Shoreline Change Detection Based on the Monsoon Seasonality by means of 'CoastSat' toolkit

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Abstract:*The sand accretion/erosion process is mainly responsible for the shoreline position changes in coastal zones. Understanding sand accretion/erosion response due to monsoon seasonality and anthropogenic effects is vital for coastal management to apply the best suitable coastal protection strategies. However, long-term monitoring of shoreline changes is expensive, time-consuming and labor-intensive. Instead, satellite imagery (Remote sensing technology) can be utilized as a substitute method to the field data collection, provided that time-series imagery is obtainable at the same location and freely downloadable using the Google Earth Engine archive. This study is mainly focused on shoreline change detection and geomorphological changes, Mirissa in southern coast of Sri Lanka. The 'CoastSat' software was employed to obtain the time-series of shoreline positions. According to the analysis of data, the beach was in three state: erosion, accretion, and steady state. Further, the most of transect locations indicate steady beach state and it is good for the development of tourism industry. In addition, the average horizontal shoreline difference ('CoastSat' and field measurement) was 7.95±1 m and that is in acceptable range. Accordingly, satellite images downloaded from the Google Earth Engine using 'CoastSat' can be used to analyze shoreline change detection very effectively with appropriate tidal correction when there is a lack of long-term field data in the area and it will be very useful for planning and evaluating coastal management strategies.*

Keywords: *Accretion, CoastSat, Erosion, Shoreline*

1. Introduction

The line of intersection of land and sea at a certain tidal height is measured as the 'shoreline'. An instantaneous coastline is defined as the position of the land-sea water boundary at a specific time (Gens, 2010). Based on the various conditions, different types of coastal boundaries such as vegetation line, wet-dry boundary, mean sea level (MSL), high tide line are also considered as shoreline (Boak and Turner, 2005; Gunasinghe et al., 2021; Ratnayake et al., 2019). Because coastlines are highly dynamic, detailed investigation of shoreline changes and maintenance of good coastal managing systems require continuous investigation and monitoring (Bouchahma and Yan, 2012; Gunasinghe et al., 2022). Nevertheless, continuous field data collection is expensive, time-consuming, and labor-intensive (Warnasuriya et al., 2018). To manage these difficulties, remote sensing (RS) technology is adapted to investigate long-term coastal changes and it has several advantages such as reduction of manual errors, cost-effectiveness, and temporal data acquisition (Gunasinghe et al., 2022; Specht et al., 2020).

Sri Lanka has a coastline of 1,620 kilometers around the country, with estuaries, sandy beaches, salt marshes, lagoons, coral reefs and dunes. Such an important coastal zone may be destroyed due to many reasons including dangerous storms, coastal erosion, and anthropogenic events, and investigation of shoreline changes offers scientific solutions and methods to develop coastal zones with protection. Coastal position changes in coastal regions of Sri Lanka are mainly controlled by monsoon seasonal changes (Amalan et al., 2018; Gunasinghe et al., 2019, 2021, 2022;

Gunasekara et al., 2020; Prabasara et al., 2021; Ratnayake et al., 2018, 2019). The coastal area focused on in this study (Mirissa, located on the southern coast) is wave-dominated (average significant wave height 1.12 m) and microtidal (tidal range 0.7 m) (Duong et al., 2017; Gunasinghe et al., 2022; Ranatunga et al., 2020; Ratnayake et al., 2013). Mirissa, a famous tourist destination of the island, is located about 129 km south of Colombo (Figure 1).

Figure 1. The study location

The main objectives of this study are to investigate shoreline changes using 'CoastSat' toolkit (the open-source and python-based) and to describe the coastal geomorphology at Mirissa. Further, such a scientific information is vital to maintain a proper coastal managing system in the area.

2. Methodology

In the present analysis, the open-source software 'CoastSat' toolkit was used to extract the coastlines relevant to the study area. 'CoastSat' is a Python-based program capable of obtaining shoreline positions (horizontal accuracy ~10 m) of any coastal region in the world using publicly available satellite images archived on Google Earth Engine (GEE) for more than 30 years (Vos et al., 2019a; Vos et al., 2019b).In Mirissa, WGS 84 coordinates of region of interest (ROI, the polygon) covering a 2 km long were entered into the 'CoastSat' software. The satellite mission was inserted as 'S2' (Sentinel-2, spatial resolution of 10 m), and the satellite image acquisition time length was expanded from 1 January 2016 to 1 May 2022. The 'CoastSat' retrieved 286 images and 65 images were selected for shoreline analysis after the pre-processing (cloud masking, panchromatic image sharpening and down-sampling) and classification process (sand, water, white-water, and other land features). The time gap between selected images was approximately 30 days and twelve shore-normal transects were defined by approximately equal distance (Figure 2) within a 2 km long coastline. After applying tidal corrections to the extracted shorelines at the location (converting instantaneous shoreline position into datum-based shoreline position, mean sea level (MSL)), the time-series of cross-shore distances along shore-normal transects were determined from landward to seaward and resultant data files were obtained as a MS-Excel *.csv format from the 'CoastSat' and timeseries of shoreline change along each transect was plotted on a graph for the analysis.The accuracy of the coastline extracted by 'CoastSat' was verified by comparison with coastal field survey data obtained through

Figure 2. Shore-normal transect locations

Global Navigation Satellite System (GNSS) technology (TOPCON GR5 GNSS receiver) and Sri Lanka Continuously Operating Reference Station Network (SLCORSnet) Correction (horizontal accuracy - 0.007 m). Accordingly, the average difference between the shoreline position obtained from 'CoastSat' and the field survey was calculated at the study location. Furthermore, the overall beach state at the Mirissa coastal zone was calculated at each transect location.

3. Results

A. Seasonal geomorphological changes

The shoreline variations at each transects based on the time is illustrated by Figure 3 and further, there are sixty-five shore-normal distances with respect to the mo monsoon seasonal variations. In general, the sand accretion is evident during the northeast monsoon season and sand erosion is evident during southwest monsoon season (Gunasinghe et al., 2021; Ratnayake et al., 2018, 2019). However, sand accretion and erosion process based on the monsoon seasonality in Mirissa is different than general process of sand accretion and erosion. The sand accretion is evident during southwest monsoon (03 May 2016), 1st inter-monsoon (27 April 2020), 2nd inter-monsoon (24 October 2020), and following general process that is during northeast monsoon (07 February 2017). Further, sand erosion is also evident during all monsoon seasons at the different times, and it is difficult to present common time duration for the sand erosion in the study area. Furthermore, there are no any significant variations of shorelines relevant to each transects.

B. Average horizontal difference of shoreline position ('CoastSat' and field observations)

The average shoreline difference of 'CoastSat' and field observation on 18 April 2022 was 7.95 ± 1 m at Mirissa coastal area. Therefore, it is suggested that the average value is in acceptable range.

C. Overall beach state

Based on the Table 1, the overall beach state can be categorized as erosion, accretion, and steady state. The values below 10 m (loss or gain), the beach state is considered as steady state. Further, first four transect locations are indicated steady beach state (Table 1). Furthermore, mean and standard deviation of shore-normal distances in each transects are presented on the Table 1.

4. Discussion

A. Seasonal geomorphological changes

Changes in shorelines depend on many factors such as existing shoreline shape, source and sink of sediment, strong storm and hydro-sediment dynamics, and longshore currents and cross-shore transport based on monsoonal changes (Deepika et al., 2014; Gunasinghe et al., 2021; Harris et al., 2020; Ratnayake et al., 2018; 2019).

Waves are propagated from southwest direction during southwest monsoon season in southern coast (Amarasekara et al., 2014) and therefore, the longshore currents move in an east-northeast direction in Mirissa. During the northeast monsoon season, waves propagate from northeast direction (Amarasekara et al., 2014) and longshore currents are towards west-southwest direction in Mirissa. Further, the sand accretion and erosion process in each transect locations is mainly controlled by longshore current direction and orientation of the coastline in Mirissa. Based on the location, and direction of the wave propagation, cross-shore transport is less effective for the coastal process (erosion/accretion).

B. Overall beach state

Based on the overall beach state, the steady state beach can be seen in many transect locations in Mirissa. It is suggested that the monsoon seasonality, wave propagation direction, orientation of the coastline, and local wind pattern are reasoned for the steady state beach in Mirissa. Therefore, Mirissa beach is most suitable for recreational activities and tourism industry. Further, sand accretion is

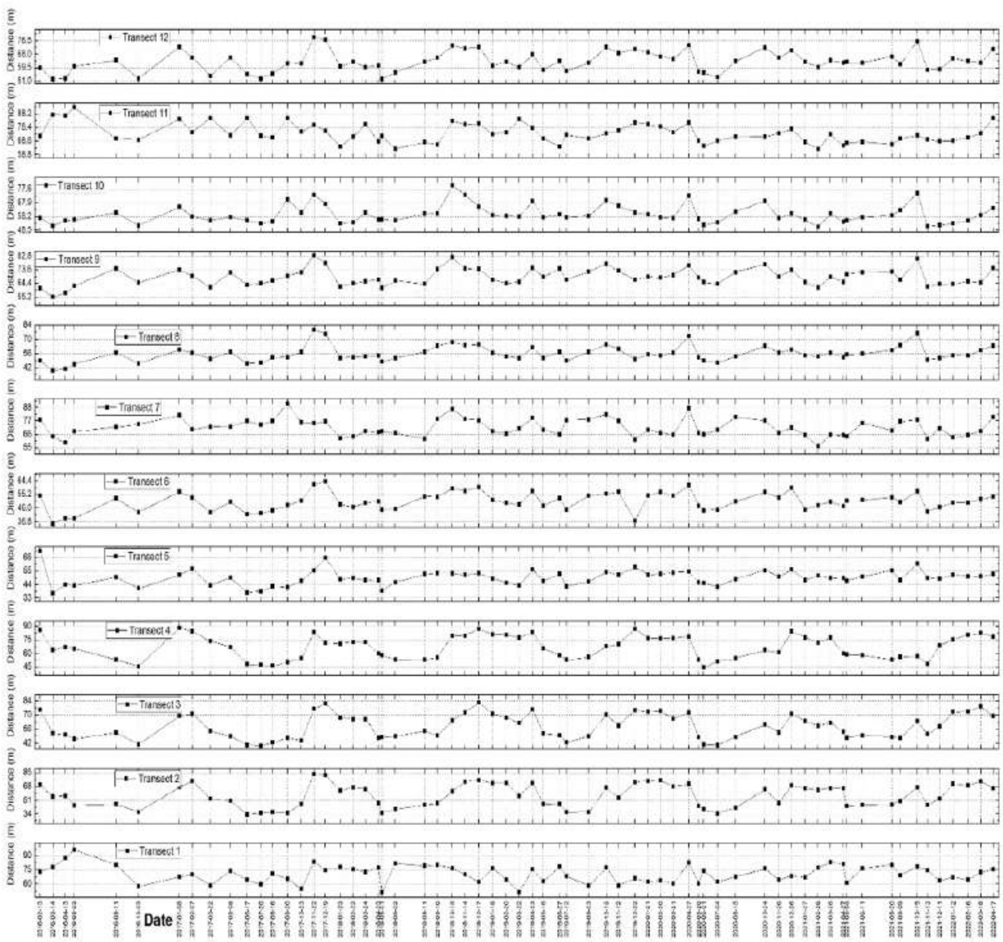

Figure 3. Transect based sholine variation

evident in many transect locations and it is a good reason for the development of the tourism industry

5. Conclusion

In this study, the 'CoastSat' toolkit was used to investigate shoreline changes in Mirissa coast. Accordingly, the following conclusions were reached.

1. If the long-term field measurements relevant to the shorelines are not available, the 'CoastSat' toolkit can be used with field verification as the best alternative.
2. The overall beach state in Mirissa shows more than 10m sand accretion and erosion based on the monsoon seasonality.
3. Sand erosion and accretion is occurred during all monsoon seasons (southwest, northeast, 1st inter-monsoon, and 2nd inter-monsoon).

Table 1. Overall beach state

Transect No.	Number of Shore lines Extracted	Time Frame	Distance between proceeding (OL) and succeeding (YG) Shorelines (OL-YG) m		Overall-Beach State	Mean (m)	Standard Deviation
			Gain	Loss			
Transect 1	65	2016 - 2022	02		Steady State	70.68	09.17
Transect 2	65	2016 - 2022		04	Steady State	56.89	14.29
Transect 3	65	2016 - 2022		06	Steady State	58.84	12.08
Transect 4	65	2016 - 2022		07	Steady State	67.00	12.67
Transect 5	65	2016 - 2022		19	Erosion	49.75	06.25
Transect 6	65	2016 - 2022		00	Steady State	50.53	06.13
Transect 7	65	2016 - 2022	02		Steady State	71.61	07.11
Transect 8	65	2016 - 2022	14		Accretion	55.94	07.74
Transect 9	65	2016 - 2022	13		Accretion	68.76	05.75
Transect 10	65	2016 - 2022	06		Steady State	59.78	06.43
Transect 11	65	2016 - 2022	12		Accretion	74.28	06.87
Transect 12	65	2016 - 2022	11		Accretion	63.51	06.46

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