The Pharma Innovation Journal 2023; SP-12(6): 225-230

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(6): 225-230

www.thepharmajournal.com
Received: 02-03-2023
Accepted: 03-04-2023

Sandip Markad
Assistant Professor, Toshniwal Arts, Commerce and Science College, Sengaon, Maharashtra, India

Dhanaji Patil
Assistant Professor, Toshniwal Arts, Commerce and Science College, Sengaon, Maharashtra, India

Adinath Markad
College of Fishery Science, Udgir, Maharashtra, India

Ajay Nakhawa
Central Marine Fisheries Research Institute, Maharashtra, India

Corresponding Author:
Sandip Markad
Assistant Professor, Toshniwal Arts, Commerce and Science College, Sengaon, Maharashtra, India

Assessment of changes along the bay and sedimentation in fishing harbor using remote sensing and GIS techniques

Sandip Markad, Dhanaji Patil, Adinath Markad and Ajay Nakhawa

Abstract
Mirya bay (17° 00' 02"N, 73° 16' 50" E), Ratnagiri, Maharashtra State, situated on the west coast of India, is protected with mountains and rocky ridges on both edges. The bay is characterized by the sandy beach flanked by rocky ridges at northern side and Mirkarwada fishing harbour at the southern side. Mirya beach faced major problem of erosion resulting in loss of beach area to substantial levels and decrease in the width of the beach whereas, Mirkarwada fishing harbor encountered the severe siltation in the basin as well as entrance channel resulting in navigational and mooring difficulties for fishing vessels. Present study was carried out to assess the changes along the Mirya bay for the time period from 1989 to 2009 by using different remote sensing and GIS tools along with field and ground truth data. Digital satellite images of different satellites with different spectral and spatial resolutions were used for the study. The digital satellite images were analyzed by the ERDAS Imagine 9.1 digital image processing software. Digital satellite images were preprocessed to curtail geometric, radiometric as well as atmospheric errors. Different digital image processing techniques were used to map the shoreline for years 1989, 1999, 2004 and 2009 from respective year satellite imageries. Sequential shoreline changes were estimated for time intervals between 1989 to 1999, 1999 to 2004, 2004 to 2009 and 1989 to 2009 by subtraction of respective date binary images derived by different image processing techniques. The Root Mean Square (RMS) error estimates of temporal satellite images used in the present study ranged from 0.1910 to 0.3255 pixels whereas, the average accuracies of 97.5%, 97.2% and 97.3% were achieved for shoreline mapping by histogram thresholding, unsupervised classification of multi-spectral images as well as principal components respectively with good overlapping of mapped shorelines. The Mirya beach was characterized by net loss of 1.83 ha beach area during 1989 to 2009 pertaining to erosion of 4.91 ha and deposition of 3.08 ha beach area. The erosion was dominant at the northern side of the beach, while eroded material was transported towards south and deposited at the entrance as well as at the embayment of the Mirkarwada fishing harbour. The sedimentation in the Mirkarwada harbour resulted in the reduction of accessibility and workability of the harbour. The study showed that there is urgent need to undertake appropriate measures such as formation of small walls or structures to trap the sediment at the northern part of the beach.

Keywords: Mirkarwada, fishing, harbour

1. Introduction
Mirya bay (17° 00' 02"N, 73° 16' 50" E), Ratnagiri, Maharashtra, is situated on the west coast of India. The bay is protected with mountains and rocky ridges on both edges. The bay is characterized by the sandy beach flanked by Mirkarwada fishing harbour at the southern side and rocky ridges at northern side. The bay has Mirkarwada fishing harbour providing mooring and landing space for the mechanised as well as non-mechanised fishing vessels. The construction work of the harbour was commenced on 1977 and was completed by 1987-88. In addition to this, the bay has a commercial jetty mostly used for the loading and unloading of cement material. These harbour structures are protected by breakwater walls at the southern part of the bay.

Mirya beach is facing problem of severe erosion while Mirkarwada Fishing harbor is facing siltation and associated navigational difficulties. This erosion of the Mirya Beach is attributed to the anthropogenic activities undertaken for development. The bay beach is generally considered stable due to protection supplied from headlands facilitating the retention of sediment material within the bay. Naturally very less sediments are lost from the beach of a bay or are recirculated regularly by the natural water currents which are generally termed as eddy current. Generally, bays are considered to be close systems since dose not enter or leave the bay systems.

Large energy or some major physical changes are required to alter this balance and cause loss of beach sediments.

Natural water currents in the Mirya bay are southward with eddy currents moving in clockwise direction. The water flows from northern edge to southern and these currents were found in relation to the water currents of the west coast of India. These water current causes movement of sediments in southern direction. Prior to the construction of Mirkarwada fishing harbor, commercial harbor and breakwater walls, these sediment transport was circular and sand was replenished at the beach, as there were no major obstacles to stop the water current and sediment transport. But after the construction of harbors and breakwater walls in the northern region of the bay, water currents are obstructed by these structures causing it to slower down. This reduction in water currents resulted in settlement of sediments in harbor basin. Thus, sediment Mirya beach faced major problem of erosion while Mirkarwad fishing harbor is facing sedimentation and associated navigational difficulties. Government of Maharashtra is spending substantial amount for dredging of sediments from the harbor basin.

Therefore, it is very important to assess the changes in the Mirya bay to formulate appropriate management action plan in order to prevent further erosion of the beach and sedimentation in the harbor basin. It is necessary to implement appropriate management action plan for conservation of coastal resources as well as to ensure sustainable development of coastal areas with respect to industries, culture, human settlements and infrastructure. Availability of detailed and timely information about different coastal processes, currents, hazards, landforms, coastline conditions and sediment dynamics of the bay is prime need for planning as well as implementation of suitable management action plans.

Methods and tools capable of collection, analysis and interpretation of multiple coastal data needs to be used to derive necessary information with minimal loss of manpower, time as well as money. Remote sensing and geographic information system (GIS) are important tools available for gathering, analysis as well as interpretation of spatio-temporal data required for planning and implementation of management action plans. Remote sensing satellite images provide multispectral and multi-temporal datasets for mapping of shoreline, different features as well as associated processes. GIS is used as platform for collection, analysis, interpretation and representation of information gathered from different sources. Thus, these tools can be utilized to understand the processes along the Mirya bay and form appropriate management action plans with minimal use of time, efforts and money. Therefore, attempts were made to analyze the changes along the Mirya Bay during past decades and associate processes using remote sensing and GIS techniques.

2. Materials and Methods

Study of changes along the Mirya bay were analyzed for the time period from 1989 to 2009 by using different remote sensing and GIS tools along with field and ground truth data. Digital satellite images of study area acquired by various sensors onboard different satellites with different spectral and spatial resolutions were used for the study of Mirya Bay. The multi- spectral digital images of Landsat TM (1989), Landsat ETM+ (1999), ASTER (2004) and IRS P6 LISS III (2009) were analyzed by ERDAS Imagine 9.1 image processing software. Ground and field based surveys were also carried out for collection of Ground Control Points (GCPs) and ground truth data.

Different digital image processing techniques were used during the study.

2.1 Image preprocessing

Image preprocessing is performed to curtail the errors in the digital satellite images. The preprocessing was applied to the digital satellite data so as to have correct satellite image data for extracting shoreline changes. The raw digital satellite image data was first transformed into image format by importing into ERDAS image processing system. The imported images were corrected for geometric errors using GCPs and were then rectified to UTM (Zone 43) map projection with RMS error threshold of 0.5 pixels.

The geometrically corrected images were then processed to convert Digital Number (DN) values of images to Top-Of-Atmosphere (TOA) reflectance. This facilitated the curtailing of radiometric errors associated with variations in the radiation due to seasonal variations, atmosphere, etc. In addition to this, TOA reflectance values represented the ratio of radiance recorded at the satellite sensor against the irradiance from the sun. This provided a standardized measure for direct comparison of digital images acquired by different sensors onboard different satellites.

The multi-spectral satellite images used were with varying spatial resolutions because of which the extraction of shoreline and associated changes was difficult. Therefore, the all images were transformed to equal spatial resolution by using single date high spatial resolution image. For this, reference image was generated from high spatial resolution image and this image was used to transform all the multi-spectral satellite images to high spatial resolution. Subsets of area of interest were then drawn from the corrected images in order to increase the processing speed and reduce the storage size of images.

2.2 Digital Image Processing

Multispectral digital satellite images, which were corrected through different preprocessing techniques were used for mapping as well as for assessment of erosion and accretion along the Mirya bay and associated structures. Binary images were produced through digital image processing to facilitate ease of shoreline mapping and change detection. (Deekshatulu and Rajan, 1984; Reddy, 2001; Lillesand *et al*., 2004) [9, 23, 19].

2.2.1 Image processing techniques employed for Shoreline Mapping

Different digital image processing techniques were used for the shoreline mapping, as described below.

2.2.1.1 Histogram threshold

The infrared band of the multi-spectral satellite images shows higher pixel values for land areas and lower pixel values for water areas producing superior contrast between land and water areas in the image. Therefore, land and water areas in the temporal infrared band images were separated by using threshold value from transition zone. The pixels with value above threshold were classified as land and those with lesser values were classified as water areas. The binary image thus produced was then multiplied with band ratio images of GREEN/NIR and GREEN/MIR so as to increase the accuracy of shoreline mapping (Van and Binh, 2008) [45]. Temporal shorelines for year 1989, 1999, 2004 and 2009 were extracted from respective date binary images.

2.2.1.2 Unsupervised classification of mutlispectral images
Unsupervised classification of multi-spectral satellite images was performed using ISODATA clustering technique to classify image pixels into several clusters. Then the clusters belonging to land area in the images were assigned with pixel value of one and those belonging to water areas were assigned with pixel value of zero, so as to produce temporal binary images with land and water classes only. These binary images were then used for mapping the shoreline positions of year 1989, 1999, 2004 and 2009.

2.2.1.3 Unsupervised classification of principal components
The multi-spectral satellite images were transformed into principal components to reduce the redundancy of the data. first three principal components were classified unsupervisely into several clusters. These clusters were then recoded as mentioned in section 2.2.1.2 to form temporal binary images. The shoreline positions for year 1989, 1999, 2004 and 2009 were then mapped from these binary images.

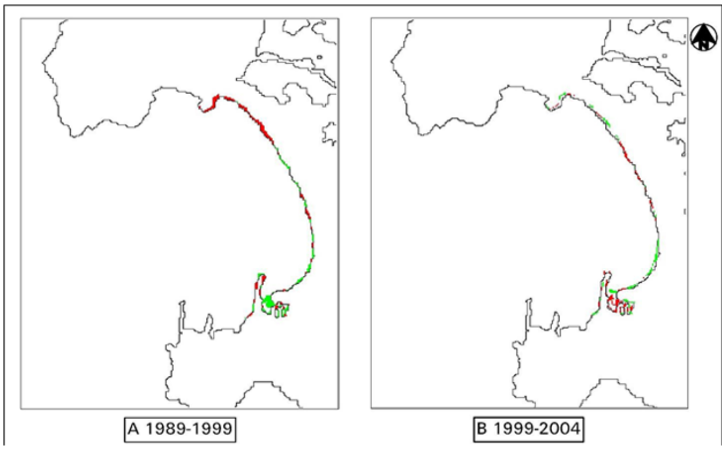
2.2.1.4 Accuracy assessment
The temporal shorelines mapped by different image processing techniques were tested for accuracy by random selection of 1000 pixels belonging to land water interface in the classified binary images. The selected pixels were then tested against ground truth data as well as visual interpretation and correctly classified pixels were counted. Chi square test was applied to correctly classified pixels so as to test the level of significance in the accuracy of shoreline mapping by different image processing techniques.

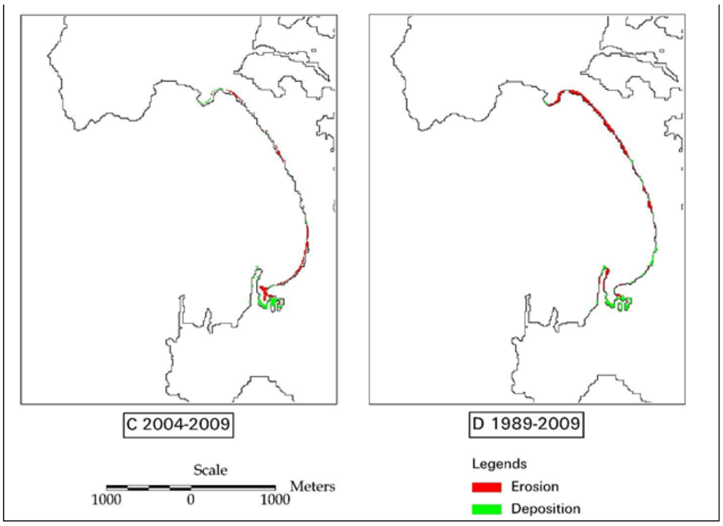
2.1.1 Shoreline Change Detection
Sequential shoreline changes were estimated for time intervals between 1989 to 1999, 1999 to 2004, 2004 to 2009 and 1989 to 2009 by subtraction of respective date binary images derived by different image processing techniques. The pixels with value zero belonged to the no change regions whereas, pixels with positive values belonged to the areas of shore accretion and those with negative one value belonged to the areas of shore erosion. Subtraction of TOA reflectance MIR bands of temporal images was also performed for analysis of shoreline changes for the same time intervals. The pixels with zero pixel values represented the areas of no change while, pixels with positive pixels values belonged to the areas of shore accretion and the areas of shore erosion were represented by pixels with negative values. The differences in the temporal shoreline change estimates, analyzed by different image processing techniques, were tested for significance by ANOVA test.

3. Results & Discussion
The Root Mean Square (RMS) error estimates of temporal satellite images used in the present study ranged from 0.1910 to 0.3255 pixels. El-Raey *et al.* (1999) [11] reported RMS errors of 0.9 pixels for the shoreline studies along Egyptian coast whereas, RMS error of 0.5 pixels was recorded by Frihy *et al.* (1998) [12] as well as Van and Binh (2008) [45] during their shoreline studies using digital image data. The RMS error reported during present study was lower as that of Wu (2007) [47] (0.21-0.33 pixels) ensuring the preciseness of shoreline estimates of the present study.

The average accuracies of 97.5%, 97.2% and 97.3% were achieved for shoreline mapping by histogram thresholding, unsupervised classification of multi-spectral images as well as principal components respectively with good overlapping of mapped shorelines. The Chi-square test did not revealed any significant difference ($p > 0.05$) among accuracy of shoreline mapping through different shoreline mapping techniques. No significant difference was revealed by ANOVA test among the temporal shoreline changes estimated by different methods ($p>0.05$). Shreedhar *et al.* (1997) and Tikekar *et al*. (1997) [36, 42] reported plannimetric errors, scale variation and non-linearity errors of different magnitude during shoreline studies through manual interpretation on hard copies of satellite images. Chen and Rau (1998) also reported error of 7.6 to 12.5% during the investigation of shoreline changes by manual digitizing on multi-spectral satellite images. These errors were associated with unavoidable human and instrumental errors. In the present study, shoreline was extracted by separating land and water areas through different digital image processing techniques to reduce inevitable human errors. Ma *et al.* (2007) achieved overall accuracy of 91.4% in change detection studies by digital image processing techniques. Moreover, the shorelines mapped using different digital image processing techniques during present study showed precise overlapping as Guariglia *et al*. (2006) reported perfect overlapping of shorelines obtained by analysis of satellite image with the shoreline obtained by GPS survey during shore studies along Ionian coast in Bassilicata Region.

The Mirya beach in the vicinity of Mirya bay, flanked by rocky ridge at northern side and Mirkarwada fishing harbour at the southern side, showed substantial changes during 1989 to 2009 as summerised in Table 01 and depicted in Map 01.





Map 1: Shoreline changes along the Mirya bay

Table 1: Changes along the Mirya Bay

Sr. No.	Time interval	Shoreline change (ha)		
		Erosion	Deposition	Net change
1	1989-1999	4.93	4.32	-0.61
2	1999-2004	3.42	2.92	-0.50
3	2004-2009	3.17	2.45	-0.72
4	1989-2009	4.91	3.08	-1.83

The Mirya beach was characterized by net loss of 1.83 ha beach area during 1989 to 2009 pertaining to erosion of 4.91 ha and deposition of 3.08 ha beach area. Net loss of 0.61 ha area was estimated from Mirya beach for the time period between 1989 to 1999 due to erosion of 4.93 ha area and accretion of 4.32 ha area. Time period between 1999 to 2004 was characterised by erosion of 3.42 ha area and accretion of 2.92 ha area resulting in net loss of 0.50 ha beach area. The accretion of 2.45 ha and erosion of 3.17 ha beach area during 2004 to 2009 resulted in net loss of 0.72 ha area from Mirya beach.

The erosion was attributed to the alteration of water currents and formation of eddy currents due to construction of breakwater at opening of Mirya bay. The erosion was dominant at the northern side of the beach, while eroded material was transported towards south and deposited at the entrance as well as at the embayment of the Mirkarwada fishing harbour. The loss of sand along the beach resulted in reduction of beach width, while the deposition of the sand in the harbour vicinity caused formation of sandbar. The eroded sediments from the northern part of beach were transported to the southern end along with water currents and were deposited in the vicinity of Mirkarwada harbor. This resulted in decrease of water depth in harbor basin and entrance creating navigational difficulties as well as accessibility problems for the vessels. The sandbar was also observed at the entrance of the harbour which was reduced during 2004 to 2009. The loss of Mirya beach area due to erosion was also recorded by Iyer (2004). Tikekar *et al.* (1997) [42] recorded sedimentation in the vicinity of Mirkarwada Fishing harbour and predicted navigational as well as mooring hindrances in the harbour.

The changes along the Mirya bay may be attributed to the alteration of water currents due to construction of harbour and associated structures at the northern edge of the bay. This resulted in the alterations of the water currents in the bay and formation of eddy flow pattern in the bay. Rajawat *et al.* (2004) [22] also reported formation of eddy currents due to construction of breakwater walls and associated shoreline changes in the different regions of the Kerala.

The changes associate with construction of breakwater walls and ports at different regions were recorded by several workers. Bezerra *et al.* (2007) [7] reported sand deposition in the vicinity of Mucurip port resulting in formation of Mansa beach in the basin and navigational difficulties. Frihy *et al.* (1998) [12] reported deposition along the jetty at the entrance of Suez Canal due to blockage of eastward longshore sand transport. Azab and Noor (2004) [4] reported sand deposition at the western side of the jetties due to obstruction to transportation of sediment in the southeast direction. They also reported erosion from eastern tip of Port Said head land, eastward movement of sediment and deposition at the embayment of Tineh bay. Wu (2007) [47] also reported reduction in the life span of the Port de l'Amitie harbour due to accumulation of the sand and predicted 13 years life for the harbour if protective measures are not undertaken. The deposition in the Mirkarwada harbour resulted in the reduction of accessibility and workability of the harbour. The sand dredging and extraction was undertaken by the Government of Maharashtra in the basin as well as at the entrance channel of the Mirkarwada harbour. This resulted in disappearance of sandbar at the entrance during 2004 to 2009 facilitating reduced navigational hindrances for the vessels and increased the workability of the harbour.

4. Conclusion

The study revealed erosion of Mirya beach resulting in reduction of beach area. The eroded material was transported southward with water currents and it was deposited in the vicinity of Mirkarwada Fishing harbor which resulted in navigational difficulties for fishing vessels. The study showed that there is urgent need to undertake appropriate measures such as formation of small walls or structures to trap the sediment at the northern part of the beach. Moreover, nourishment of the beach with sand which may be dredged from harbor basin or the other parts of the bay.

5. References

1. Alesheikh AA, Ghorbanali A, Nouri N. Coastline change detection using remote sensing. International Journal of Environmental Science and Technology. 2007;4(1):61-66.
2. Anon. ERDAS field guide, Leica Geosystems Geospatial Imaging, LLC, 5051 Peachtree Corners Circle, Suite 100, Norcross, GA, 30092, USA; c2005. p. 744.
3. Anon. Report of Sustainable Coastal Protection and Management Project (TA 4965-IND) prepared for The Asian Development Bank and the Government of India, ANZDEC Limited in association with ASR Marine Consulting and Research, New Zealand; c2009. p. 107.
4. Azab MA, Noor AM. Change detection of north Sinai coast by using remote sensing and geographic information system. In: Proceedings 3rd International Symposium on Geophysics, Tanta; c2004. p. 564-572.
5. Bedini E, Naco P. Automated change detection from remote sensing data- A case study at the Pali Cape-Erzeni River mouth coastal sector. In: M. Morell, C. Popovska; c2008.
6. Morell O, Stojov V, Kostoski G, Dimitrov D, Drobot R, Radic Z, Seleneca A. (Eds) Proceedings of conference on water observation and information system for decision support, BALWOIS, Ohrid, Republic of Macedonia: 1-7.
7. Bezerra MO, Pinheiro L, Morais JO. Shoreline change of the Mucuripe Harbour Zones (Fortaleza-Ceara, Northeast of Brazil) 1972-2003. Journal of Coastal Research, Special Issue. 2007;50:1163-1167.
8. Chen LC, Rau JY. Detection of shoreline changes for tideland areas using multi- temporal satellite images. International Journal of Remote Sensing. 1998;19(10):3383-3397.
9. Deekshatulu BL, Rajan YS. Remote sensing. Indian Academy of Sciences, Bangalore; c1984. p. 304.
10. Dinesh Kumar PK, Gopinath G, Laluraj CM, Seralathan P, Mitra D. Change detection studies of Sagar Island, India, using Indian Remote Sensing Satellite 1C Linear Imaging Self-Scan Sensor III data. Journal of Coastal Research. 2007;23(6):1498-1502.
11. El-Raey M, Sharaf El-Din SH, Khafagy AA, Abo Zed AI. Remote sensing of beach erosion/accretion patterns along Damietta-Port Said shoreline, Egypt. International Journal of Remote Sensing. 1999;20(6):1087-1106.
12. Frihy OE, Dewidar KM, Nasr SM, El-Raey MM. Change detection of the northeastern Nile Delta of Egypt: shoreline changes, Spit evolution, margin changes of Manzala lagoon and its islands. International Journal of Remote Sensing. 1998;19(10):1901-1912.
13. Ganesan P. Delineation of high tide line and seasonal beach profiling at Kalbadevi bay, Maharashtra, central west coast of India. Technical Report: NIO /TR- 8/ 2004, Geological Oceanography Division, National Institute of Oceanography, Goa, India; c2004. p. 52.
14. Guariglia A, Buonamassa A, Losurdo A, Saladino R, Trivigno ML, Zaccagnino A *et al*. A multisource approach for coastline mapping and identification of shoreline changes. Annals of geophysics. 2006;49(1):295-304.
15. Gujar AR. Morphogenetic controls on the distribution of the littoral placers along central west coast of India. In*:* Desai, N. and Ganapati, S. (Eds) Proceedings of National seminar on recent researches in geology of western India, Goa; c1995. p. 171-180.
16. Hanamgond PT, Mitra D. Dynamics of the Karwar coast, India, with special reference to study of tectonics and coastal evolution using remote sensing data. Journal of Coastal Research. 2007;50:842-847.
17. Iyer JC. Coastal erosion and protection- A national perspective. In: Proceedings of workshop on coastal protection measures, Cochin, India; c2004. p. 135-138.
18. Kunte PD, Wagle BG, Sugimori Y. Remote assessment of net shore drift along the west coast of India. In: PORSEC (Ed) Proceedings of the fifth Pacific Ocean Remote Sensing conference, PORSEC, Goa, India. 2000;2:685-689.
19. Lillesand TM, Kiefer RW, Chipman JW. Remote sensing and image interpretation, Fifth Edition, John Wiley & Sons (Asia) Pte. Ltd., Singapore; c2004. p. 763.
20. Ma M, Wang X, Veroustraete F, Dong L. Change in area of Ebinur Lake during the 1998-2005 period. International Journal of Remote Sensing. 2007;24(20):5523-5533.
21. Makota V, Sallena R, Mahik C. Monitoring shoreline change using remote sensing and GIS: A case study of Kunduchi area, Tanzania. Western Indian Ocean Journal of Marine Science. 2004;3(1):1-10.
22. Rajawat AS, Pradhan Y, Thomaskutty AV, Gupta M, Nayak S. Coastal processes along the Indian coast–case studies based on synergistic use of IRS-P4 OCM and IRS-1C/1D data. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. 2004;34(30):159-164.
23. Reddy AM. Textbook of Remote Sensing and Geographic Information System, Second Edition, BS Publication, Hyderabad; c2001. p. 418.
24. Ganesan P. Delineation of high tide line and seasonal beach profiling at Kalbadevi bay, Maharashtra, central west coast of India. Technical Report: NIO /TR- 8/ 2004, Geological Oceanography Division, National Institute of Oceanography, Goa, India; c2004. p. 52.
25. Guariglia A, Buonamassa A, Losurdo A, Saladino R, Trivigno ML, Zaccagnino A, Colangelo A. A multisource approach for coastline mapping and identification of shoreline changes. Annals of geophysics. 2006;49(1):295-304.
26. Gujar AR. Morphogenetic controls on the distribution of the littoral placers along central west coast of India. In*:* Desai, N. and Ganapati, S. (Eds) Proceedings of National seminar on recent researches in geology of western India, Goa; c1995. p. 171-180.
27. Hanamgond PT, Mitra D. Dynamics of the Karwar coast, India, with special reference to study of tectonics and coastal evolution using remote sensing data. Journal of Coastal Research. 2007;SI(50):842-847.
28. Iyer JC. Coastal erosion and protection: A national perspective. In: Proceedings of workshop on coastal protection measures, Cochin, India; c2004. p. 135-138.
29. Kunte PD, Wagle BG, Sugimori Y. Remote assessment of net shore drift along the west coast of India. In: PORSEC (Ed) Proceedings of the fifth Pacific Ocean Remote Sensing conference, PORSEC, Goa, India. 2000;2:685-689.
30. Lillesand TM, Kiefer RW, Chipman JW. Remote sensing and image interpretation, Fifth Edition, John Wiley &

Sons (Asia) Pte. Ltd., Singapore; c2004. p. 763.
31. Ma M, Wang X, Veroustraete F, Dong L. Change in area of Ebinur Lake during the 1998-2005 period. International Journal of Remote Sensing, 24(20): 5523-5533.
32. Makota V, Sallena R, Mahik C. Monitoring shoreline change using remote sensing and GIS: A case study of Kunduchi area, Tanzania. Western Indian Ocean Journal of Marine Science. 2004;3(1):1-10.
33. Rajawat AS, Pradhan Y, Thomaskutty AV, Gupta M, Nayak S. Coastal processes along the Indian coast–case studies based on synergistic use of IRS-P4 OCM and IRS-1C/1D data. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. 2004;34(30):159-164.
34. Reddy AM. Textbook of Remote Sensing and Geographic Information System, Second Edition, BS Publication, Hyderabad; c2001. p. 418.
35. Markad S, Nakhawa A, Kamble S, Shirdhankar M, Mohite A, Chuadhari K. Detection of Shoreline Changes in Ratnagiri Block, Maharashtra, India using Remote Sensing and GIS Techniques, Fishery Technology. 2014;51(4):229-233.
36. Shreedhar V, Sherieff AN, Bannur CR, Rao RS, Nayak SR. Coastal wetland and shoreline change mapping of the Karnataka coast. Technical Note: SAC/RSA/RSAG/DOD-COS/SN/15/97, Space Application Center, Ahmedabad, India; c1997. p. 42.
37. Shaghude YW, Wannas KO, Lunden B. Assessment of shoreline changes in the western side of Zanzibar channel using satellite remote sensing. International Journal of Remote Sensing. 2003;24(23):4953-4967.
38. Singh A. Digital change detection techniques using remotely-sensed data. International Journal of Remote Sensing. 1989;10(6):989-1003.
39. Snedecor GW, Cochran WG. Statistical methods, Sixth Edition, Oxford and IBH Publishing Co., New Delhi; c1967. p. 593.
40. Tandale TD. Coastal environ of Maharashtra-Evolution and human activities (Aided with satellite remote sensing). Journal of the Indian Society of Remote Sensing. 1993;21(2):59-65.
41. Thanikachalam M, Ramachandran S. Shoreline and coral reef ecosystem change in Gulf of Mannar, Southeast coast of India. Journal of the Indian Society of Remote Sensing. 2003;31(3):157-173.
42. Tikekar SS, Mishra MC, Chauhan HB, Nayak SR. Coastal wetland/landform and shoreline change mapping of the Maharashtra coast. Technical Note: SAC/RSA/RSAG/DOD-COS/SN/14/97, Space Application Center, Ahmedabad, India; c1997. p. 38.
43. Tirkey N, Birabar RS, Pikle M, Charatkar S. A study of shoreline changes of Mumbai coast using remote sensing and GIS. Journal of the Indian Society of Remote Sensing. 2005;33(1):85-91.
44. Unnikrishnan AS, Rupa Kumar K, Sharon EF, Michael GS, Patwardhan SK. Sea level changes along the Indian coast: Observations and projections. Current science. 2006;90(3):362-368.
45. Van TT, Binh TT. Shoreline change detection to serve sustainable management of coastal zone in Cuu long estuary. In: H. M. Hien (Ed) International symposium on geoinformatics for spatial infrastructure development in earth and allied sciences; c2008. p. 571- 576.
46. Vanderstraete T, Goossens R, Ghabour TK. The use of multi-temporal Landsat images for the change detection of the coastal zone near Hurghada, Egypt. International Journal of Remote Sensing. 2006;27(17):3645-3655.
47. Wu W. Coastline evolution monitoring and estimation-a case study in the region of Nouakchott, Mauritania. International Journal of Remote Sensing. 2007;28(24):5461-5484.
48. Zakariya R, Rosnan Y, Saidin SA, Yahaya MH, Kasawani I, Lokman H. Shoreline detection and changes for Terengganu River mouth from satellite imagery (Landsat 5 and Landsat 7). Journal of Sustainability Science and Management. 2006;1(1):47-57.
49. Zoran M, Anderson E. The use of multi-temporal and multispectral satellite data for change detection analysis of the Romanian Black Sea coastal zone. Journal of optoelectronics and advanced materials. 2006;8(1):252-256.