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Geospatial Based Study to Predict Future Shoreline Positions from Historical Data for a Part of Palk Bay Coast, South India

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***Abstract:** The coastal zone has been receiving the tremendous attention of the geoscientific community worldwide, as 70 percent of global population, over two-third of world's mega cities, huge industrial complexes, major economic zones, etc., are concentrated along the global coast. Developing and most populated country like India changes along the shoreline and coastal environment due to the coastal process are the direct impact coastal economic development and land management (Welch et al. 1992; Stokkom et al. 1993). Hence, the present study has focused on studying the shoreline modification of 43 years of periods between 1972 and 2015. For attempting of this unique freely available software Digital Shoreline Analysis System (DSAS) is used which works within the Environmental Systems Research Institute (ESRI) Geographic Information System (ArcGIS) software (Ref). The rate of shoreline change statistics for 43 years of duration between 1972 to 2015 has been calculated using LRR model. In addition, using EPR model to predict future shoreline positions in Palk Bay. Thus the present study has been calculated from chronological observations of different satellite data and disastrous impacts of tsunami and storm have not been taken into consideration (Mukhopadhyay et al. 2012; Fenster et al. 1993).*

***Keywords:** Shoreline, Erosion, Accretion, DSAS, LRR, Tondi, Protruding Delta.*

I. INTRODUCTION

The shoreline is defined as the line of intersection between the land and water body. Accurate detection and frequent monitoring of shorelines are very essential to understand the coastal processes and dynamics of various coastal features. Sandy beaches have some natural character that changes shape constantly [1]. Those movements can cause landward (retreat) or seaward (advance). The changes are caused by changes in the forces that move the sand, wind, waves, and currents, and by the supply of sand. Short and long-term relative sea-level changes also control shoreline movement [1]. The Geomorphic Processes of erosion and sedimentation, periodic storms, flooding and sea level changes continuously modify shoreline [2]. The developmental and human-induced activities can also bring changes in coastal zones. Remote sensing satellite images have been effectively used for monitoring shoreline changes in different parts of India [3], [4]. A well-defined concave coast at Manamelkudi, the absence of beach ridges and increased tidal activity, along with the growth of mangroves during the past 50–60 years on the Manamelkudi coast [5].

II. STUDY AREA

The study area includes an unconsolidated coastal stretch from Tondi to Rajaratnam that are located in three districts namely Ramanathapuram, Pudukkottai, and Tanjore. The study covers a coastal length of about 89 km, occupying an area of 1550.1 sq.km, stretching between 9°44'24"N & 10°32'24"N Latitude and 78°45'36"E & 79°22'48"E Longitude that falls in SoI with topographic sheet nos 58J/16; 58K/13; 58K/14; 58N/3; 58N/4; 58N/6; 58N/7; 58N/8;58O/1 and 58O/2 (Fig. 1).

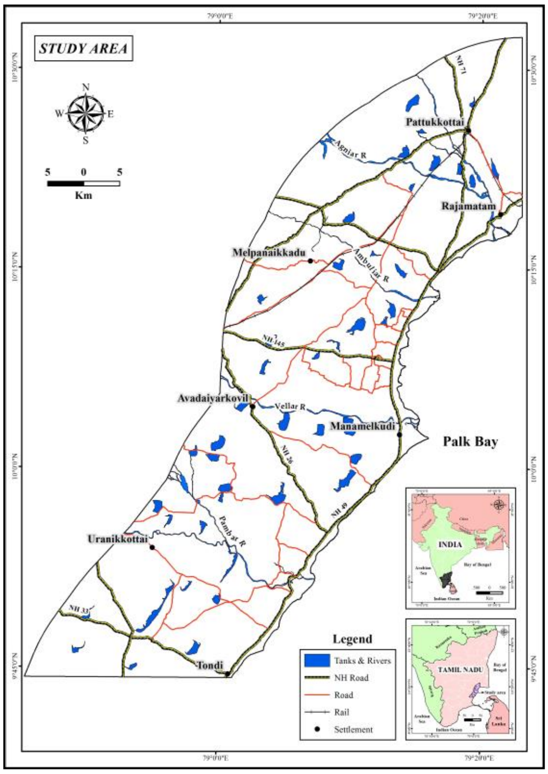


Fig.1 Study area

III.DATA PROCESSING

The different temporal data were used to map the shoreline changes over a 43-year time period (1972-2015). For the present study, freely available Landsat series of satellite data sets were obtained from USGS and Survey of India toposheets are used for different periods of shoreline boundary. All the data sets are projected in UTM projection with zone no 44 and WGS 84 datum. A reference line has been considered as baseline and images of 1972, 1981, 1991, 2001, 2010 and 2015 have been co-registered using first-order polynomial model.

IV.SHORELINE DELINEATION

In reality, the shoreline is not easy to identify and delineate because of its dynamic nature and presence of water saturated zone at the land-water boundary (Ryu et al., 2002; Maiti and Bhattacharya, 2009). In order to delineate the actual shoreline position, Image processing techniques such as Band ratio between the NIR and Green bands were used to identify the water-land boundary and the pixels signifying the shoreline has been converted into vector layer by digitized using Arc Map 10.2 to get the real shoreline position of different periods of time. The digitized shoreline for the years 1972, 1981, 1991, 2000, 2010 and 2015 in the vector format was used as the input to the Digital Shoreline Analysis System (DSAS) to calculate the rate of shoreline change. The inputs required for this tool are shoreline in the vector format, date of each vector layer and transect distance. The rate of shoreline change is calculated for the entire study area in 1 meter of transects distance and transect lines were generally divided into two sectors; Northern part and Southern part. These sectors are further divided into 3 grids each and thus totally 6 grids cover the entire study area.

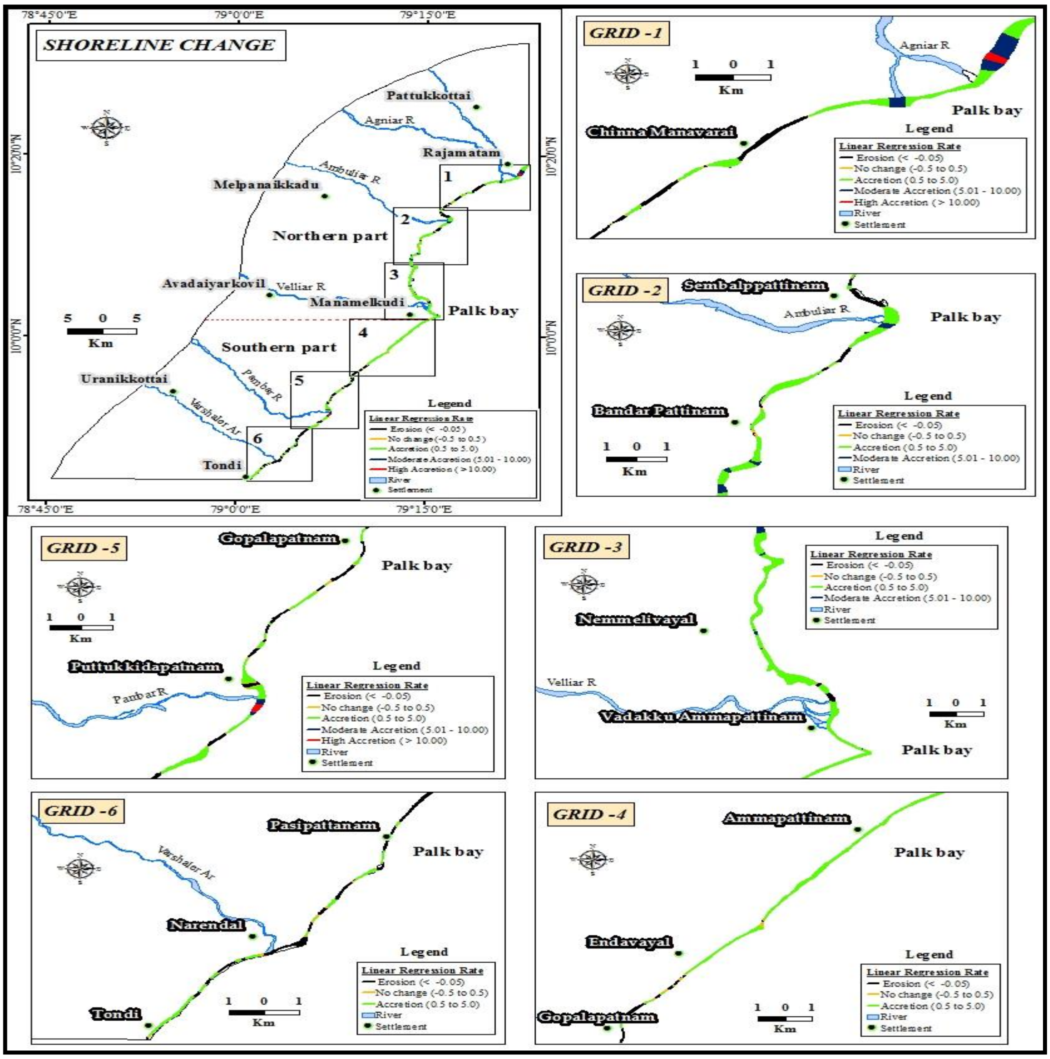
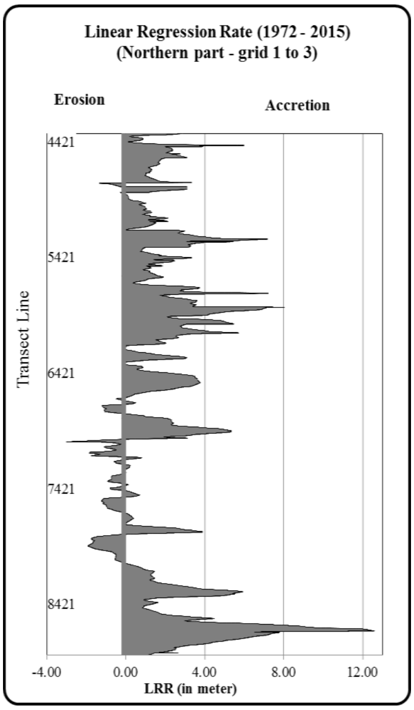


Fig.3 Shoreline modification a. Northern part and b. Southern part

V. SHORELINE MODIFICATION (1972 – 2015)

The present study adopted the statistical method 'Linear Regression Rate' (LRR) to calculate the shoreline change rate using DSAS. The major E-W fault along Manamelkudi divides the study area into the Northern part and Southern part (Fig. 2). For the Northern part (Grid 1 to 3) rate of change was measured along 51.55 km of shoreline length and observed both Erosion and Accretion, but 71 % of the transects are shown accretion because the dominant wave action with large amount of sediments derived through rivers and littoral currents make the beaches as the most dynamic landforms of the study area (Fig. 3a). The severe accretions are observed in Kilathotam (12.59m), Kuppattevon (8.05m) and Kattumavadi (7.23m). During the same period, high rate of erosion was observed in the coastal areas namely Sembalppattinam (3.00m), Chinna Monavarai (1.92m) and Vadakku Ammapattinam (1.34m). In the Southern part (Grid 4 to 6) of the study area that covers the coastal stretch with 45.57 km length and 4420 of 1-meter interval transect are covered along the coastal stretch extends from Tondi in the south to Manamelkudi in the north. Significantly, in this area, 2677 transects have shown accretions and 1725 transects have shown erosion along the study area (Table. 1). The maximum accretions are seen at Puttukkidapapatnam (11.19m), Sundarapandiyanpattanam (2.87m) and Jagadapatnam (2.08m). Also, Erosions are observed in Mutturamalingapattinam (2.48m), Tittandanam (1.30m) and Sengaipillaimadam (1.22m) around a narrow stretch of beach are observed in those areas. The main causes of coastal erosion along this coast were the strong tidal currents accompanied by wave action and reduced in sediment input from the river (Fig.3b). The concave shoreline of the Fig. 2 Shoreline modification (LRR) northern part has more accretion compare to the southern part.



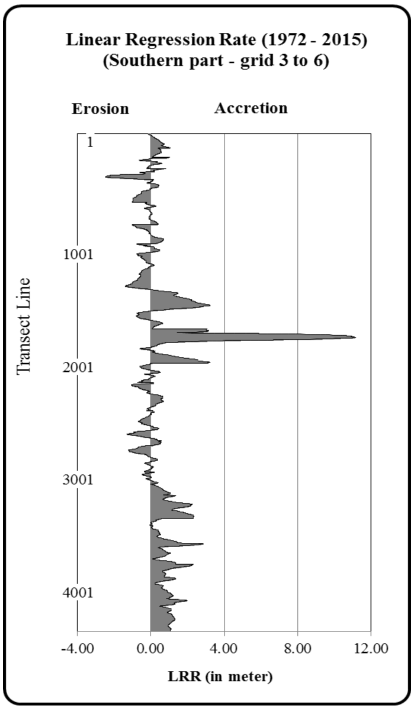


Table. 1 Results of shoreline change Northern and Southern sector using LRR (1972 - 2015)

	Northern Sector (Grid 1 to 3)	**Southern Sector (Grid 4 to 6)**	**Total**
Total Number of Transect	4512	4420	8932
Shoreline length (km)	51.73	45.57	97.30
Mean shoreline change rate (m/yr)	2.46	0.53	1.51
Mean erosion rate (m/yr)	1.03 (Maximum 12.59m)	0.71 (Maximum 11.19m)	0.82 (Maximum 12.59m)
Mean accretion rate (m/yr)	3.36 (Maximum 03.00m)	1.33 (Maximum 02.48m)	1.77 (Maximum 03.00m)
Shoreline Change Rate (Minimum)	-4.32	-3.23	-4.32
Shoreline Change Rate (Maximum)	12.23	10.04	12.23
Total transect that record erosion	916	1725	2641
Total transect that record accretion	3588	2677	6255
Total transect that record in neutral	8	18	26
Zone wise overall Trend	Accretion	Accretion	Accretion

VI. VALIDATION OF EPR MODEL

For prediction of future shoreline position along the coastal area of the study area, the End Point Rate (EPR) model has been used (Mukhopadhyay et al., 2012). But before the prediction of future shoreline, the model has been validated with the present scenario. The rate of shoreline movement calculated from shoreline position in 1972 and 2010 was applied and based on this; the estimated shoreline of 2015 was calculated. The estimated shoreline was compared with the actual shoreline delineated from satellite imagery of 2015. The model error or positional shift is very high in Chinnamanvarai and Tondi region. In Chinnamanvarai region, accretion is more and in Tondi erosion percentage is more during these periods compare to earlier (Fig. 4).

The positional error varies from -131.11m to 482.50m. It has been found that model prediction error is higher along the river nose. The overall error for the entire predicted shoreline was found to be 51.34 m (RMSE).

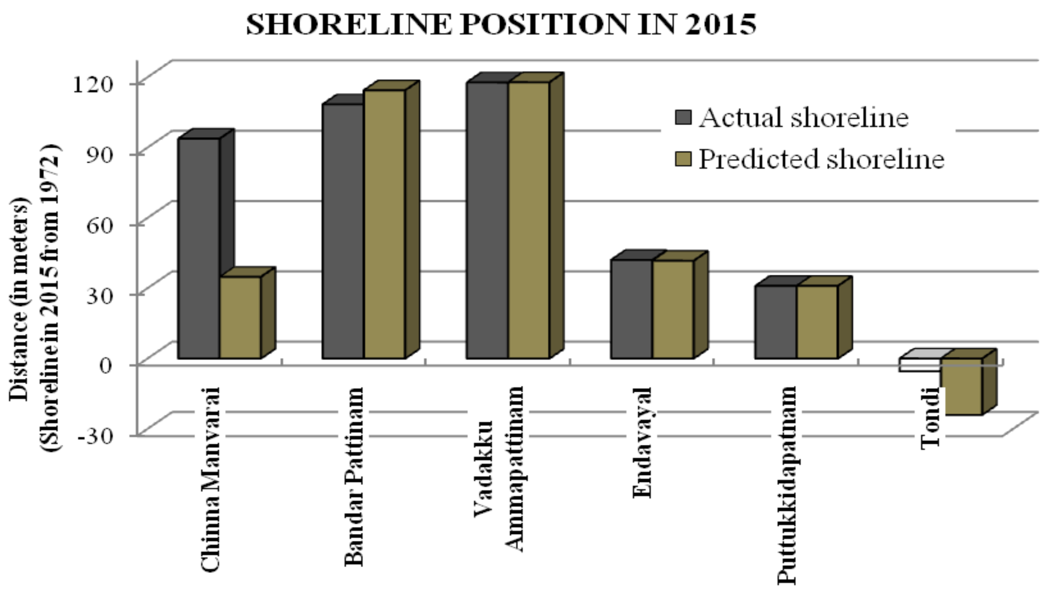


Fig. 4 Validation of EPR Model

VII. FUTURE SHORELINE PREDICTION USING EPR MODEL

EPR model has been used to predict the shoreline position in 2020, 2050 and 2100 along the study area (Table.2). In this prediction, shoreline change rate has been computed from historical observations and catastrophic impacts of tsunami and storm have not been considered. Shoreline boundaries of different periods are mapped using time periods of satellite data (Fig. 5). The predicted shoreline indicates that the maximum accretion of 340.61 m in 2100 will take place in the Bandar Pattinam region and the maximum erosion of 71.48 m in Tondi region. Overall the average shoreline shift will be 152.94 m in 2100. The modification of shoreline during the periods between 1972 and 2015 was observed the same (Fig. 5). This suggests that the cumulative effect of various processes like sediment transport system, littoral process, which is captured in the observed rate of change is relevant to predict the future shoreline positions. This suggests that the predicted shorelines were relevant to cumulative effect of various processes like sediment transport system, littoral current movement…etc.

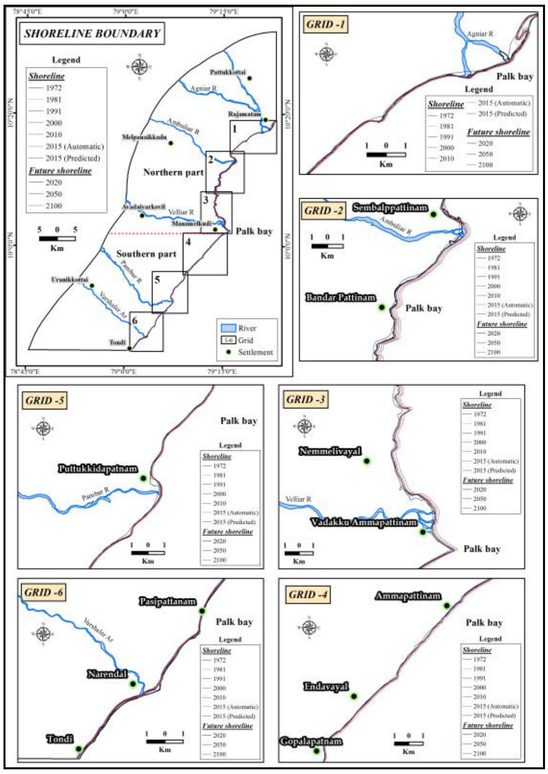


Fig. 5 Shoreline boundary

Table.2 DSAS transect and future shoreline position (2020, 2050 and 2100)

Grid No	Coastal Zone		DSAS Transect Numbers	Coastal Length (in km)	Shoreline in 2010 (From 1972) (in meters)	Actual Shoreline 2015 (From 1972) (in meters)	Predicted Shoreline 2015 (2010 + (EPR*5)) (in meters)	Shoreline 2020 (2010 + (EPR*10)) (in meters)	Shoreline 2050 (2010 + (EPR*40)) (in meters)	Shoreline 2100 (2010 + (EPR*90)) (in meters)
1	Northern part	Chinna Manvarai	7267 to 8932	18.46	30.79	93.80	34.84	38.89	63.20	103.71
2		Bandar Pattinam	5889 to 7266	16.40	101.12	108.42	114.42	127.73	207.36	340.61
3		Vadakku Ammapattinam	4421 to 5888	16.87	104.14	117.79	117.84	131.54	213.75	305.78
4	Southern part	Endavayal	2802 to 4420	17.18	36.86	42.06	41.71	46.56	75.65	124.15
5		Puttukkidapatnam	1472 to 2801	14.40	27.38	30.98	30.98	34.58	56.19	92.22
6		Tondi	1 to 1471	13.99	-21.22	-5.39	-24.01	-26.81	-43.56	-71.48
Total			1 to 8932	97.30	45.40	64.73	51.38	57.35	93.20	152.94

CONCLUSION

The present study has revealed that satellite data has the unique capability to detect the changes and monitor the shore line for long term periods between1972 to 2015 (43 years). The Northern part has more accretion takes place due to the major rivers and littoral currents also develop protruding deltas along the rivers nose of major rivers Agnar, Ambuliar and vellar rivers. While southern part Tondi and Pudukudipattinam due to the subsiding coast they were must subject to severe erosional activities. The study reveals most of this study area confined with accretion activities. EPR model has been validated with an available shoreline boundaries of 2010 and 2015 which are extracted from temporal data of the study area. Using this validated model future shoreline positions were mapped.

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