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Evaluation Of Shoreline Changes Around Northern And Southern Chennai Harbor Using Historical Satellite Data And Geospatial Approaches Along Coastal Watersheds

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Abstract

The findings of shoreline variation analysis conducted from 1991 to 2022 in the vicinity of Chennai Harbor, focusing on erosion rates along the northern and southern regions revealed substantial variations in erosion rates, ranging from -1.66 m to -176.59 m in the north and from -1.11 m to -27.82 m near Adayar mouth in the south for a period of 31 years. The study findings highlight the dynamic character of coastal processes in the area and showed a notable retreat of the shoreline throughout the time frame i.e 1991-2022. The observed rates of erosion demonstrate how susceptible coastal regions are to both human activity and natural processes. The study underscores the need for continued monitoring and research to assess long-term trends in shoreline evolution and to inform adaptive management strategies in response to ongoing environmental changes. In order to evaluate long-term patterns in shoreline evolution and to provide adaptive management techniques in response to ongoing environmental and anthropogenic changes, the study emphasizes the use of modern techniques towards monitoring and assessing the coastal vulnerability. The results have significant implications for coastal policymakers, planners, and stakeholders, underscoring the criticality of adopting sustainable coastal development practises and efficient erosion mitigation techniques.

Keywords: *Digital shoreline analysis, DGPS Survey, DEM, High water line, Satellite Data, Erosion and Accretion.*

Introduction

The Indian coastline is under constant threat from several natural hazards that can seriously harm people and property. Coastal risks along the Indian coast are influenced by hydrologic factors such as storm sur[1]ge, coastal erosion, floods, sea level rise, and tropical cyclones. Seasonal tropical cyclones that occur during the return NE monsoon also strike India's east coast, but they mostly affect the west coast during the SW monsoon. The Bay of Bengal is particularly vulnerable to storm surge events. Since 1737, there have been 23 large surge episodes, each of which killed more than 10,000 people.((Murty and Flather, 1994); (Murty et al., 1986)). The main causes of damage from landfalling cyclones include rain, severe gusts, and storm surges. Storm surges resulting from severe tropical cyclones are by far the most dangerous. (Dube et al., 2009).

Additionally, modern predictions based on global climate models (Wigley and Raper, 1992) show that the sea level may rise by 15 to 95 centimetres (cm) by the year 2100. The IPCC anticipates a 59cm maximum SLR by 2100. This estimate is generally recognised as

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conservative because to its omission of future dynamical changes in ice flow, which encompass critical ice sheet processes that accelerate glacier movement, specifically in the polar ice caps (IPCC 2007). This is more than double the rate of sea-level rise for the past century ((Paulik et al., 2020)). The Scientific Committee on Antarctic Research predicts that the mean sea level will rise by up to 1.4 metres by 2100. Other scientists also expect SLR to rise by one to several metres.(Ivins et al., 2005), (Larour et al., 2017) in the same period. Of course, the seas will keep rising even after 2100 if the warming doesn't stop. The German Advisory Council on Global Change (WBGU) thinks the water level will rise about one metre by 2100 and several metres by 2300.((Wbgu, 2010)). As a result, sea level rise will have a long-lasting effect on how coastlines change over time. This will happen at a time when both population and infrastructure are expected to grow along the coast. So, predictions are made about how far the shoreline will move and how much land will be lost, and plans are made for how to manage the coast in the future.

Study area

The Shoreline Variation Study, which spans 30 km in a SW-NE direction between 80º10'43" and 80º20'12" E longitudes and 13º40'45" and 13º16'17" N latitudes, was carried out between Ennore and Adayar covering 4 coastal micro-watersheds (Figure 1).

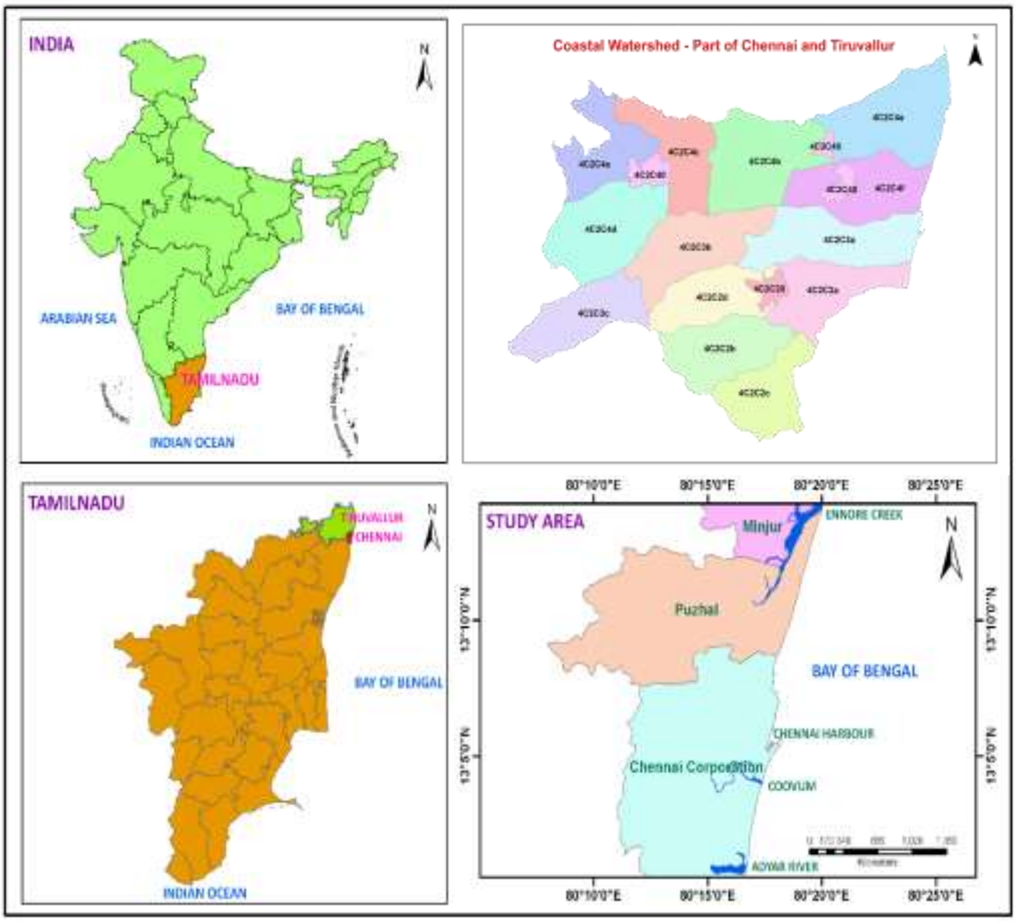


Figure 1. Study area – Part of Chennai

Materials and Methods

Materials

Survey of India topographic map and multi-date satellite images are used to create a Geographic Information System of long-term coastline positions. These shorelines are used to study shoreline position changes from 1969 as base line and satellite imagery from 1991 to 2022 as indicated in (Table.1).The temporal changes in the shoreline position can be used to derive quantitative estimates of the rate of shoreline change i.e. erosion or accretion. The pace of shoreline change, such as accretion or erosion, can be quantitatively estimated using the temporal variations in the shoreline location. In a geologic or scientific setting, these rates can be utilised to enhance comprehension of the size and timing of shoreline changes, as well as the evolution of coastal environments in response to wave and current processes.

A collection of satellite imagery was employed to acquire historical shorelines for the current investigation (Table 1)

Table 1: Satellite images used for analysis of shoreline change

Sensor	Spatial Resolution (m)	Year
LANDSAT TM	30	25 Aug 1991
LANDSAT TM	30	28 Oct 2000
IRS LISS III	23.5	4 Jun 2004
LISS IV MX	5.8	16 Mar 2005
LANDSAT TM	30	7 Apr 2006
LISS IV MX	5.8	03 Mar 2008
SENTINAL -II	10	04 Oct 2021
IKONOS	4	06 Jun 2022

The field data pertaining to the coastal topography of Chennai was acquired utilising the Leica TC405 Total station. The measurement of any topographic changes along the coast was conducted using the SOI Benchmark situated at Chennai Port. About 2500 ground control points were obtained from the LTL to the 5m topographic contour elevation i.e. about 2 km from the shoreline. A comprehensive survey was conducted in the villages of Thiruvottiyur, Kasikovilkuppam, Thazankuppam, Netukuppam, Periyakuppam, Chinnakuppam, and Ernavur Kuppam within the study region. In ArcGIS-10.6, the control points acquired via a Total station/DGPS survey were imported in order to generate the Digital Elevation Model (DEM).

METHODOLOGY-

The methodology used for the study is shown in the figure-2 listed below.

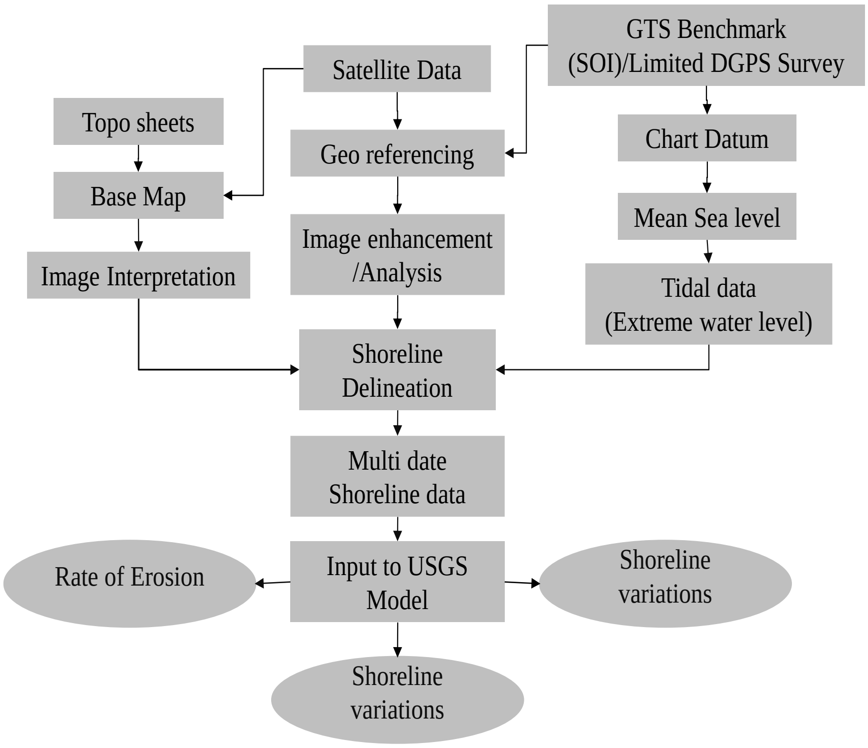


Figure 2 – Methodology for shoreline change analysis

Shoreline Change

The base map utilised in this study were Survey of India toposheets No. 66c/4, 66c/7, and 66c/8 of 1960 (scale 1:50,000). ARC GIS was utilised to digitise, modify, geometrically project, and transform the data while preserving real-world coordinates. The conventional techniques for determining the rate of change of shoreline position were field measurements, shoreline extractions from aerial photographs and topographic sheets (Maiti and Bhattacharya, 2009). An enhanced approach for gathering historical coastline data has been devised in the current research, which combines remote sensing technologies with limited DGPS surveys and integrates the data into GIS. A base map was generated using the toposheets obtained from the survey of India. The coastline was digitised on-screen and is represented as a single layer in the GIS environment. Establishing a dependable shoreline reference feature through the utilisation of remote sensing methods presents a formidable and complex undertaking, owing to various factors including disparities in pixel accuracies, fluctuations in meteorological conditions, and diverse ranges of tide-induced variability. To ascertain the coastal oscillations, tide data pertaining to the date of the satellite pass at the nearest station was gathered from the Survey of India tide gauge station. Tidal readings obtained during the satellite's passage were utilised to precisely outline the shoreline.

Extraction of waterline from satellite imageries

The 'waterline' in a remotely sensed image is the demarcation line that separates an exposed land mass from a body of water (Mason et al., 2001). The IR band provided the most useful information by clearly demarcating the best land/ water contrast due to the thermal difference between in land and water, as also observed by (Nayak and Sahai, 1985). NIR is transparent to clear water and sensitive to surf at the breaker zone (Frouin et al., 1996).

Clear water boundaries can be effectively detected using a straightforward density slicing method that employs Landsat (TM) Band 5 (SWIR).(Tong et al., 2020) tried the band ratio approach to extract the waterline from the tidal flats since it reduce the suspended sediment concentration near the shoreline. The visible band (0.45-0.69μm) is used to discriminate clay and silt. In general, NIR (TM Band 4 i.e. (0.76– 0.90μm) and SWIR (TM Band 5 i.e. 1.55 to 1.75μm) are commonly used to delineate the waterline.

The current investigation utilized the processed NIR/SWIR bands of Landsat MSS, Landsat TM, LISS IV MX, SENTINEL 2, and IKONOS to identify and outline the shorelines. The NIR/SWIR bands were processed using spatial enhancement with convolution filtering and the edge-enhanced level sliced technique at the proper spectral wavelength to extract shorelines from satellite data, comparable to the research conducted by (Khan et al., 2019). The selected pixels, representing shorelines as described above, have been converted into vector layers in GIS. Using ArcGIS 10.6, the high-water shoreline seen in satellite imagery was digitised. A range of zoom levels were employed in order to provide the most precise possible delineation of the shoreline.

Methods of shoreline rate-change calculation

Several approaches for estimating the rate of change have been proposed, including Average of Rates (LR), Jackknife (JK), and End Point Rate (EPR) (Fenster et al., 1993), (Dolan et al., 1991). On the basis of parameters such as temporal variability, number of coastline positions, total time span of shoreline data collection each approach has benefits and drawbacks. Utilizing statistical methodologies, the LR method for calculating the rate of shoreline change is significant because it reduces potential mistakes and short-term unpredictability (Douglas and Crowell, 2000). All approaches for calculating shoreline rates-of-change measure shoreline position differences over time. Yearly shoreline change is measured in distance. Positive numbers suggest accretion, while negative values indicate erosion (seaward movement of the shoreline).

Digital Shoreline Analysis System

This study calculated shoreline change using the Digital Shoreline Analysis System (DSAS) software inbuilt in GIS which calculated rate-of-change figures from many historic shoreline sites. DSAS constructs orthogonal transects at a user-defined separation and calculates attribute table rates of change and statistics, but requires a data format. For change analysis, multiple shoreline positions and user-generated baseline are created. Using remote sensing and restricted DGPS surveys, this work enhanced the approach for determining historical coastline information in GIS. Base map was made using Survey of India 1980 Toposheet and shoreline was digitised onscreen and placed in GIS.

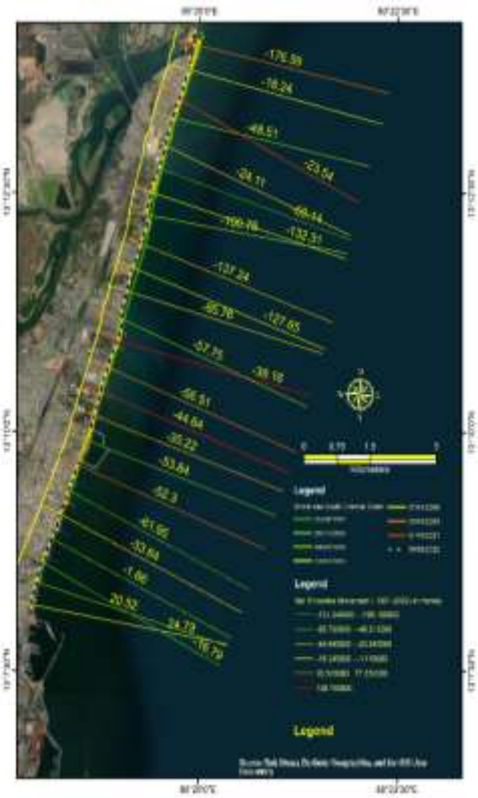
The DSAS model calculated the rate of change through transects at ~5km in the shore-normal direction using multi-date shoreline layers from 1991, 2000, 2004, 2005, 2006, 2008, 2021, and 2022.A crucial determinant in forecasting the forthcoming trajectory of shoreline displacement is the rate of change in shoreline location. Using 1969 shoreline as a baseline, a buffer line was drawn along the landward side to evaluate shoreline movement along each transect. According to the baseline, seaward coastline shift along transect is positive and landward shift is negative. Like Thieler et al. 1994, GIS software was used to quantify shoreline fluctuations using EPR and LRR methods to locate erosion and accretion zones along the research area's coasts.

Segmented historic coastline data was analyzed. Data segmentation criteria were included into analysis procedures for consistent, accurate, and fast temporal shoreline change analysis. A baseline/buffer on the landward side and three shorelines were used to aggregate spatial variability in 24 north and 16 south transects for every 250 m. Baselines were digitized and orthogonally oriented transects had the best chance of matching manual 'best fit' techniques (Dusen, 1979). Baselines and historic coastline data coverage for each study segment were "INPUT" into the USGS Digital Shoreline Analysis System (DSAS) Model to construct transects, analyse, and the results are saved as ArcGIS geo-database format.

RESULTS AND DISCUSSIONS

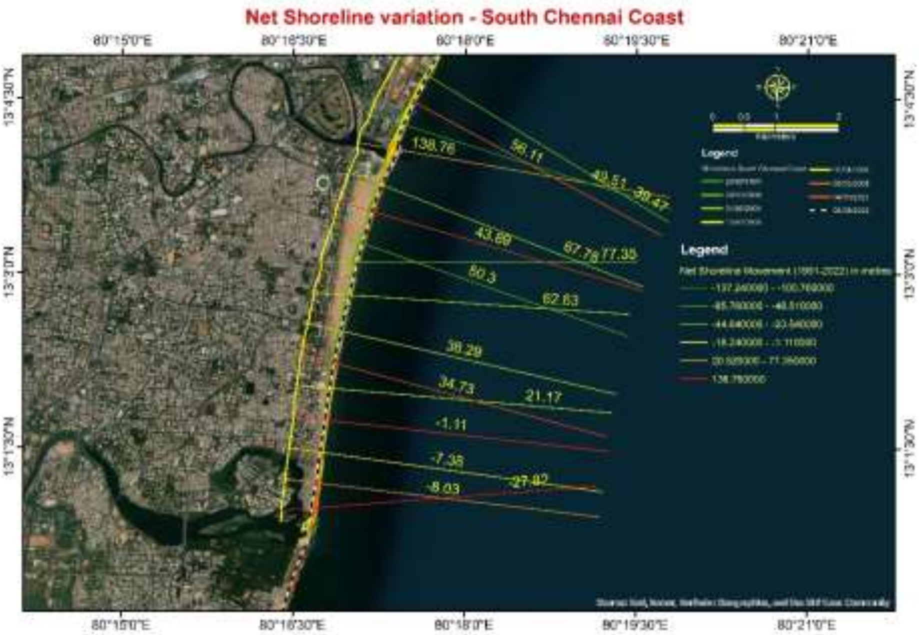
The shoreline change analysis indicated that the region north of Chennai harbor is eroding at the rates indicated in the figure for the regions Thiruvottiyur, Kasikovilkuppam, Thazankuppam, Nettukuppam, Periyakuppam , Chinnakuppam, Ernavur kuppam from the present shoreline. The erosion rates from 1991 to 2022 varied from -1.66 m to -176.59 m in the north and -1.11 to -27.82 near Adayar mouth around south of harbor as indicated in the figures(3a,b,and c).The study results are nearly matching with the published reports of NCCR with 43% of the 991.47km long Tamil Nadu coast is facing erosion and the north madras region is having the maximum erosion of ~7m/yr by (Kankara et al., 2014). The study results are validated by ground surveys and also closely matching with the published literature values of 5.6 m/yr near Chinnakuppam (Riyaz Khan N H & Subash Thanappan, 2020). Further the study recommends vertical structures like seawalls, revetments, T,L and Y shaped groins, steel sheet pile walls and concrete walls, and non-structural shore protection methods like vegetation planting, beach nourishments and sand bypassing methods to prevent the shoreline and to safeguard the ecosystem.

Net shoreline variation - North Chennai coast



3a

3b



3c

Figure 3a - Net shore line movement North Chennai , 3b – Predicted Shoreline position overlaid on land for next 20 years and 3c - Net shore line movement South Chennai.

References

Dolan, R., Fenster, M.S., Holme, S.J., 1991. Temporal analysis of shoreline recession and accretion. J. Coast. Res.

Douglas, B.C., Crowell, M., 2000. Long-term shoreline position prediction and error propagation. J. Coast. Res.

Dube, S.K., Jain, I., Rao, A.D., Murty, T.S., 2009. Storm surge modelling for the Bay of Bengal and Arabian Sea, in: Natural Hazards. https://doi.org/10.1007/s11069-009-9397-9

Dusen, C. Van, 1979. Vector Based Shoreline Change Analysis. Analysis.

Fenster, M.S., Dolan, R., Elder, J.F., 1993. A new method for predicting shoreline positions from historical data. J. Coast. Res.

Frouin, R., Schwindling, M., Deschamps, P.Y., 1996. Spectral reflectance of sea foam in the visible and near-infrared: In situ measurements and remote sensing implications. J. Geophys. Res. Ocean. https://doi.org/10.1029/96JC00629

Ivins, E.R., Rignot, E., Wu, X., James, T.S., Casassa, G., 2005. Ice mass balance and antarctic gravity change: Satellite and terrestrial perspectives, in: Earth Observation with CHAMP: Results from Three Years in Orbit. https://doi.org/10.1007/3-540-26800-6_1

Kankara, R.S., Chenthamil Selvan, S., Rajan, B., Arockiaraj, S., 2014. An adaptive approach to monitor the shoreline changes in ICZM framework: A case study of Chennai coast. Indian J. Geo-Marine Sci.

Khan, M.S., Das, J., Kabir, M.H., 2019. Monitoring Coastline Changes in the Coastal Belt of Chittagong in Bangladesh Using GIS and Remote Sensing. Asian J. Geogr. Res. https://doi.org/10.9734/ajgr/2019/v2i330087

Larour, E., Ivins, E.R., Adhikari, S., 2017. Should coastal planners have concern over where land ice is melting? Sci. Adv. https://doi.org/10.1126/sciadv.1700537

Maiti, S., Bhattacharya, A.K., 2009. Shoreline change analysis and its application to prediction: A remote sensing and statistics based approach. Mar. Geol. https://doi.org/10.1016/j.margeo.2008.10.006

Mason, D.C., Davenport, I.J., Flather, R.A., Gurney, C., Robinson, G.J., Smith, J.A., 2001. A sensitivity analysis of the waterline method of constructing a digital elevation model for intertidal areas in ERS SAR scene of Eastern England. Estuar. Coast. Shelf Sci.

https://doi.org/10.1006/ecss.2000.0789

Murty, T.S., Flather, R.A., 1994. Impact of Storm Surges in the Bay of Bengal. J. Coast. Res.

Murty, T.S., Flather, R.A., Henry, R.F., 1986. The storm surge problem in the bay of Bengal. Prog. Oceanogr. https://doi.org/10.1016/0079-6611(86)90039-X

Nayak, S.R., Sahai, B., 1985. Coastal morphology: A case study of the gulf of Khambhat (Cambay). Int. J. Remote Sens. https://doi.org/10.1080/01431168508948478

Paulik, R., Stephens, S.A., Bell, R.G., Wadhwa, S., Popovich, B., 2020. National-scale built-environment exposure to 100-year extreme sea levels and sea-level rise. Sustain. https://doi.org/10.3390/su12041513

Riyaz Khan N H & Subash Thanappan, 2020. Shoreline Change Analysis along the Chennai Coast: Digital Shoreline Analysis System. J. Xidian Univ. https://doi.org/10.37896/jxu14.11/034

Tong, S.S., Deroin, J.P., Pham, T.L., 2020. An optimal waterline approach for studying tidal flat morphological changes using remote sensing data: A case of the northern coast of Vietnam. Estuar. Coast. Shelf Sci. https://doi.org/10.1016/j.ecss.2020.106613

Wbgu, 2010. Climate Policy Post-Copenhagen: A three-level strategy for success. AIDS policy law.

Wigley, T.M.L., Raper, S.C.B., 1992. Implications for climate and sea level of revised IPCC emissions scenarios. Nature. https://doi.org/10.1038/357293a0