

Potential Usage of Remote Sensing Data in Studying the Behaviour of Shore Drift Along Kerala Coast, India

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Landsat images were analysed to examine direction, amount and behaviour of long-shore drift and its contribution towards deciding areas vulnerable to coastal erosion and accretion along the coast of Kerala. Two approaches are adopted while utilizing the remote sensing data. Net shore-drift direction is determined firstly by studying various coastal landform indicators and secondly by studying offshore turbidity distribution patterns. Landform indicators study suggest that during the south-west monsoon period, strong southerly currents are eroding protruded sectors and depositing eroded material, though partially, along varying sectors. Whereas during the rest of the year, under the influence of a northerly current, accretion is taking place along retreating sectors which has been reflected in the development of beach ridges. Turbidity pattern distribution exhibited by satellite image suggests that for January and February, long-shore drift is from south to north. The results of the two studies were found to be comparable. It may be concluded that shore-drift direction, which can be determined effectively by remote sensing, is season-dependent and plays a significant role in deciding the areas of coastal erosion and accretion.

Introduction

The coastline of India extending over 6300 km is quite variable, both in form and nature. The western coastline is highly irregular, cliffed and wave eroded. The coast of Kerala state forms the south-western segment of the complex western margin. Of the 560 km-long shoreline of Kerala, a cumulative 360 km of shoreline is vulnerable and shows wide fluctuations in its stability, causing considerable damage to life and property and loss of arable land (Nair, 1987).

Shore drift may be defined as the movement of beach material parallel to the coast in the near-shore region caused by waves approaching to the coast at an angle. It plays an important role in deciding the areas of coastal erosion and accretion, in shaping and orienting coastal landforms and finally in the evolution of the coast. Hence, in the analysis of coastal erosion–accretion problem, for the development of harbour and construction of coastal structures, the direction, amount and behaviour of long-term average shore drift is of vital importance.

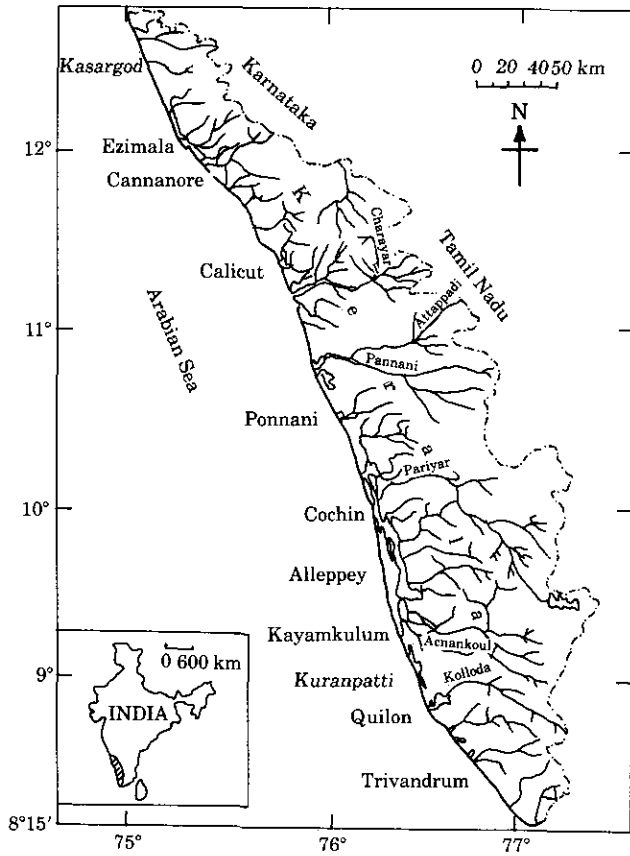


Figure 1. Location map of the study area.

Earlier investigations in determining shore drift and its relation to erosion and accretion along the Kerala coast were based on (1) beach profile study (Varma *et al.*, 1981; Shenoj & Kumar, 1982; Shamsuddin & Suchindar, 1987), (2) grain size trends (Prakash & Prithviraj, 1988) and (3) construction of wave refraction diagrams (Chandramohan, 1989). Most of these studies are seasonal, short term and of local importance. Coastal landforms are considered as the most reliable and long-term shore-drift indicators. They have been used as indicators in determining net shore-drift direction in recent years by Schwartz and Anderson (1986), Taggart and Schwartz (1988), Wallace (1988), Taggart (1989) and Kunte and Wagle (1991; 1993*a,b*).

The present study is an attempt to recognize drift cells and to understand the behaviour of shore drift along the Kerala coast using remotely sensed data. Further efforts are also made to identify regions of coastal erosion and accretion.

Study site and environment

The Kerala coast forms the south-western segment of the west coast of India and is bounded by latitude 8°15'N to 12°45'N (Figure 1). The entire coast is exposed to

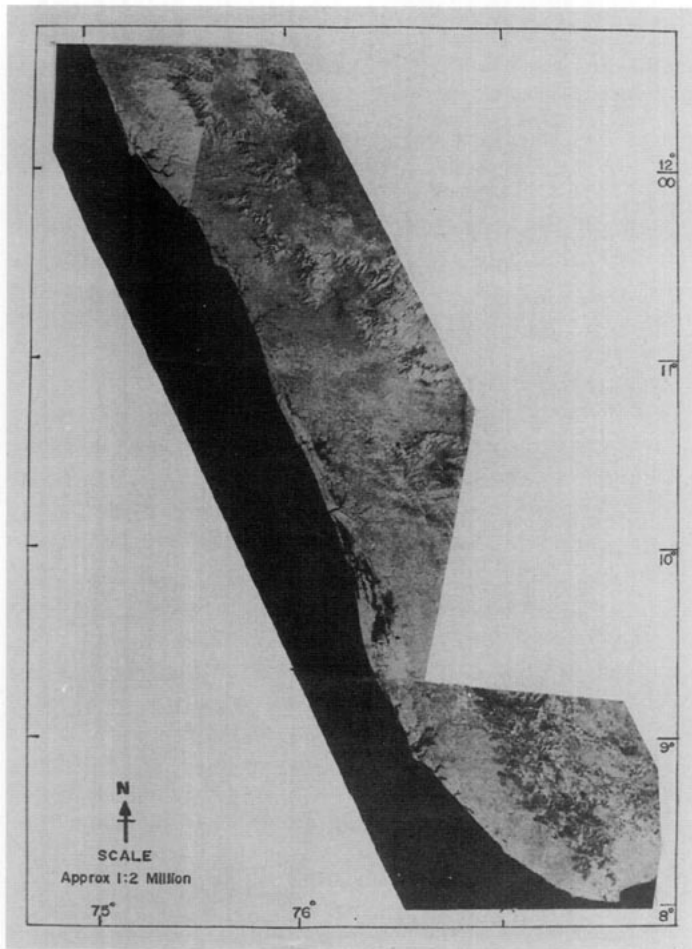


Figure 2. Mosaic of reduced photographs of six imageries covering Kerala coast.

seasonally changing winds—the monsoons. The reversal of these winds takes place predominantly from a south-west (during May–September) to a north-east (during December–March) direction. The wave climate associated with these winds also shows similar changes as the wind's intensities and spectral ranges depend mostly on the available fetches and their proximity to the coast. The mean tidal range varies from 0.9 m in the south to 1.8 m in the north. The tides are semi-diurnal (12 h) type. The highest wave average of 3.2 m and wave period of 9–12 s are reported (Moni, 1980).

Materials and methods

Landsat black and white imageries of spectral bands 4, 5 and 7 on a scale of 1:1 million were used for interpretation. A mosaic of reduced photographs of six imageries covering the Kerala coast are shown in Figure 2. Details of imageries used during this study are as follows:

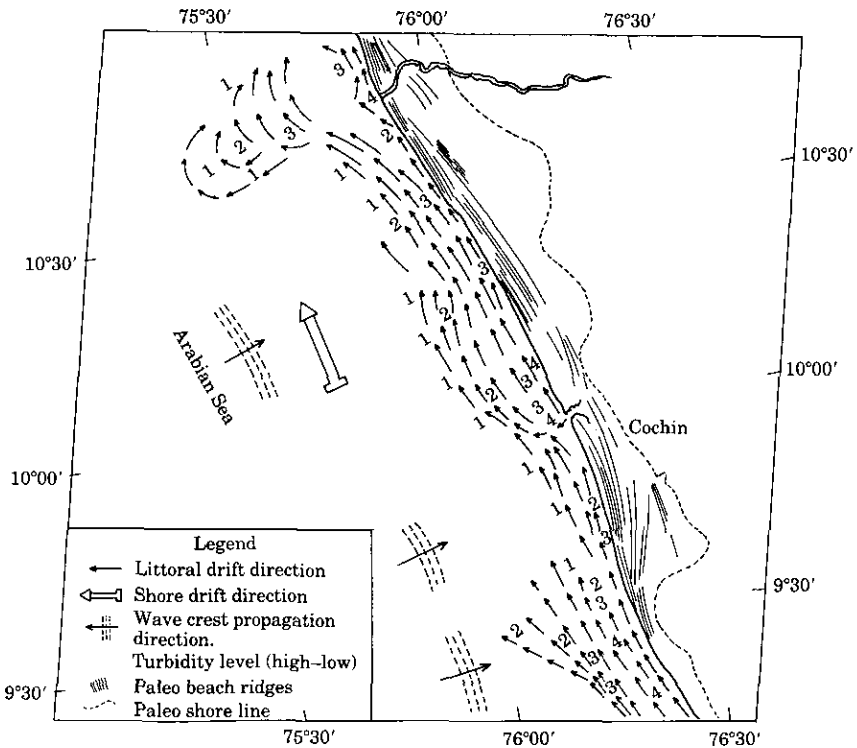


Figure 3. Offshore turbidity distribution map.

Identification No.	Image date	Spectral bands
D154-054	20/01/82	4, 5 & 7
D155-053	21/01/82	4, 5 & 7
D155-052	21/01/82	4, 5 & 7
D156-052	22/01/82	4, 5 & 7
E-1201-04402	09/02/73	4, 5 & 7
E-1184-04452	23/01/73 & 10/02/73	4, 5 & 7
E-1184-04450	23/01/73	5 & 7
E-1203-04510	11/02/73 & 01/03/73	4, 5 & 7
E-1131-04504	01/12/72 & 06/01/73	4, 5 & 7

Using enlarged Landsat images (1) major geomorphic forms observable in the coastal zone alone are demarcated, (2) coastal landform indicators have been studied and (3) an offshore turbidity map has been prepared (Figure 3). Based on these, shore-drift direction within each drift cell has been identified and marked on the map which is presented in two parts for convenience [Figures 4 (a,b)]. Shoreline changes were detected by observing satellite images pertaining to years 1972-73 and 1982.

Results

Shoreline

On the satellite imagery, the coastal area of Kerala is recognized by a barrier strip of land between the Arabian Sea and a chain of backwaters (locally called 'kayals'), estuaries

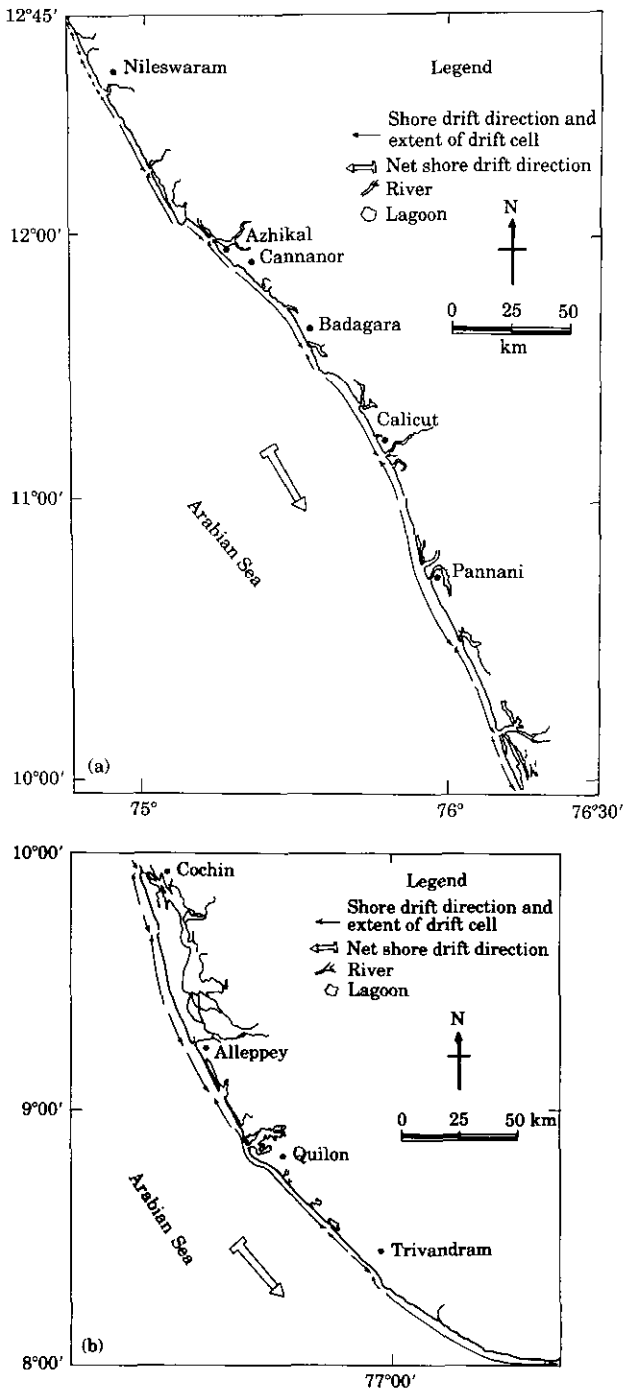


Figure 4. Map showing extent and direction of drift cells along Kerala coast. (a) Northern sector. (b) Southern sector.

TABLE 1. Description of spits of the study area

No.	Spit name	Location latitudes		Total length (km)	Distal end			Deflection of river			Spit type
		From	To		Length (km)	Breadth (km)	Description	Pointing	Name of river	Towards	
1	Puvar	8°19'50"-8°18'20"		4.50	0.20	Pointed, narrow	S	Nayar	S	1.00	Simple
2	Pulinakudi	8°21'20"-8°20'55"		1.50	1.00	Thick, blunt	S	Creek	S	1.00	Simple
3	Kovolam	8°24'00"-8°25'30"		4.00	0.20	Pointed, narrow	N	Creek	N	3.00	Simple
4	S of Trivendram	8°26'25"-8°25'35"		2.00	1.00	Pointed, narrow	S	Creek	S	1.50	Composite
5	Kadinamkulam	8°36'30"-8°38'10"		3.75	0.40	Pointed, narrow	N	Kadinamkulam canal	N	2.00	Composite
6	Chirayinkil	8°40'10"-8°38'10"		4.75	0.10	Pointed, narrow	S	Creek	S	4.00	Simple
7	Kappil	8°47'05"-8°46'00"		2.75	0.50	Pointed, narrow	S	Edavi Kayal	S	1.50	Simple
8	S of Qulton	8°52'00"-8°49'00"		7.50	4.50	Pointed narrow	S	Iravipuram Kayal	S	3.50	Simple
9	Nindkara	8°58'00"-8°56'00"		4.00	3.00	Thick, blunt	S	Laggon	S	1.00	Composite, curved
10	Karunagapalli	9°01'00"-9°08'00"		14.00	0.50	Thin, blunt	N	Kayamkulam Lagoon	N	0.50	Composite
11	Arattupuzha	9°14'30"-9°08'15"		12.50	0.70	Pointed, narrow, thin	S	Kayamkulam Kayal	S	12.50	Composite
12	Eranakulam	10°04'00"-9°59'00"		11.00	1.00	Pointed, split	S	Creek	S	10.00	Composite
13	Pallippuram	10°06'00"-10°10'45"		10.00	6.00	Pointed, split	N	Tattapalli	N	9.00	Composite
14	Azicod	10°14'30"-10°11'00"		7.00	1.00	Thin, blunt	S	Periyar	S	1.00	Simple, hooked
15	Vadanapalli	10°27'30"-10°30'20"		5.50	4.00	Narrow,	N	Creek	N	4.00	Composite
16	Kadappuram	10°33'50"-10°30'25"		7.00	2.50	Knife shaped	S	Karanjira	S	2.50	Simple
17	Kadavanad	10°45'15"-10°43'40"		3.00	2.00	Pointed, narrow	S	Kanniramuksu	S	2.00	Simple
18	Pannani	10°46'30"-10°47'00"		1.00	0.10	Narrow, pointed	N	Pannani	N	0.90	Simple
19	S of Tirur	10°55'00"-10°47'00"		15.00	7.50	Narrow, pointed	S	Tirru Puzha	S	7.50	Simple
20	N of Tirur	11°01'00"-10°58'00"		5.75	2.00	Pointed, narrow	N	Purapparamba	N	1.50	Composite
21	Vengalam	11°23'30"-11°21'00"		4.50	3.00	Pointed, narrow	S	Kora Puzha	S	0.50	Composite
22	Kattakkal	11°30'00"-11°33'00"		6.00	2.00	Narrow, blunt	N	Morat	N	3.00	Composite
23	Badagara	11°35'30"-11°33'00"		5.50	5.00	Knife shaped	S	Murat	S	2.00	Simple
24	Vallapattanam	11°55'00"-11°56'30"		3.50	3.00	Triangular	N	Valapattam	N	5.00	Simple
25	Manul	11°57'00"-12°00'00"		7.50	7.00	Thick, blunt	S	Talipparamba	S	7.00	Composite
26	Karingote	12°14'00"-12°12'10"		3.00	1.00	Narrow, hooked	S	Karingote	S	1.40	Composite
27	N of Hosdurg	12°23'00"-12°20'30"		5.00	2.50	Pointed, hooked	S	Chittari Hol	S	2.50	Simple, loop
28	S of Kasaragod	12°27'00"-12°28'50"		3.75	1.50	Knife shaped	N	Chadragiri	N	1.50	Simple
29	N of Kasaragod	12°30'40"-12°29'00"		4.75	4.00	Knife shaped	S	Kasaragod	S	2.00	Simple

3-4, 10-11, 15-16, 22-23, 28-29 are paired spits.

and river outlets. In the synoptic view, the shoreline of Kerala is seen to be almost straight, trending NNW–SSE. However, it shows from north to south, a dextral shift. The shoreline is highly irregular and indented especially around promotories. Both the innermost shore and the present one, are of the Atlantic type and truncate the geologic grain of the hinterland. The innermost shoreline is irregular and crenulate, with several rias. The coastal features identified include narrow beaches, beach ridges, islands, spits, bars, rivers, estuaries, lagoons, mudflats, tidal flats, deltaic plains, paleo shoreline, etc. The shoreline is a compound one, with a variety of features, some of which have resulted from submergence and others from emergence.

Shore-drift direction determination

As net shore-drift direction is the resultant of all shore-drift directions, it is necessary to understand the behaviour of shore drift within each drift cell. Since the shore drift is variable with respect to direction, time, place, duration and amount, the task of determining the net shore drift requires a method which will take these variables into consideration. The following two methods have been used for determining net shore drift in the study area.

Using coastal landform indicators

Coastal landforms respond to all the variables of shore drift during their course of formation and hence these landforms can be considered as the most reliable and long-term shore-drift indicators. Their shape, size, form, pattern, development, location, orientation and their association with other landforms are important to study while determining shore-drift direction.

Several coastal drift indicators are reported in literature (Taggart & Schwartz, 1988). Out of these, only available indicators like river mouth deflection, spit growth, beach width, paleo beach ridges and man-made structures interrupting shore drift, which can be clearly mapped by remote sensing technique, are considered. One indicator, namely mud banks, which is not previously reported in literature is also considered. All these indicators and their utilization are described below:

Spit growth. Along Kerala coast, 29 spits having length more than 1 km have been identified on enlarged satellite images and topographic maps. Table 1 presents a detailed description of these spits. It is seen from this table that most of the spits are simple, narrow, long and have pointed distal ends. Typical spit complexes are shown in Figure 5. Distal ends of 19 spits are pointing towards the south and 10 spits have their loose ends towards the north. The observations indicate that shore drift is strong, consistent and is towards north and south as spits form in response to wave action and grow in the direction of prominent drift direction (Taggart & Schwartz, 1988).

Beach width. A narrow stretch of sandy beaches is observable all along the coastline except in areas of cliffs. They are not extensive and do not have a width more than 100 m except in the sandy stretches north of Kurungapatti to Ponnani. When carefully observed on images and subsequently on topographic maps, it was noted that the beach widths are wider at either ends of the beaches than in the middle. Beach width in the southern end is greater than in the northern end. These observations indicate that the

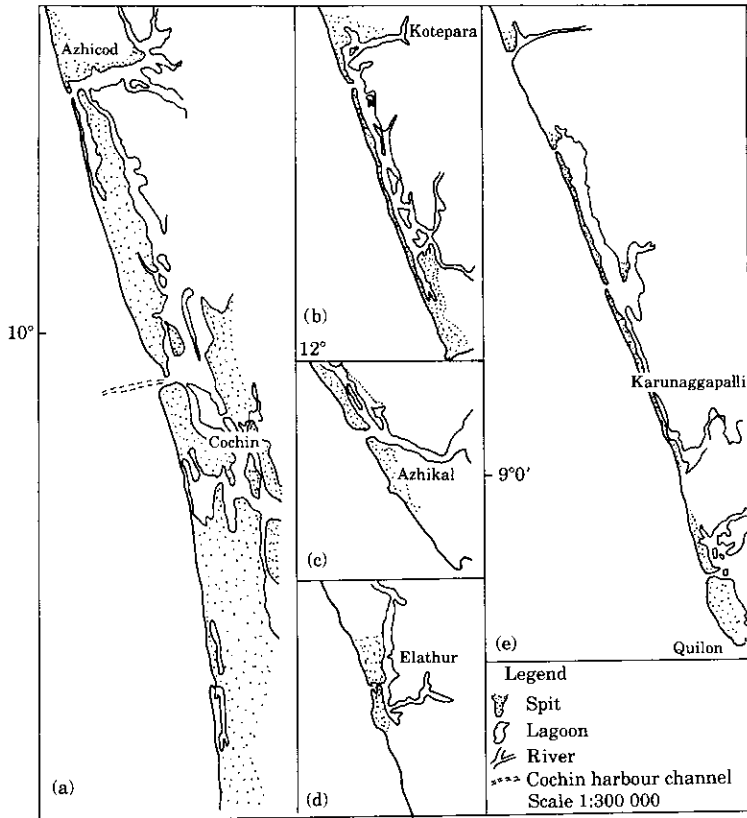


Figure 5. Typical spit complexes of the study area.

shore drift is in both directions, namely north and south, as beach width increases through a drift cell, in downdrift direction (Taggart & Schwartz, 1988).

Paleo-beach ridges. Between the present and the old shoreline (Figures 2 and 3), a number of parallel beach sand ridges alternating with swales are observed. These beach ridges have been recognized as representing successive still-stand positions of sea of an advancing shoreline. More than three sets of such ridges are recognized around Ezimala, Alleppey, and north of Quilon. It is observed that spacing between the beach ridges is variable. Parallel and broadly spaced beach ridges are located near places like Cochin. Whereas converging and closed spaced beach ridges are observed near the headlands of Alleppey and Ponnani. As the beach ridges represent the paleo-shores, the deflection of long-shore currents due to headland projections are represented by a converging configuration of ridges along the coast of Ezimala, Alleppey and Kayamkulam. The converging nature on either side of parallel placed beach ridges indicates that the shore drift in the past was bi-directional.

River mouth deflection. Forty-one out of 44 rivers of the area are flowing westerly. In many cases, river mouths and lagoon entrances are found deflected either to the north or south due to the growth of spits (Table 1) and are seen to be prolonged in the direction of

long-shore drift (Figure 5). If the volume accumulating on the updrift side of the river exceeds the stream's capacity to remove it, the river will become progressively offset in the direction of net shore drift (Taggart & Schwartz, 1988) and hence based on river mouth deflection, drift direction within each drift cell is determined as towards the north or south.

Mud banks. The formation and behaviour of 'mud banks' is a phenomenon peculiar to the Kerala coast. Mud banks are appearing close to the shore at certain locations like Cannanore, Ponnani, Cochin etc. along the Kerala coast, only during the south-west monsoon season. They affect the coastal processes by trapping littoral sediments from the updrift side and thereby preventing their down-coast movement. Mud banks are not visible on satellite images. It is reported (Moni, 1980) that the presence of mud banks near Alleppy and Cochin causes very severe erosion along Purakkad and Chellanam beaches, respectively, which are located to the south. This evidence indicates that shore drift is southwards during the south-west monsoon season.

Man-made structures interrupting shore drift. Close observations of satellite images pertaining to 1973 and 1983 indicate that the southern margin of Vypeen bar has prograded westwards whereas the northern margin of Cochin bar has retrograded. This shoreline change has occurred after construction of Cochin harbour channel [Figure 5(a)] which acts as a barrier against sediment transport (Kumar *et al.*, 1990). This evidence clearly suggests that the shore drift off Cochin harbour is southwards because, due to the existence of man-made structures, sediment accumulates on the updrift side and the downdrift side experiences sediment starvation and subsequent erosion (Taggart & Schwartz, 1988).

Offshore turbidity distribution pattern study Satellite images provide a synoptic view of discrete turbid water masses in the near-shore region. Depending on the type of particulate matter, stratification, depth of settling and bottom conditions, the turbid waters will be more reflective than clear water and will appear in different shades of grey tones based on turbidity. On the satellite images, the sharp contrast between various sediment-laden waters is clear and mappable. Tonal variation is considered as a measure of turbidity concentration. Texture and pattern help in monitoring distribution and movement of turbid water masses.

Careful observations of fourth and fifth spectral band images of the study area indicated high to low gradation in turbidity from south to north and from coast to seaward side. On the satellite images, the current directions are indicated by the sediment laden plumes as they become elongated and pointed in the direction of flow. When the shape of plumes are studied, it is found that along the coast most of the plumes are seen to be elongated and are pointing northwards. Whenever plumes are obstructed by headlands, they are seen to be dispersed and deflected seawards. Parallel arranged alternate grey and dark bands are observed over the deep-sea region. This pattern is interpreted as deep-sea ocean waves. The direction of wave crest propagation is marked by arrows (Figure 3). Based on tonal gradation and current direction, the shore-drift direction is determined and marked on the offshore turbidity distribution map, prepared by overlying on the Landsat image. Though the entire coast is studied, for convenience only the prominent image (Figure 6) and interpreted map (Figure 3) are presented.

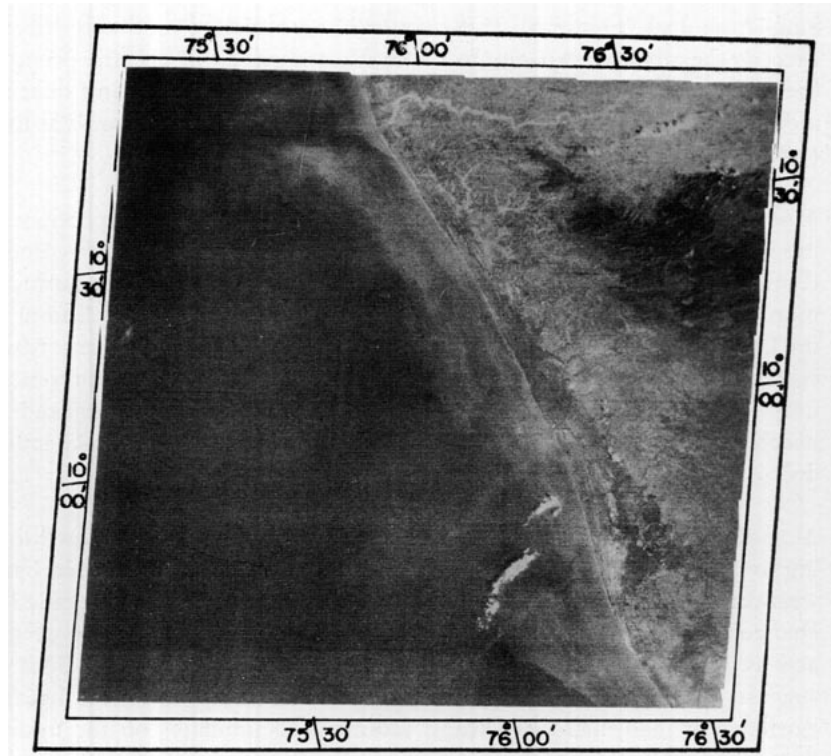


Figure 6. Photograph of Landsat image showing offshore turbidity distribution pattern and onshore paleo beach ridges.

Discussion and conclusion

Considering the evidence obtained from the study of landform indicators, 32 drift cells have been identified and shore drift within each drift cell has been determined. The extent of each cell is marked by the length of the arrow, and its direction indicates shore-drift direction in each cell [Figure 4(a,b)]. It is noted that drift cells have a shore-drift direction either towards the north or the south. Many adjacent cells have an opposite drift direction. Though some drift cells have a northwardly drift direction, those drift cells which have a southwardly drift direction are much larger and are more pronounced. Hence, it is confirmed that the net shore-drift direction is southwards.

The entire Kerala coast is exposed to an early onslaught of the south-west monsoon, and so the coast has to face high wave conditions during the period which develops strong southwards littoral currents. Due to (1) the influence of mud banks, (2) littoral barriers like the Cochin channel, (c) non-replenishment of sediments from upland and (4) that many rivers deposit sediment loads in the backwaters, littoral drift is supplied with limited littoral material. This causes very severe erosion of the coast during the south-west monsoon which has also been reported in earlier studies by Moni (1980), Earattupuzha and George (1980) and Thri vikramaji *et al.* (1983). Southward drift erodes protruded sectors and deposits eroded material, though partially along varying sectors.

However, a detailed comparison of satellite images of the year 1982 with those of 1972, reveals that the shoreline of the study area has almost remained unchanged during

the time span of 10 years except at Cochin (as mentioned earlier) and near Alleppey. This observation and the presence of depositional features like large spits and bars, chain of lagoons and beach ridges, indicate that in spite of erosion, active deposition is also taking place along the varying sectors. Northward facing spits and other coastal landform indicators suggest that seasonal reversal of littoral drift is taking place during the fair weather season (pre- and post-monsoon season). This northward littoral drift is responsible for the redeposition of eroded material.

Sediment transport normal to the shore may not be contributing much towards net erosion because though destructive waves are moving sediments offshore during the south-west monsoon season, sediments are returned to the shore by constructive waves during the fair weather season. Shore drift probably uses this material as well for growing spits and bars.

Based on the numerical modelling of wave data (Chandramohan, 1989), the annual rate and direction of the long-shore sediment transport is computed as $0.623 \times 10^6 \text{m}^3 \text{year}^{-1}$ towards the north $-1.573 \times 10^6 \text{m}^3 \text{year}^{-1}$ towards the south at Quilon. Whereas at Cochin, it is $0.693 \times 10^6 \text{m}^3 \text{year}^{-1}$ towards north and $-0.977 \times 10^6 \text{m}^3 \text{year}^{-1}$ towards south. His study, which suggests that the long-shore transport direction is towards the south from January–March and June–September and towards the north in April, May and October–December between Tirvendram and Cochin, also supports the above finding.

Turbidity pattern distribution exhibited by the satellite image suggest that for the months of January and February 1973 (date of imagery), long-shore drift is from south to north consistently along the coast. This corroborates with the earlier results.

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