potential to cause losses such as reduced land area and threaten settlements and activities of residents living in coastal areas (Tarigan, 2010).

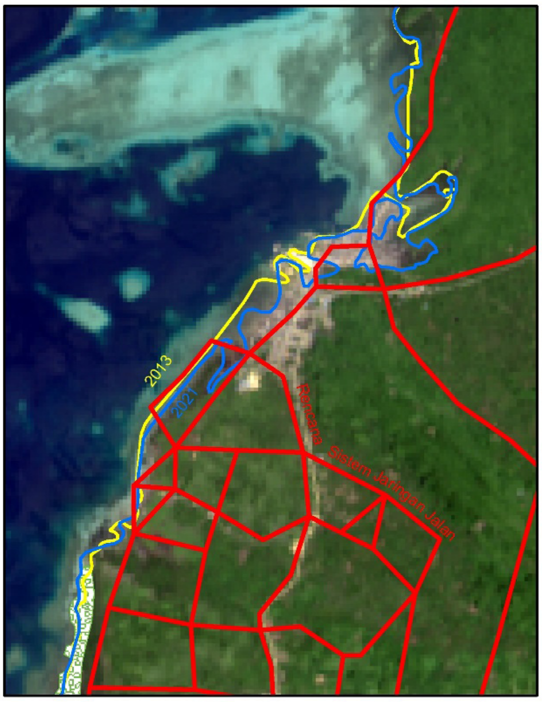


**Figure 7.** The incompatibility of the current coastline with the Spatial Pattern Plan specifically for the Road Infrastructure Network System Plan in the Coastal Areas of Mata Langgara Village and Pasir Putih Village, Wawonii Barat District

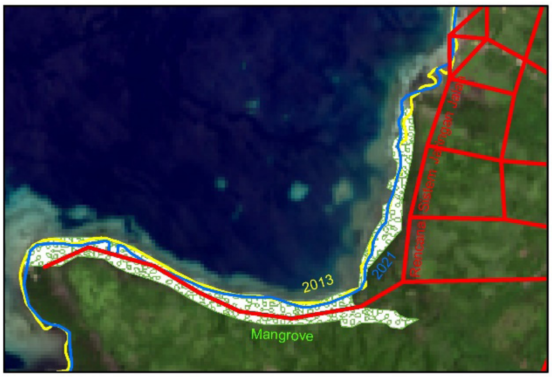


**Figure 8.** The incompatibility of the current shoreline with the Planned Mangrove Ecosystem Area at the Coast of Pasir Putih Village, Wawonii Barat District

Citizens in Wawonii District need a breakwater building, especially in coastal areas which are residential areas and face directly to the Banda Sea which has quite strong sea waves (Agus, 2016). Several villages such as Mata Langgara Village, Langgara Iwawo, Langgara Indah, Langgara Bajo, Wawobili and Langgara Laut Village with settlements that are starting to develop need special attention. In the study by Setyasih et al. (2020) in shoreline, Biduk-Biduk District, breakwater building have a good effectiveness as abrasion countermeasures and are effective in controlling abrasion.

Re-evaluation of the RTRW spatial pattern of protected areas in the form of mangrove forests also needs to be carried out, especially in Pasir Putih Village. In the study of Prismayanti et al. (2021) that abrasion and accretion are caused by damage to the mangrove ecosystem in Tangerang Regency. Replanting mangroves to replace lost mangrove forests aims to restore the function of the coastal border so that it can work according to its function. In addition, the road system network plan that is determined needs to be given double protection such as a breakwater building followed by planting mangroves along the coastal border to prevent abrasion on the coastal area road network system plan in the future.

## CONCLUSION

Overall accuracy and the Kappa coefficient of all maps are above 0.93 and 0.86 respectively. The average shoreline has experienced abrasion of up to -10.58 m/year with the highest abrasion of -264.2 m/year. Based on the RTRW of Konawe Kepulauan, Southeast Sulawesi Province needs to be re-evaluated, especially in relation to plans for a road infrastructure network system and mangrove ecosystem areas due to the degradation of the shoreline which has exceeded the limit set in the RTRW. The recommendation proposed is to prevent abrasion by creating retaining wall and breakwater bays in coastal areas that are directly related to settlements and planting of mangroves along the coast.

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