J.Natn.Sci.Foundation Sri Lanka 2022 50 (4): 813 - 826
DOI: http://dx.doi.org/10.4038/jnsfsr.v50i4.10823

RESEARCH ARTICLE

Coastal erosion

Assessment of wave climate change and its impact on littoral drift along the Kalutara and Kalpitiya beaches in Sri Lanka

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Submitted: 07 December 2021; Revised: 01 July 2022; Accepted: 26 August 2022

Abstract: Natural and anthropogenic activities have accelerated the coastal erosion in Sri Lanka by threatening the economic developments and livelihoods in coastal zones. However, there is a limited number of studies on coastal erosion in Sri Lanka due to the lack of observed wave climate data around the island. This study identified the impact of wave climate changes on the littoral drift of seven selected locations in Sri Lanka. The reanalyzed wave climate data were used to estimate sediment transport rate in seven locations using empirical methods. The chronological volumetric changes of Kalutara and Kalpitiya beach volume were estimated, as those beaches experienced severe morphological changes during the above period. The relationship among the capacity of coastal sediment transportation of littoral drift, actual sediment accretion (and erosion), and shoreline management activities was critically discussed by collecting data from diverse sources to its fullest extent. The wave climate becomes rough on the western and southern coasts during the southwest monsoon and the eastern coast during the northeast monsoon. The average wave direction periodically changes on the southwest coast, and thus, the littoral drift occurs southwards at the Kalutara coast. The Kalpitiya areas were the main sediment accretion areas, but the Kalplitiya peninsula is slowly eroding with the recently intensified wave climate. Coastal erosion is an integrated effect of shoreline management, wave climate change, and reduction of river sediment supply. Therefore, coastal erosion should be studied with accurate numerical and physical model studies for the betterment of erosion management.

Keywords: Coastal erosion, Kalpitiya, Kalutara, littoral drift, wave climate.

INTRODUCTION

Coastal erosion occurs when waves and currents remove the sediments from the beach; thus, the beach becomes narrow and steep in elevation (Orme 2005). As a result of coastal erosion, we lose valuable land, which adversely affects the livelihoods of beach users (Dayananda 1992; Samaranayake 2007; Senevirathna *et al*. 2018). The capacity for sand transportation by littoral drift mainly depends on the wave climate (*i.e*., significant wave height (H_s), peak wave period (T_p), and the angle (θ) of the direction of the incoming wave) (Kamphuis *et al*., 1986; Bayram *et al*., 2007; Ratnayakage *et al*., 2020). A coast with predominant littoral drift is highly sensitive to wave climate and its changes. Wave climate changes are assessed worldwide (Ranasinghe, 2016), and it has been found that global climate change is directly contributing to shaping beaches worldwide (US EPA, 2021). The disappearance of sand splits, the narrowing of wide sandy beaches, and damage to existing coastal protection works are the most common impacts of wave climate changes. Those cases highlight the importance of the assessment of wave climate changes to mitigate their adverse effects. Kalutara is located in the western region of Sri Lanka and plays a vital role in attracting tourists through its Calido beach. As a result of the coastal erosion of Calido beach, livelihoods have been heavily affected in this area (Ampitiyawatta & Guo, 2010; Perera & Ranasinghe,

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2021). Not only are the livelihoods of the residents in the Kalu river estuary affected, but they also face the issue of salinity intrusion along the river, thereby affecting the quality of raw water abstracted for water supplies (Ratnayake *et al*., 2013). High-energy, steep, southwest monsoon waves lead to the reduction of beach breadth and flatten the intertidal shoreface (Ratnayake *et al*. 2019). In the recent past, approximately 0.8 billion Sri Lankan rupees have been invested in erosion management annually. Upstream erosion in the Kalu river estuary was measured as 4.88 m/yr; its downstream erosion is 0.83 m/yr, and sediment deposition occurs towards the north (Lakmali *et al*., 2017).

Kalpitiya has massive sand dunes, which are presumed to be sediment-deposited areas. Lagoonal and estuarine deposits of the Holocene period are found in the Puttalam, Kalpitiya, and Dutch Bay areas. High rates of accretion and erosion are evident on the coasts of the Kalpitiya peninsula. It is important to understand wave climate change and erosion and accretion in those areas, which must be estimated by clearly differentiating the anthropogenic and natural erosion drivers to develop policies and strategies to conserve the coastal region.

Archived wave climate data is required to assess wave climate change. In the absence of such wave climate data, it is impossible to predict sediment transport rates in coastal areas. Moreover, there will not be sufficient data to develop policies on the conservation of the coastal environment and related economic strategies. However, such data is lacking in many developing countries (Stronkhorst *et al*., 2018). Reanalyzed wind data can be used to predict the wave climate data using wave models such as WAWEWATCH III (Reguero *et al*., 2012; Stopa & Cheung, 2014; Kalourazi *et al*., 2021). With the aid of such reanalyzed data, the capacity of the littoral current can be estimated.

Sri Lanka is a country surrounded by 1,340 km of coastline; the coastal environment consists of rich biodiversity, which brings high environmental, economic, and social value to the island. Since the 1970s, coastal erosion has become a severe threat to the country in connection with the development of fishery, commercial harbours, logistics, and tourism-related industries (Samarasekara *et al*., 2018). The coastal segment of 685 km extending from Kalpitiya to Yala loses about 175,000–285,000 m^2 of its coastal land each year (CCD, 1997). During annual monsoon seasons, erosion is very severe in Kalutara and Kalpitiya. From south to north along the western coast, a strong longshore current is generated during these seasons due to monsoon waves (Dayananda, 1992). During the southwest monsoon, swell waves break and hit the southern and western coastlines. Thereby, the net annual sediment transportation rates are very high during monsoon seasons (Ansaf, 2011). The estimated longshore drift capacity from south to north is 1.1 million m^3/year (Dayananda, 1992). However, the longshore drift capacity of recent years has not been estimated due to the lack of measured wave data.

Not only anthropogenic causes, such as coastal reclamation and management, but also natural causes, such as wave climate changes, could accelerate the coastal erosion in Sri Lanka. Though there are some recent studies that elaborate on the anthropogenic causes (Ratnayakage *et al*., 2020; Gunasinghe *et al*., 2021) that accelerate coastal erosion, there is a limited number of studies on natural causes in Sri Lanka. The lack of observed data is the main issue, and this research aims to fill that gap by estimating the capacity of littoral drift with the modelled wave climate data by using reanalyzed wind data. This study firstly estimates the littoral drift along the Sri Lankan coast and secondly evaluates the erosion and accretion rates in the Kalutara and Kalpitiya beaches. Thirdly, the estimated values of littoral drift along the western coast are compared with the Kalutara and Kalpitiya cases by differentiating the anthropogenic and natural drivers of erosion. This study emphasizes the patterns of erosion and accretion of sediments on the western coast of Sri Lanka by collecting data from diverse sources to their fullest extent.

MATERIALS AND METHODS

Study location

In this study, coastal cell segments were defined as shown on satellite images in Figure 1. Cells 1, 2, and 3 are on the Kalpitiya coast, and Cells 4 and 5 are on the Kalutara beach. Each cell is bounded by either a headland or breakwater of a fishery harbour or a river mouth. The boundary of cells 4 and 5 goes through the Kalu river mouth. The five points demarcated are the points and ocean depths where wave climate data and information have been extracted. The nearshore sediment transport rate is determined at each defined cell by considering the orientation of wave breaking.

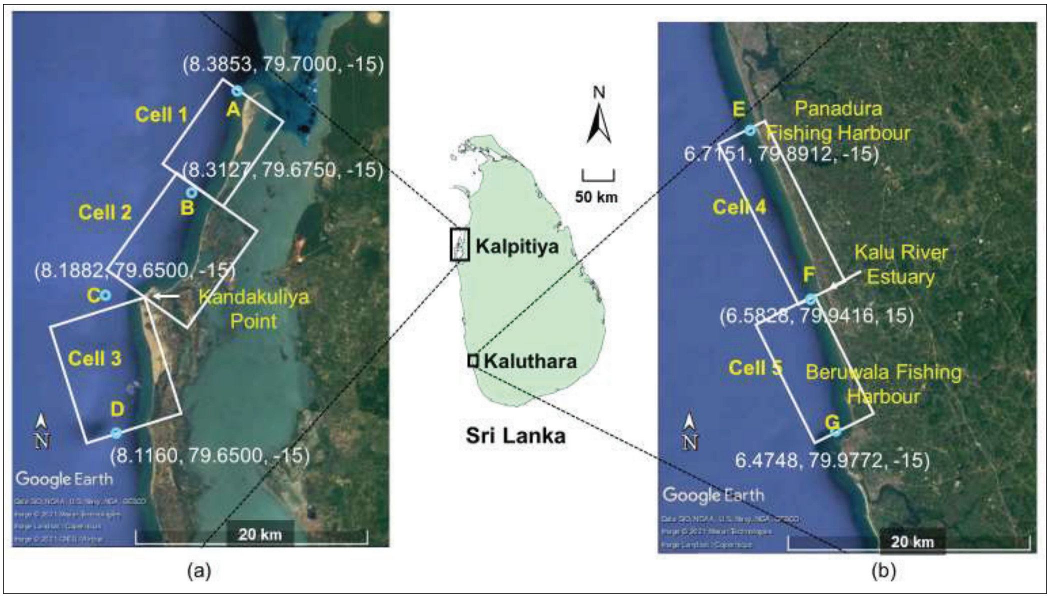

Figure 1: Locations of defined coastal cells and extracted points along the Kalutara and Kalpitiya coasts (Source: Google Earth, Data SIO, NOAA, US Navy, NGA, GEBCO)

Assessment of wave climate

In this study, the wave climate data from 1 January 2007 to 31 December 2017 were collected from a recently concluded study (Samarasekara, 2019) in netCDF format. The wave data were modelled from WAVEWATCH III (Tolman, 2009) using the reanalyzed wind data from NCEP/NCAR Reanalysis 1 (2000). The authors extracted daily time series of Hs, Tp, and θ in CSV format at the locations of nodes of study (Figure 1) by developing a Python Code. The depth of the sea at the nodes is approximately 15 m. The wave breaker line, shoreline orientation, and wave angle at the breaker line were observed from satellite images in respective years. When a satellite image is not available for a year, the wave angle values at the breaker line for the nearest year were assumed in this analysis. The capacity of coastal sediment transportation was estimated by using the CERC (Coastal Engineering Research Center) equation, as shown in equation 1 (Van Rijn, 2013).

$$Q_{t,Volume} = 0.0483(H_{s,br})^{2.5} sin(2\theta_{br}) \quad ...(01)$$

where, θ_{br} = wave angle at breaker line (between wave crest line and coastline); $H_{(s,br)}$ = significant wave height (m) at breaker line, and $Q_{(t,\ Volume)}$ = longshore sediment transport rate (m^3/s).

Analysis of erosion and accretion

The west coast of Sri Lanka has experienced erosion and accretion since the 1970s (Bandara *et al*., 1987; Fittschen *et al*., 1992b). The transportation of sediment along the western coast occurs mainly due to the Southwest monsoon (Gunarathna *et al*., 2011). These transported sands accumulate near the Kalpitiya area and generate sandy islands (Ratnayakage *et al*., 2020). In this research, chronological changes in the shoreline of the Kalpitiya and Kalutara areas were observed using satellite images in Google Earth Pro. The available clear satellite images of December 2004, October 2009, November 2011, October 2012, October 2013, February 2014, March 2015, March 2016, and March 2017 were chosen for analysis. The accreted (and eroded) shore areas were calculated relative to the shoreline of December 2004.

Firstly, the shoreline is demarcated using Google Maps. Thereafter, the demarcated shoreline files are inserted into ArcGIS. Each shoreline was split into equidistant segments. The split coordinates were extracted to Microsoft Excel. Afterwards, the reference line coordinates were calculated based on the shoreline. Successively the perpendicular distance was calculated from shoreline coordinates. Finally, the area was assessed using the above steps.

Different years of shorelines are denoted as t = t_1, t_2, t_3, t_4..., t_n and particular shoreline polylines are split into equal segments of approximately 1 m. The midpoint coordinate of each segment is obtained by using ESRI-ArcGIS in two decimal degrees. Particular coordinates are denoted as i = i_1, i_2, i_3, i_4..., i_n. A reference line is considered, as shown in Figure 2. The term 'Q' is denoted as the coordinates of split points of a particular shoreline, the term 'L' is denoted as the perpendicular distance from a particular shoreline, the term 't' is denoted as the day of shoreline, the term 'u' is denoted as points of split shoreline, and $Q_{t+1,\ u+3}$ is denoted as the coordinate of u+3 point at t+1 day shoreline.

A perpendicular line is drawn from a particular coordinate i to the reference line. The relative accreted (or eroded) area to day t is calculated by using equations 2 and 3.

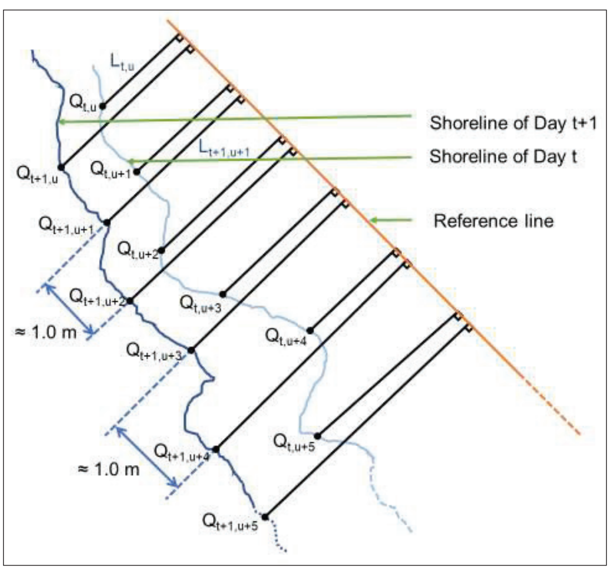

Figure 2: Schematic diagram of the shoreline (plan view) at time t_1, t_2 and reference line

$$L_{t,u} = \sqrt{\left(X_{t,u} - \frac{X_{t,u} + mY_{t,u} - mC}{m^2+1}\right)^2 + \left(\left(y_{t,u} - \frac{m^2 Y_{t,r} + mX_{t,u} + C}{m^2+1}\right)^2\right)} \quad ...(02)$$

$$A_{\Delta t,\Delta u} = \frac{(L_{t+1,u} - L_{t,u}) + (L_{t+1,u+1} - L_{t,u+1})}{2} \quad ...(03)$$

$$V_{t+1,\Delta u} = \frac{1}{4}[\,(L^2_{t+1,u} - L'^2_{t+1,u})\,tan\phi_{t+1,u} + (L^2_{t+1,u+1} - L'^2_{t+1,u+1})\,tan\phi_{t,u+1} - (L^2_{t,u} - L'^2_{t,u})\,tan\phi_{t,u} - (L^2_{t,u+1} - L'^2_{t,u+1})\,tan\phi_{t,u}\,]\,tan\phi_{t,u+1} \quad ...(04)$$

The altitude between the shoreline and coastline ($\tan\phi\tan\phi$) is extracted for Kalutara from the literature (Gunasinghe *et al*., 2021). The altitude data between the shoreline and coastline is extracted from Google Earth Pro for Kalpitiya. It is assumed that the value of the beach slope uniformly changed throughout the considered periods. The beach volume change between two consecutive periods is calculated from the methodology provided by Ratnayakage *et al*. (2020). The coastline, which can be determined from *L*, is also obtained similarly to the shoreline. The beach volume change (*V*) between point u and *u+1* was calculated from equation 4.

Overall methodology

Figure 3 shows key data and methodologies involved in the study. Firstly, the wave climate data at Kalutara and Kalpitiya were collected. Based on that, a study of the sediment transport rate in both locations was carried out. This was followed by the study of the chronological volumetric change of Kalutara and Kalpitiya beaches. Using the results so derived, a study was done on the relationship between the capacity of coastal sedimentation transportation and actual sediment transportation under the influence of wave climate change. Finally, the change in volume and area was assessed. After clearly observing the impact of shoreline management, a relationship between the capacity of coastal sedimentation transportation and actual sediment transportation was observed and discussed to identify the influence of wave climate change.

RESULTS AND DISCUSSION

Littoral drift along the Sri Lankan Coast

Sri Lanka experiences two monsoons and two inter-monsoon seasons. The littoral drift and its direction are mainly governed by the northeast monsoon

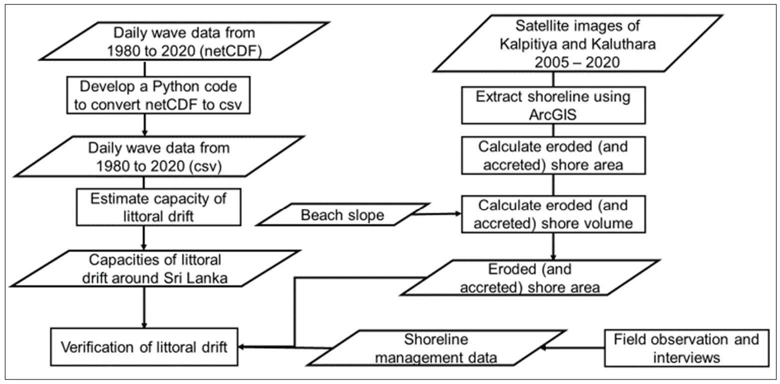

Figure 3: Key data and methodologies involved in the study

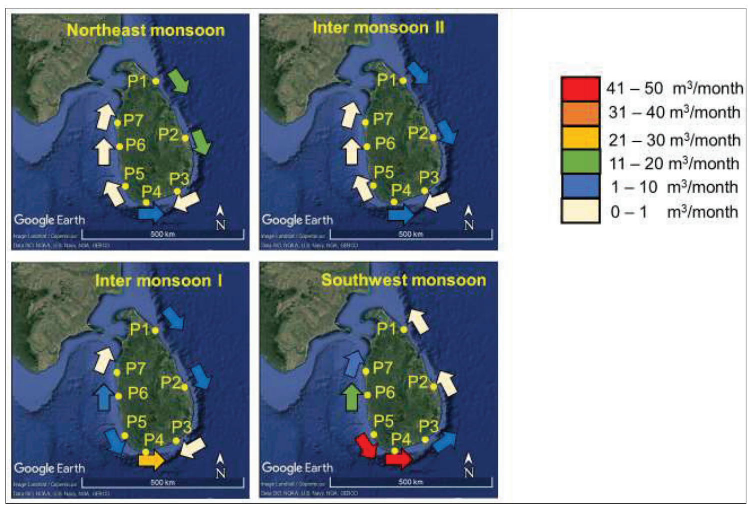

Figure 4: Monthly sediment transport potential values in northeast monsoon (December-February), inter-monsoon 1 (March-April), southwest monsoon (May-September), and inter-monsoon 2 (October-November) based on daily average littoral drift from 2007 to 2017

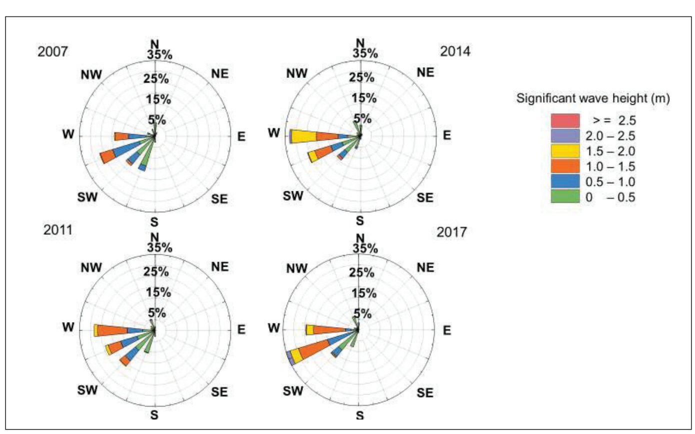

Figure 5: The wave rose diagrams at Kalutara in 2007, 2011, 2014, and 2017

(December-February), inter-monsoon 1 (March-April), southwest monsoon (May-September), and inter-monsoon 2 (October-November). Figure 4 shows monthly sediment transport potential values based on the daily average of littoral drift from 2007 to 2017. Sediment transport potential values are shown for 6 locations around the island during four seasons. Those locations are Mullaitivu (P1), Kattankudy (P2), Yala (P3), Dondra (P4), Kalutara (P5), Chilaw (P6), and Kalpitiya (P7). Sediment transportation on the eastern coast is predominant during the northeast monsoon, but sediment transportation on the western and southern coasts is predominant during the southwest monsoon. The wave climate is slightly rough on the southern coast during inter-monsoon 1 as well. The wave climate during the southwest monsoon could transport more sediment compared to the wave climate during the northeast monsoon.

Figure 5 shows the wave rose diagrams at Kalutara in 2007, 2011, 2014, and 2017. It shows that the direction of littoral drift is quite a sensitive parameter as the direction of the wave front slightly changes from year to year. The shorelines are also changed due to major shore protection and development activities. Therefore, the direction of littoral drift from time to time changed southwards and northwards.

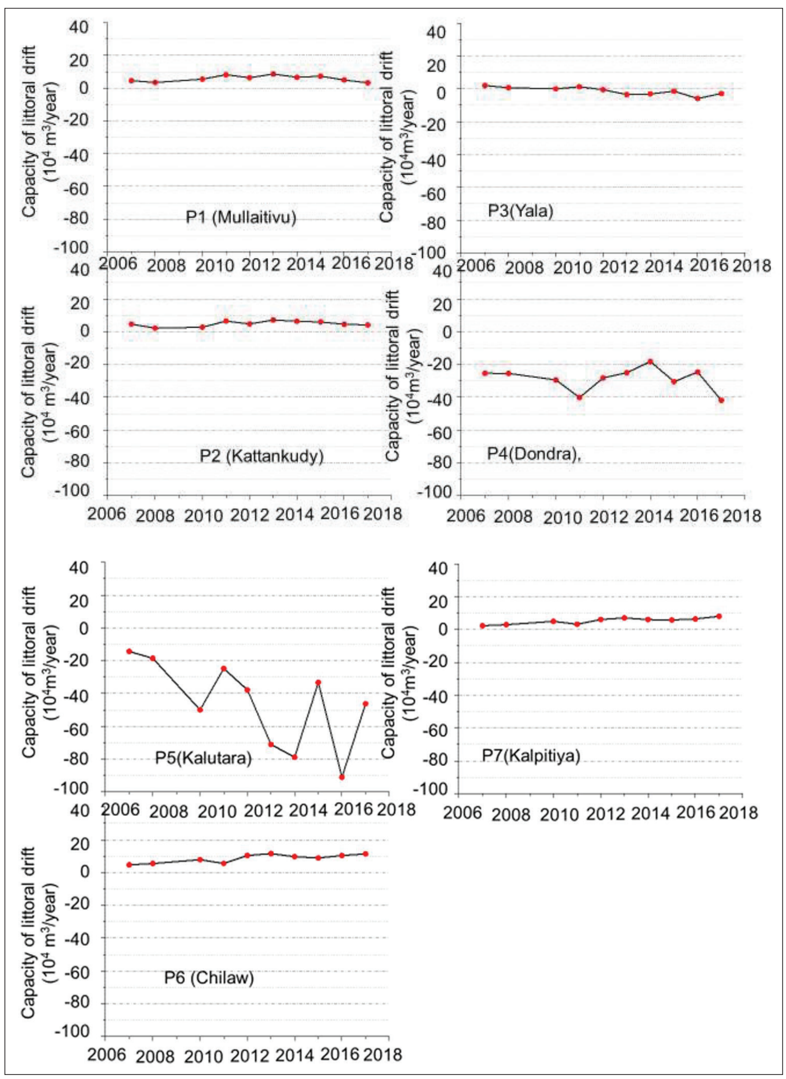

Figure 6: The annual average sediment transport potential of littoral drift at P1 (Mullaitivu), P2 (Kattankudy), P3 (Yala), P4 (Dondra), P5 (Kalutara), P6 (Chilaw), and P7 (Kalpitiya)

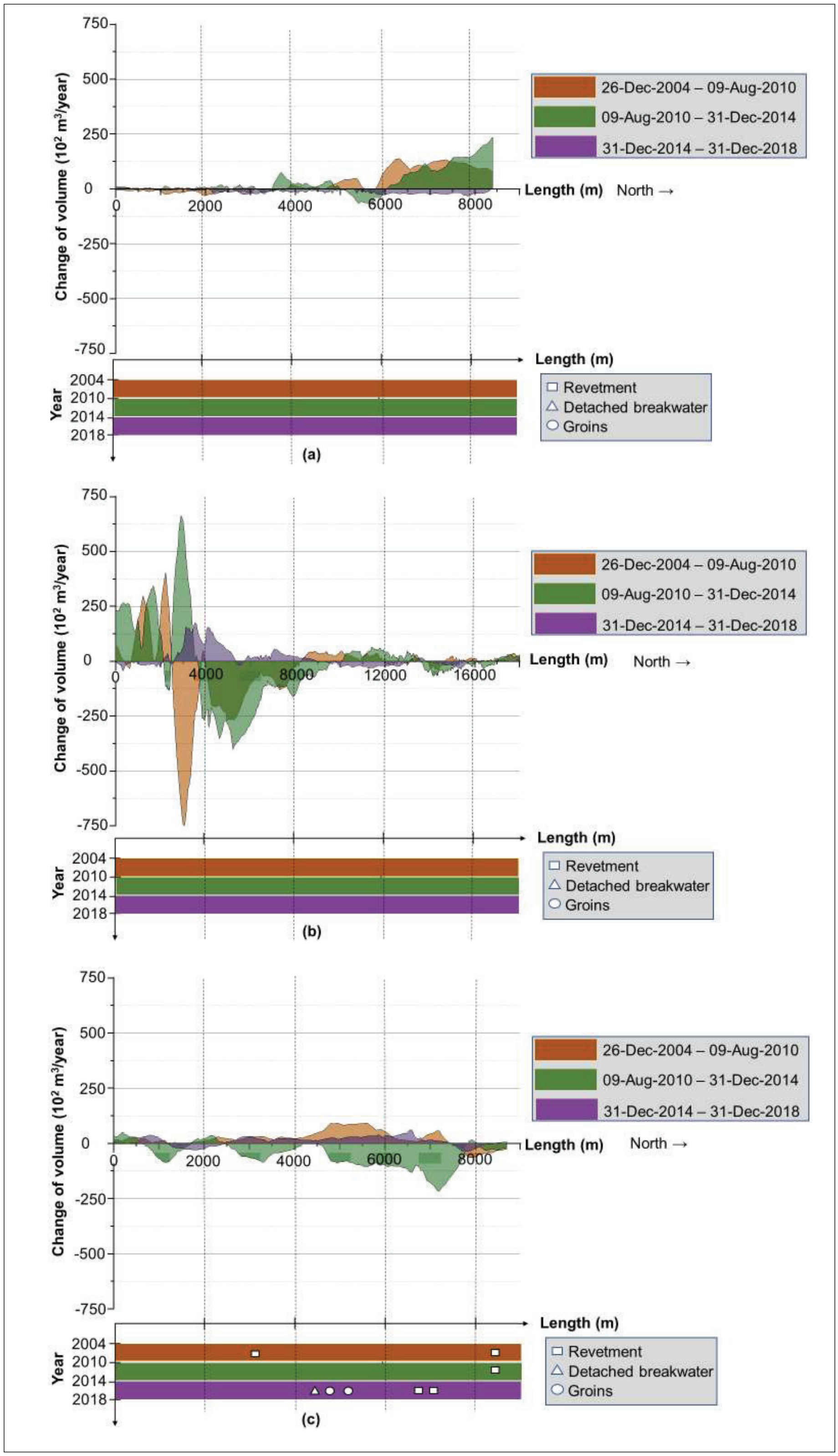

Figure 7: The beach volume accretion in sediment (a) cell - 1, (b) cell - 2 and (c) cell - 3 in Kalpitiya during 26 December 2004 - 31 December 2018

A couple of past researchers have studied the wave climate on the southwest coast, mainly the significant wave height relative to the wave direction (Sheffer & Frohle, 1991; Fittschen *et al*., 1992a; Gunaratna *et al*. 2011). The sediment transportation direction of the southwest coast is considered as south to north by some researchers (Ansaf, 2011; Abeykoon *et al*., 2021), but the results of this study show that the average littoral drift is from north to south during 2005 and 2017. It is evident that the littoral drift could have been periodically changed southwards and northwards because the sand spit which the Kalu river builds periodically moves southwards and northwards (Bandara *et al*., 1987). Figure 6 shows the annual average sediment transport potential of littoral drift at the locations P1 to P7. The annual average littoral drift in Kalutara is predominately southwards during 2004.

Erosion and accretion rates in Kalpitiya and Kalutara

Figure 7 illustrates the beach accretion (and erosion) in each cell in different years. The shoreline volume change values are given in the order of 10^4 m^3. The negative values refer to erosion, and the positive values refer to accretion. Figure 7 (a), (b), and (c) show the beach volume accretion in cells 1, 2, and 3 in Kalpitiya, respectively. The x-axis is the linear distance of the beach, and the y-axis is the rate of beach accretion in the unit of m^3 per year. The shoreline management activities which took place are shown under the plot of beach accretion (and erosion).

The most northern area in cell 1 is an accreting area. Beach accreted in this area at a maximum rate of 25,000 m^3/year during 2005 and 2014. The accreted beach slightly eroded during 2014 and 2018. Kaldakuliya point, which is the southern boundary of cell 2, is a sensitive area. Figure 8 shows satellite image photos of sediment accretion in the field of groynes on 11 March 2011, 29 August 2013, and 27 December 2019. It shows evidence of high sedimentation sensitivity in cell 2 (Kalpitiya peninsula). There are detached breakwaters and groynes which were constructed before 2004 in this area. Sediments accreted at the beach where the protection structures were constructed by eroding neighbouring beaches in the north because of the reduction in sediment in the northward littoral drift. Similar incidents are also observed in Marawila beach (Samarasekara *et al*., 2018) and on coasts in Colombia (Rangel-Buitrago *et al*., 2018). Many shore protection activities have taken place in cell 3, and they protected the beach, maintaining net accretion in cell 3 during 2014 and 2020.

11 March 2011 | 29 August 2013 | 27 December 2019

Figure 8: Satellite image photos of sediment accretion in the field of groynes on (a) 11 March 2011, (b) 29 August 2013 and (c) 27 December 2019

Figure 9 (a) and (b) show the beach volume accretion in cells 4 and 5 in Kalutara, respectively. Cell 4 is bounded by Panadura harbour in the north and the Kalu river estuary in the south. Cell 4 is quite a stable coast and receives sediments from the Kalu River. A series of groynes were constructed in cell 4 during 2014 and 2018. Cell 5 is bounded by Beruwala harbour in the south and Kalu river estuary in the north. Cell 4 experienced severe erosion, and detached breakwaters were constructed before 2004. However, the tombolos were not fully developed due to the Indian Ocean Tsunami in 2004. Figure 9 (b) shows that the left-hand sides were accreted, and the right-hand sides were eroded at tombolos in cell 4 during 2014 and 2018. It is evidence of the southward littoral drift.

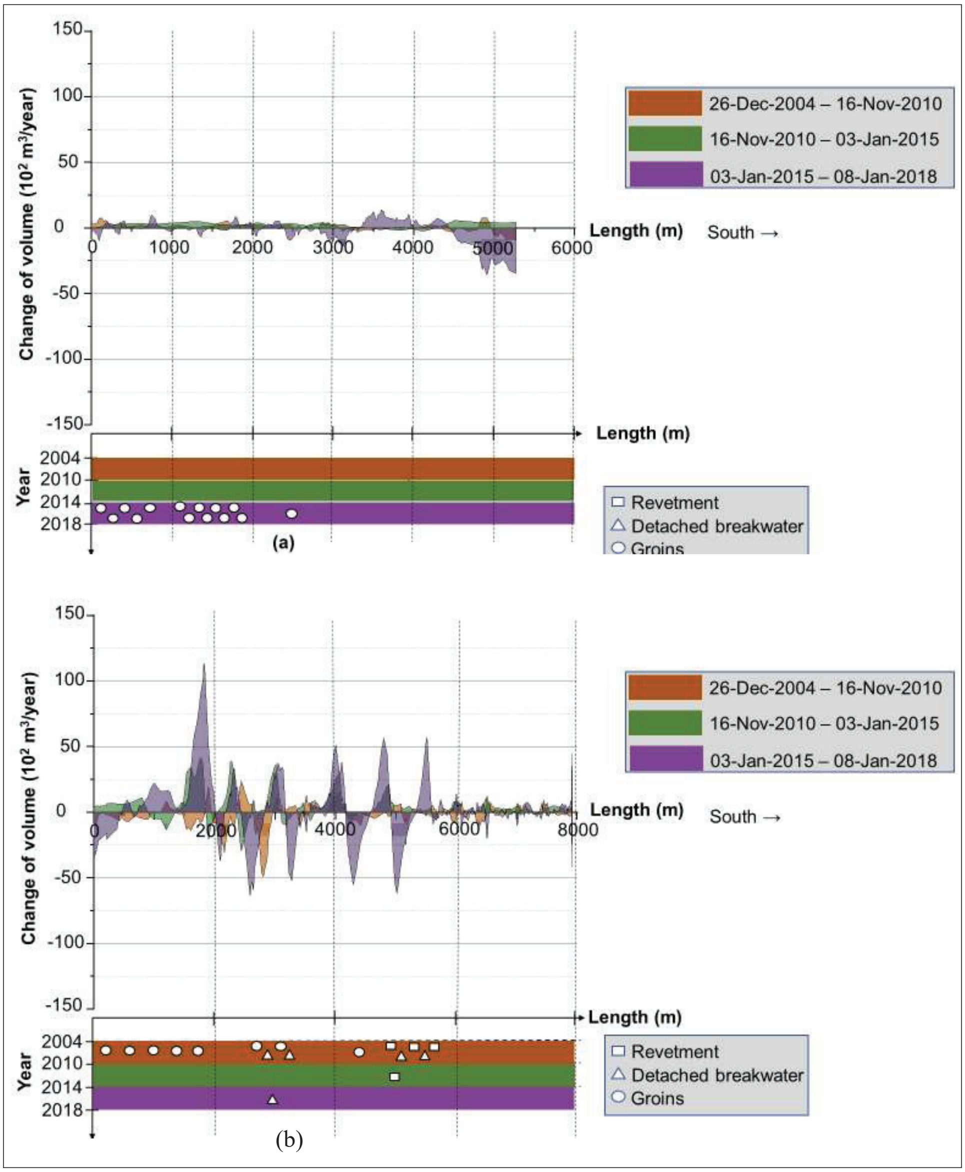

Figure 9: The beach volume accretion in sediment (a) cell - 4 and (b) cell - 5 in Kalutara during 26 December 2004 and 31 December 2018 (Source: Google Earth Pro, Maxar Technologies).

Impact on littoral drift at Kalpitiya and Kalutara

The capacity of the littoral drift at nodes, shore accretion (and erosion), and shoreline management strategies during (a) 26 December 2004 – 09 August 2010, (b) 09 August 2010 – 31 December 2014, (c) 31 December 2014 – 31 December 2018 are shown in Table 1. The capacity of littoral drift is in the unit of m^3 per year. The length of cells is different in each cell; therefore, the beach volume was mentioned per unit length. Positive (+) values denote northward drift, and negative (–) values denote southward drift. Beach volume change along the shoreline is in the unit of m^3 per year per unit length. Positive (+) values denote beach accretion, and negative (–) values denote coastal erosion.

Table 1: Comparison of the capacity of littoral drift, the erosion accretion rate, and shoreline management activities have taken place in Kalpitiya (a) 26 December 2004–09 August 2010; (b) 09 August 2010–31 December 2014; (c) 31 December 2014–31 December 2018

Kalpitiya				
Node	The capacity of Littoral drift (10^4 m^3/year)	Cell	Change of volume along the shoreline (10^5 m^3/year/km)	Management activities which have taken place
26 December 2004–09 August 2010				
A	1.05	1	-0.08	-
B	2.98			
B	2.98	2	-1.32	6 Groynes are constructed
C	3.98			
C	3.98	3	0.75	1 Detached breakwater is constructe
D	4.33			
09 August 2010–31 December 2014				
A	1.66	1	1.26	-
B	4.34			
B	4.34	2	-0.43	-
C	6.38			
C	6.38	3	-2.64	2 Detached breakwaters are constructed
D	6.52			
31 December 2014–31 December 2018				
A	2.00	1	-0.91	-
B	4.87			
B	4.87	2	0.59	-
C	7.96			
C	7.96	3	0.47	2 Groynes and 2 detached breakwaters are constructed
D	7.81			

The capacity of littoral drift reduces towards the north along the Kalpitiya peninsula. An increase in the capacities can be observed in those cells. Therefore, erosion is predominant though the area is historically a beach accreting area. Two detached breakwaters were constructed at cell 3 during 09 August 2010 and 31 December 2014 and it caused sedimentation in subsequent years. Two detached breakwaters were constructed in cell 3 during 09 August 2010 and 31 December 2014. Two groynes and detached breakwaters were constructed in the same cell during 31 December 2014 and 31 December 2018 by resulting sedimentation. The beach area was increased due to shoreline management activities in cell 3. The erosion (and accretion) is a result of the combined effect of the capacity of littoral drift, shoreline management, and the transported sediments from the south. The Kalpitiya peninsula is eroding at a slow pace with intensified wave climate.

Sediment transportation capacities of littoral drifts are also amplified in cells 5 and 6, as in the Kalutara beach area. The direction of littoral drift is from north to south. The capacity is comparatively low near the

Table 2: Comparison of the capacity of littoral drift, the erosion accretion rate, and shoreline management activities have taken place in Kalutara areas from (a) 26 December 2004 to 16 November 2010 (b) 16 November 2010 to 03 January 2015 (c) 03 January 2015 to 08 January 2018

Kalutara				
Node	The capacity of Littoral drift (10^5 m^3/year)	Cell	Change of volume along the shoreline (10^5 m^3/year/km)	Management Activities which have taken place
26 December 2004 to 16 November 2010				
E	-2.76	4	0.05	-
F	-0.78			
F	-0.78	5	-0.15	1 Groyne, 4 coves, 1 revetment (250 m), and 3 detached breakwaters are constructed
G	-2.42			
16 November 2010 to 03 January 2015				
E	-4.45	4	0.25	3 new groynes were constructed
F	-1.75			
F	-1.75	5	0.46	Tombolos are fully developed at built detached breakwaters. A new detached breakwater is constructed
G	-4.06			
03 January 2015 to 08 January 2018				
E	-6.23	4	-0.34	6 Groynes are constructed
F	-2.91			
F	-2.91	5	0.26	1 Groyne and 1 detached breakwater are constructed
G	-5.89			

Figure 10: Satellite images of a detached breakwater on 2 August 2005 and 1 January 2013 in cell 5 (Source: Google Earth Pro, Maxer Technologies)

river mouth. Cell 4 is an accreting area as the capacity of littoral drift reduces towards the south. However, cell 4 eroded with the intensified wave climate. Therefore, revetment and a field of groynes were constructed by CC&CRMD to protect the shoreline during 26 December 2004 and 16 November 2010. December 2004 is the date of the Indian Ocean Tsunami. Revetments, groynes, and detached breakwaters were constructed during 2004 and 2010; as a result, the shore was accreted during 16 November 2010 and 03 January 2015. Figure 10 shows a satellite image of the detached breakwater in cell 5, and vegetation is also full-grown in the evolved tombolo on 1 January 2013, where there was no beach on 2 August 2005. Another detached breakwater also constructed further sediment upstream and thus, further sediment accretion was observed during 03 January 2015 and 08 January 2018. The sediment accretion and erosion are more linked to shoreline management instead to wave climate change in Kalutara.

It was identified that the wave climate in the Indian Ocean has become severe in recent years (Gupta *et al*., 2015; Nurfaida & Shimozono, 2019), and this study also confirms a wave of intensified climate change. This study also confirms that coastal erosion (and accretion) is linked with shoreline management activities as well. The current erosion management activities in Kalutara and Kalpitiya are successful in coast protection. Lack of sediment supply from rivers and streams is the main reason for coastal erosion on the western coast of Sri Lanka (CCD, 2003; Samarawikrama *et al*., 2009; Wickramaarachchi, 2012; Samarasekara *et al*., 2018); thus, both Kalpitiya and Kalutara also experience coastal erosion. Therefore, coastal erosion can only be controlled by combined protection using beach nourishment with hard structures such as detached breakwaters. Beach nourishment combined with hard structures has been successful in Sri Lanka (Ratnayake *et al*., 2019; Ratnayakage *et al*., 2020), Thailand (Saengsupavanich, 2013), and Italy (Pranzini, 2018).

CONCLUSION

The sediment transportation capacity of littoral drift was measured between 2007 and 2017. The wave climate becomes rough during the southwest monsoon period on the western and southern coasts and the northeast monsoon period on the eastern coast. As a result, the capacity of littoral drift on the southwest coast is the largest among all coasts. Those values are relatively small in the Yala and Kalpitiya areas, and thus those areas became major sediment accretion areas. However, the Kalplitiya peninsula is slowly eroding with the intensified wave climate. The average wave direction periodically changes between west and west-south-west, and the littoral drift was predominantly southwards at the Kalutara coast from 2007 to 2017. Beaches in both Kalutara and Kalpitiya generally erode, but the beaches accrete where detached breakwaters are constructed as a shoreline protection measure. Beaches erode as an integrated effect of shoreline management, wave climate change, and reduction of river sediment supply. The reality of coastal erosion is more complex, and more studies are required to identify the causes of erosion and accretion based on hydraulic model studies and numerical estimation. However, this study provides an empirical framework to verify the results of numerical studies where there are no observed results. As a result of the erosion, the tourism-based and fishing communities would be heavily affected due to the loss of valuable beaches. Wave climate change-induced coastal erosion cannot be evident, and thus, a sufficient budget needs to be allocated to protect the shoreline of Sri Lanka.

Conflicts of interest

The authors disclose that they have no conflicts of interest concerning this article.

Acknowledgement

The authors acknowledge Mr HHADMN Hettiarachchi, Mr KWND Withanarachchi, Mr J. Kavinthan, and Mr RKDG Kaluarachchi for their scientific support.

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