DIFFERENCES OF SHORELINE CHANGES IN THE AREA AFFECTED BY LAND COVER CHANGES AND COASTAL GEOMORPHOLOGICAL IN SOUTH BALI 1995 - 2021

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Abstract. The South Bali coast is prone to abrasion due to its geographical position facing the Indian Ocean. High sea waves and currents in the south of Bali will erode beaches whose lithology and morphology are prone to abrasion. Land cover conditions that do not support coastal protection will also affect the high abrasion of the southern coast of Bali. This study aims to analyze the shoreline changes in South Bali from 1995-2021. The analytical method used is the Digital shoreline analysis system (DSAS), with data from Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI/TIRS, and Sentinel 2A. The analysis results show that the area directly facing the waves is relatively high, with volcanic rock formations, and there is no mangrove as coastal protection. The lack of good coastal management shows the area with the highest abrasion. It was found in the western part of Tabanan Regency, eastern Gianyar, and southern Badung. Meanwhile, the average coastal accretion was relatively high in the neck of South Bali, in areas where the land cover was mangrove and adjacent to river mouths, which experienced much sedimentation.

Keywords: *shorelines, digital shoreline analysis system, land cover change, volcanic morphology*

1 INTRODUCTION

Shoreline changes are influenced by various geological factors, such as river and sea sedimentation and human socioeconomic activities (Chen, et al., 2005; Naji & Tawfeeq, 2011; Xu, et al., 2016; Mutaqin, 2017). Beach morphology, sea wave characteristics, coastal land conditions, wind direction and speed, and reclamation and development activities also affect coastal abrasion (Chen et al., 2005; Kaliraj et al., 2017; Mutaqin, 2013; Morton, 2003).

The shoreline in South Bali is geographically vulnerable to changes in shoreline due to the condition of the coast, which is directly opposite the sea off the Indian Ocean in the south of the island of Bali. According to a study by Parwata et al (2012), land-use change in Bali exceeds 1,000 hectares per year for constructing housing and public buildings, and this number will continue to grow as needed. The most famous land reclamation in Bali island reclamation on Serangan Island in southern Bali changed the quality and order of land use. Since it was restored in 1996, the area of Serang Island has quadrupled. The reclamation creates a narrowing of the shoreline, which residents usually enjoy because almost 75% of the shoreline is in the PT after restoration BTID (Bali Turtle Island Development). This makes shoreline changes in reclaimed areas different from those not reclaimed (Darmawan, 2013; Marfai et al., 2019; Parkinsonm, et al., 2018).

The coast, which is the meeting place between land and marine ecosystems in a balance, is vulnerable to changes in shoreline due to reclamation. Infrastructure development and population growth in coastal areas also significantly influence changes in coastal areas' carrying capacity and capacity (Beatley et al., 2003; Tian et al., 2016; Marfai et al., 2018)

According to Mortimore et al., (2004), the spatial variation in the level of abrasion becomes smaller with increasing time intervals, which means that coastal abrasion will occur over a long period on the coast with slight variation along the coast based on the characteristics of the ocean waves and lithology. Differences in lithological characteristics that erode sooner or later are essential for predicting when, where, and how the subsequent abrasion will occur. In Vasuki et al. (2017), typical lithological boundaries for segmentation are contacts between different stratigraphic units, contact surfaces of intrusive geological units, or fault lines separating different units. It is associated with discontinuities or visual cues such as color and texture variations due to variations in mineralogy assemblages across different geological units (Obert, 2017; Randazzo et al., 2020; Young et al., 2009).

Many previous researchers have carried out the development of remote sensing technology and geographic information systems to analyze the development of coastal areas and changes in shorelines. The use of this technology has been proven to help manage coastal areas (Kaliraj, 2017; Siddiq et al., 2020; Marfai et al., 2016; Van et al., 2009)

Research related to shoreline changes can provide information for monitoring and policymaking on the planning, development, and management of coastal areas, especially those aimed at conserving the environment and its ecosystem (Marfai, et al., 2011; Dimyati, et al., 2021). For this reason, research using remote sensing data analyzed by DSAS in the southern part of Bali was carried out.

This research objective is to analyze the shoreline changes using Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI/TIRS, and Sentinel 2A in South Bali from 1995-2021. Furthermore, I also want to know how much influence and spatial distribution of shoreline changes in areas affected by land cover change and volcanic morphology in South Bali.

2 MATERIALS AND METHODOLOGY

This research was conducted in South Bali or covered the districts of Badung, Gianyar, Tabanan, and Denpasar City. This research area has a shoreline of more than 120km. The research location is bordered by three oceans, the Bali Strait, the Badung Strait, and the Indian Ocean. The research area has a relatively significant influence on ocean currents and waves, especially in the southern region because it is directly adjacent to the Indian Ocean. So that in some places, there is influence from humans in the form of coastal protection from abrasion in the form of groins and coastal embankments to avoid the impact of abrasion.

Each geological unit is segmented, and categories provide an approach to extracting features from object images. These objects are created through an image segmentation process in which adjacent pixels with similar spectral characteristics become one segment. Segments that exhibit specific shape, spectral, and spatial characteristics can further become objects. Objects can then be embodied into classes that represent real-world features in the field (ESRI, 2016). Segmentation analysis in this study is divided into four parts, and each segmentation contains at least five samples based on the characteristics of the coast, accretion, abrasion, and lithology.

The variables used in this research are abrasion, accretion, lithology, land cover change, current direction, and ocean waves. In identifying the shoreline, the RGB (Red-Green-Blue) composite band is used based on the research of Torahi & Rai (2011). The sensitive band used for land cover and shoreline analysis on Landsat 7 is 7-4-2, Landsat 5 is 4-3-2, on Landsat 8 is 7-5-3, and on Sentinel-2A, it is 12-8-3. They were digitizing the shoreline based on the rationing method using band 5 and band 2 on Landsat 7 imagery. The ratio of band 5 and band 2 helps identify water bodies and generate wetland information 66 (Jensen, 2005). From the results of the comparison that has been made, the land will look black, and the water body will be white. The process produces shoreline information. The results will be processed with DSAS software to calculate and measure shoreline changes.

The condition of the observation location in South Bali is divided into five segmentations based on different lithological characteristics (Ngcofe and Minnaa, 2012). Segmentation analysis was conducted to compare shoreline changes in the study area at different locations. Field observations were carried out to compare the results of land cover categories in the image with actual conditions. The results of land cover categories from different segments are then compared based on the segmentation division, and the changes are calculated.

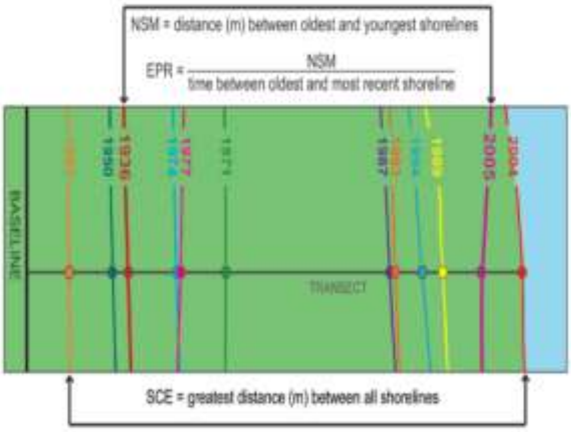

Figure 2-1: NSM, EPR, and SCE Algorithm
Source: U.S. Geological Survey. (2018)

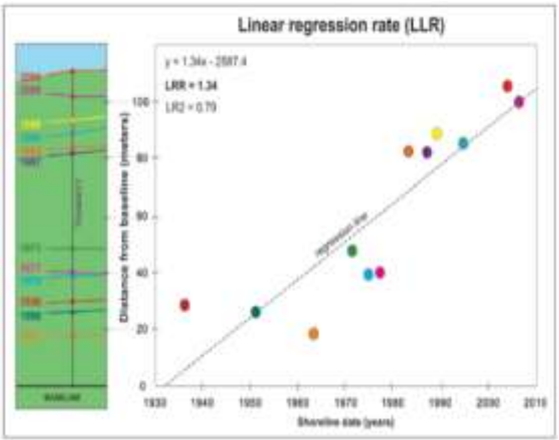

Figure 2-2: Line Regression Rate (LRR) Algorithm. Source: U.S. Geological Survey. (2018)

Abrasion and accretion were analysed based on the movement of shoreline distance values. The Net Shoreline Movement (NSM) will link data from the two beaches and provide the distance between the oldest and newest shores for each transect section. This method is used to generate statistics on NSM and End Point Rate (EPR). The depiction of abrasion and accretion in the study area was carried out at 50 m transect line intervals in Figure 2-1. DSAS is the basis for measuring and calculating shoreline changes through processed images (USGS, 2018). The shoreline change rate was analysed using the linear regression rate (LRR) statistical approach, which is algorithms in Figure 2-2.

Temporal analysis was carried out using the shorelines of 1995 – 2005, 2005 – 2015, 2015 – 2021. Temporal observations of shoreline changes were carried out by comparing the conditions of land cover changes in 1995 – 2005, 2005 – 2015, and 2015 – 2021. This is essential to examine the occurrence of sediment transport and abrasion over several years and shows that the direction of sediment transport varies spatially and temporally (McCave, 1978), and significant changes likely occur at a time scale of decades. Analysis of shoreline change at different temporal scales can analyse the primary factors and evolving interactions of variability, land cover change, ocean currents, and anthropogenic interventions.

3 RESULTS AND DISCUSSION

Observations were made through Landsat and Sentinel 2-A satellite images whose shorelines had been extracted using ENVI with a single band threshold NIR. Landsat 5 and Landsat 7 have a radiometric resolution of 8 bits (0 – 256), and the shoreline pixel data value is 26, while Landsat 8 and sentinel 2-A have a radiometric resolution of 16 bits (0 – 65536). The results of the shoreline extraction can be seen in Figure 3-1 with the satellite image of Sentinel 2-A in 2021, which is located in the eastern three segments. Figure 3-2 shows Landsat 7 2015 satellite imagery and shoreline extraction for each period.

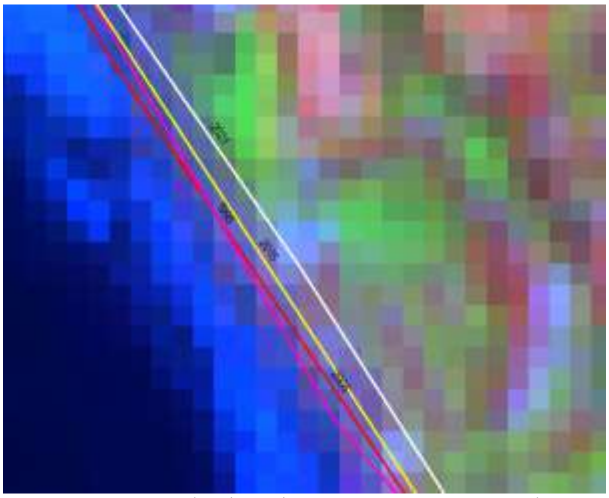

Figure 3-1: RGB Composite band 12-8-3 Remote Sensing Sentinel 2A
Source: Sentinel-2A Remote Sensing

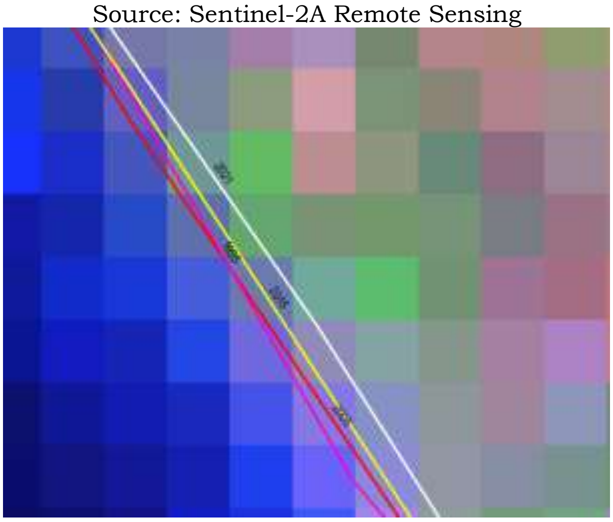

Figure 3-2: RGB Composite band 7-5-3
Source: Landsat 8 Remote Sensing.

The shoreline extracted and analysed by DSAS is shown in Table 3-1 and Figure 3-3. The change in shoreline with average abrasion on the Line Regression Rate (LRR) method in the range 1995 – 2021 is 1.46m/year. The most significant abrasion value occurred in 2005 – 2015 with an average of 4.2m/year and the second-highest in 2015-2021 with an average value of 3.58m/year. The year with the lowest average abrasion value was 1995 – 2005 with an average of 1.22 m/year, and the second-lowest abrasion was in 2005 – 2015 with an average of 1.84 m/year. These results are by the research of Mortimore et al. (2004) that the spatial variation of lithology makes a big difference in abrasion and accretion along different coasts.

Table 3-1: Average abrasion and accretion in South Bali 1995 – 2021.

Segmentation	Accretion (m/year)	Abrasion (m/year)
1	0,62	2,37
2	0,60	1,46
3	3,74	0,91
4	1,18	0,85
5	0,14	1,73

This difference can be seen in Figure 3-3 the average accretion on the Line Regression Rate (LRR) method in 1995 – 2021 in picture, which is 1.26m/year. The most significant average accretion is in the range of 2015-2021 with an average of 14,314m/year, followed by the second-highest in 2005-2015 with an average of 3.96m/year. The lowest accretion occurred in 1995 – 2005 with an average of 0.14m/year and the second-lowest accretion rate was in 2005 with an average of 1.48m/year.

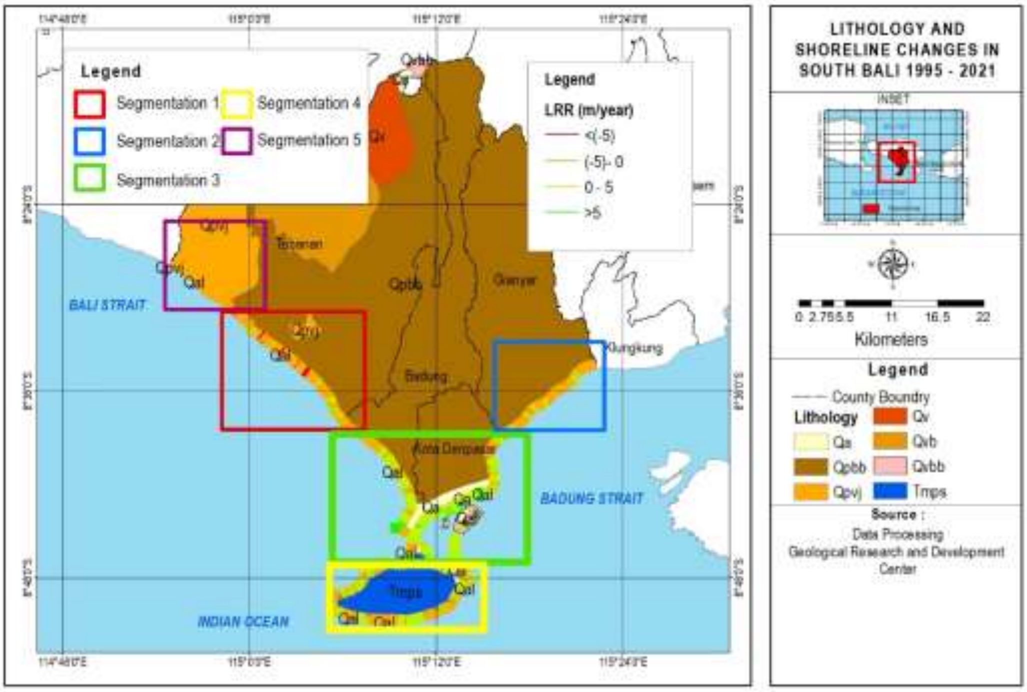

Figure 3-3: Map of Lithology and shoreline Change in South Bali 1995 - 2021
Source: Processing Data, 2021.

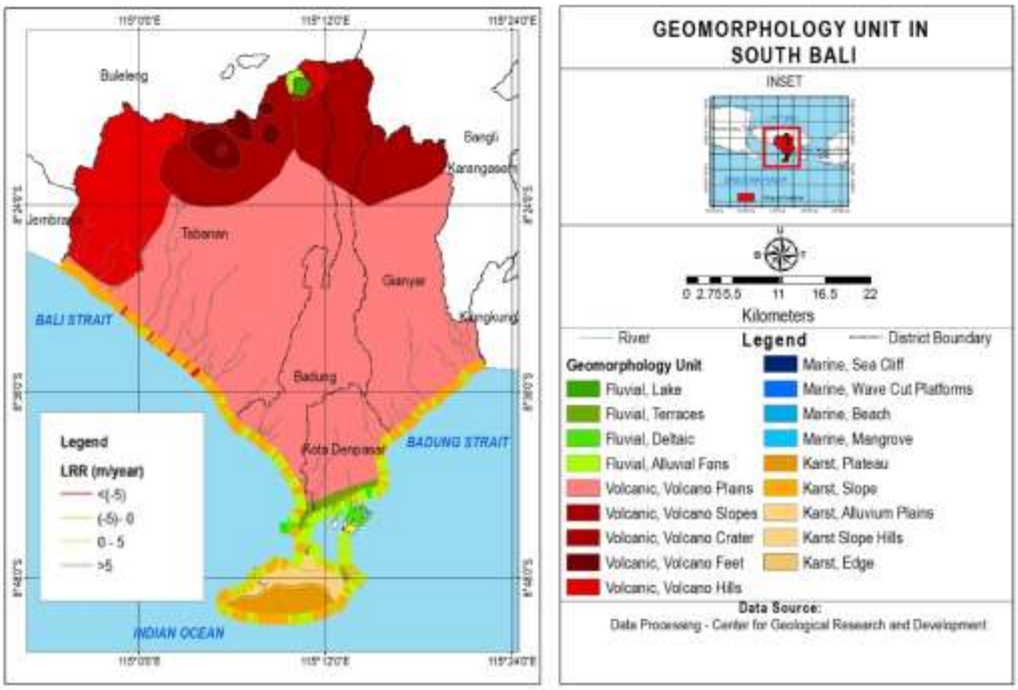

Figure 3-4: Map of Geomorphology Unit in South Bali 1995 - 2021
Source: Processing Data, 2021.

Differences in geomorphology characteristics in Figure 3-4 make the average magnitude of abrasion or beach eroded differently in each beach segmentation. Segmentations 1 and 2 has volcanic geomorphology characteristics, namely volcanic parent rocks experiencing changes in shoreline, dominated by abrasion with an average size of 1-2 m/year. Sunamura (2015) in segmentation 1 with Qpbb lithological characteristics, including the geological age of the quarter with an abrasion level of 1–10 m/year. Segmentation 3 with Qal lithological characteristics, namely alluvium source rock, is dominated by an accretion process of 3.74 m/year due to sediment results in the mangrove forest area. Segmentation 4 with the lithology of the Tmps formation, namely limestone parent rock, has a slight abrasion of 0.85m/year on average. In comparison, segmentation 5 with the Qpj characteristic has an abrasion of an average of 1.73m/year.

The most significant accretion occurred in segmentation 3, which was 3.74m/year on average due to the runway area at I Gusti Ngurah Rai airport in South Kuta District, Badung

The river mouth, the reduced shoreline tends to be low and becomes accretion due to sedimentation.

Regency. Another factor in segmentation 3 is the characteristics of alluvial lithology (Qa) as a coastal river deposition area. Changes in the shoreline in general, abrasion occurs in segment 1 with an average of 2.37 m/year due to the condition of the area with Qpbb lithological characteristics and the coast which is directly opposite the Indian Ocean, causing quite large sea waves which can increase the occurrence of abrasion.

The influence of land cover on shoreline changes, namely on river estuary sedimentation, can be seen in segmentation 3 in Figure 3-4. The area at the end of the river estuary was experiencing more significant accretion due to sedimentation in segment 3. This area is included in alluvium characteristics and becomes the mouth of the Tukad Badung River. The Tukad Mati River and the Tukad Rangda River, which make sediment filling higher, is supported by Bomer et al. (2020) research that due to sediment filling at

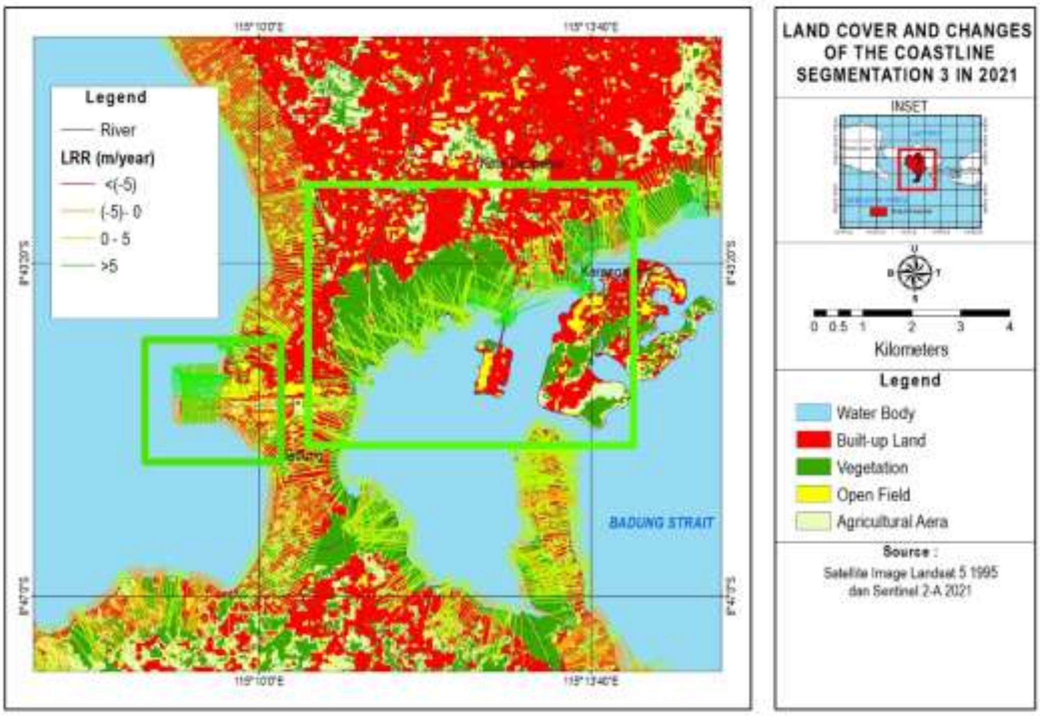

Figure 3-5: Map of Land Cover and shoreline Changes Segmented 3 1995 - 2021
Source: Processing Data, 2021.

Accretion shoreline changes by an average of 5m/year in areas close to river mouths. It is also protected from sea waves due to its geographical position in Benoa Bay and is surrounded by mangrove forests for abrasion prevention. The factor of changing coastal land cover into built-up land, namely the runway of I Gusti Ngurah Rai airport, is also the cause of significant accretion in this segmentation. The accretion rate in the airport area is up to 40m/year. This is also supported by the research of Shimozono et al. (2019), which explains that the rapid development in river estuary over the last ten years has caused the shallowing of sea waters due to increased sedimentation every year and accretion occurs.

In areas with marine and volcanic origins in segmentation 1, 2, and 5, it is dominated by an average abrasion of 1 – 2m/year with a geomorphological unit characteristic of the wave-cut platform as shown in Figure 3-5 In areas with marine and fluvial origin, and segmentation 3 is dominated by an average accretion of 1-3m/year with the geomorphological unit being mangroves and close to rivers, thus supporting sedimentation to accretion. In areas with karst and marine origins in segmentation 4, it is dominated by abrasion with 1-2 m/year with the geomorphological unit in the southern part, namely karst and coastal slopes, where dissolution and coastal abrasion occur every year as shown in Figure 3-6

Figure 3-6: Beach Conditions in Segmentation 1(a), 2(b), 5(c) 3(d) and 4(e)
Source: Survey Documentation (2021).

The condition of the coastal geomorphological unit that is close to fluvial at the neck of the South Bali study tends to occur sedimentation to cause the dominance of accretion compared to abrasion because of its characteristics close to Benoa Bay which is surrounded by mangroves in Randy (2015) research which explains that it can reduce abrasion. Beaches close to volcanic geomorphological characteristics are dominated by abrasion because they are far from mangroves, except for coastal conditions close to river mouths, which are indicated to carry sediment and become accretion. The slightest abrasion occurs in coastal geomorphological units close to karst in the south.

The influence of the direction of currents and ocean waves in segmentation 1 and 5 are included in the characteristics of an average wave height of 2m, and the direction of ocean currents from the Indian Ocean is experiencing relatively high abrasion up to an average of 1 - 2m/year. In segmentation 2, which has a current direction from the Badung strait, the wave height is relatively low, namely 1.25 m in average experiencing abrasion and low accretion, which is around 1.46 m/year, dominated by abrasion.

In segment 3, which has a characteristic low wave height of 1.5 m with alluvial lithology, the accretion of shoreline changes on average 3.74 m/year with a relatively low level of abrasion because mangrove forests block it. In segmentation 4, directly facing the Indian Ocean, has a relatively high level of sea waves of 2.5m on average, 1-5m abrasion occurs. This is supported by research conducted by Viitak et al. (2016) that the factors of current direction and ocean waves affect shoreline changes due to the mechanism of energy transfer from ocean waves to the coast. Segmentation 5 includes the characteristics of an average wave height of 2m and the direction of ocean currents from the Indian Ocean experiencing extensive abrasion up to an average of 0.85 m/year.

4 CONCLUSION

Changes in the shoreline on the coast of South Bali from 1995 - 2021 are spatially and temporally influenced by several variables. The highest abrasion is located in the area facing the sea off the Indian Ocean, where the area is volcanic rock, and there is no good coastal management, and no mangroves are planted. These locations are found in the western part of Tabanan Regency, eastern Gianyar, and southern Badung. The average coastal accretion occurs in the neck of South Bali, namely in the central part of Badung Regency and Denpasar City. This is because of the alluvial characteristics, namely the area close to the mangrove ecosystem so that sedimentation carried by sea currents is held in this area and added close to the mouth of many rivers. Carry sediment. Changes in coastal accretion occurred significantly in the downstream area of the river, namely around areas covered by mangroves.

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