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ISSN: 2348 - 5612 | Volume: 04 Issue: 01 | January – March 2017

Spatial-temporal Analysis of Shoreline Change and sea level rise along Krishna delta, India,

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Abstract

Due to global warming, sea level rise and its impact on shoreline became a burning issue in all over world especially low laying coast like Maldives and East Indian coast.There are number of reports and studies on sea level rise and its impact on shoreline changes. Shoreline is highly productive and most dynamic zone because of interference of three processes namely terrestrial, atmospheric and marine, acting on the earth surface.Due to this it's becoming an area of development like rapid urbanization and industrialization in the world. This is also an area which is very sensitive to sea level rise along coast. So as level of sea is increasing, the population of the coast becoming very Vulnerability to natural phenomena. So analysisof shoreline changes and relation with sea level rise becomes very important due to its importance in the coastal management and planning program in all over the world. Therefore, the present studyis focusing on the effect of sea level change on shoreline position alongAndhra coast. Because Shoreline change study helps to understand provides useful data on predicting the future trend which is useful in further planning.

ISSN : 2348-5612 © URR

Keywords: Sea Level Rise, shoreline, remote sensing and GIS, EPR, NSM

Introduction

Shoreline is a dynamic linear feature between land and sea. It is very sensitive to physical process like sea level rise; wave direction speed, current,tidal flooding etc. as well as anthropogenic process. These changes occur long and short terms and involve hydrodynamic, geomorphic, tectonic and climatic forces (McBride et al., 1995; Thom and Cowell, 2005). These days, Coastal erosion is a chronic problem and is often thought of as inevitable along most open shores of the country. Shoreline and coastal processes are not restricted by administrative boarders and constantly change in response to wind, waves tides, sea level fluctuation, seasonal and climatic variation, human alteration, and other factors that influence the movement of sand and material within a shoreline system. The loss and gain of economically, ecologically and culturally valuable land is visible result of the way shorelines are reshaped in the face of these dynamic conditions. Although the impacts of climate change may not be the largest itself, they become serious threats when coupled with anthropogenic impacts. So the study of shoreline position became an important for the planner in the context of the coastal management and estimation of regional scale sediment budgets etc.

There are many processes which affect the shoreline dynamics over time viz. sea level, human interventions, storms etc. But sea shore is most sensitive to sea level change. In the present world due to the hype of global warming there is a general tendency comes that shoreline fluctuate in response to sea level fluctuation. Pritam Chand and Prasenjit Acharya, 2010 find out that Mean Sea Level height was in an increasing trend during same time span when shoreline experience high magnitude of shifting along the coast of Bhitarkanika Wildlife Sanctuary, Orissa.

According to Unnikrishnan et al;(2006) sea levels are increasing along the east coast of India too. Studies based on the analysis of long-term tide gauge data from various stations along the Indian coastal regions, corrections for vertical land movements included, indicated that sea levels are rising at a rate of about 1.0 – 1.75 mm per year due to globalwarming. Pronounced erosion even along certain majordepocentres like deltas of the east coast of India although wasmainly attributed to anthropogenic forcing (Baskaran, 2004;Hema Malini and Nageswara Rao, 2004; Nageswara Rao et al.,2008), perhaps reflect the impact of eustatic sea-level rise as well.

Apart from that, there are number of reports and studies on sea level rise and its impact on shoreline changes. Therefore, the present study is focusing on the effect of sea level change on shoreline position along Andhra coast. Because Shoreline change study helps to understand provides useful data on predicting the future trend which is useful in further planning.

The general morphology of the coast reflects a complex and dynamic interaction between the physical processes (waves and tidal currents) that act on the coast, the availability of sediment transported by waves and tidal currents, the local geology, and changes in sea level (Carter and Woodroffe, 1994). Variations in these factors from one coastal region to the next are responsible for the different coastal landforms, such as beaches, barrier islands, and coastal cliffs that are observed along the coast today. Based on knowledge developed from studying the geologic record, the scope and general nature of the changes that can occur in response to sea-level rise are well established (Curray,1964; Carter and Woodroffe, 1994; FitzGerald et al. 2008).

In the last two decades, remote sensing and geographical information system (GIS) techniques have been widely employed in various coastal morphodynamic studies as The applications of remote sensing and GIS have proved particularly effective in delineation of coastal configuration and coastal landforms,detection of shoreline positions, estimation of shoreline and landform changes, extraction of shallow water bathymetry (Jantunen and Raitala, 1984; Singh, 1989; White and El Asmar, 1999; Lafon et al., 2002; Ryu et al., 2002; Siddiquiand Maajid, 2004; Yamano et al., 2006; and Maiti and Bhattacharya, 2009).

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Study area

The study area occupies the coast a long Krishna - Delta zone, Andhra Pradesh which is the part of eastern coast. It is a passive continental margin developed during separation of India from Antarctica in the Late Jurassic (Bastia and Nayak. 2006). The total shoreline length of this of the length of this delta coast is 140 Km . According to Nageswara Rao et al., (2008), this region is in under low energy marine environment with microtidal where spring tide range is <1.5m and low to moderate wave condition which is have about<2m height. This area is under the influence of semi-arid climate with temperatures ranging between 22°C in January and >35°C in April. This region gets the average annual rainfall about 970mm.

The coastline of Krishna delta mainly the deltaic coast is comprised of bays, creek, extensive tidal mudflats, spits, bars, mangrove swamp, marshes ridges and coastal alluvial plains.

The area has remained as most vulnerable coastal zone since it faces cyclones of different intensity frequently, tsunami and associated floods and tidal surges causing loss of land, life and property in the region. In addition to this, the future sea level rise, urbanization, settlement expansion, construction of artificial structures, reclamation of wetlands and such others also contribute to this. Salt-water intrusion into the agricultural lands due to flooding creates problem to the coastal agricultural population.

Apart from that massive infrastructural development associated with population growth in future will cause the coastal zone under increasing pressure and result in shoreline erosion, degradation of coastal ecosystems and diminishing the coastal resources. Excessive exploitation of resources will make communities vulnerable to sea storms and other Ecological disasters.

Thus in this background, shoreline assessment along Krishna delta coast is made in this study aimed at identifying pattern of shoreline changes over the period along different coastal segments because of coastal planning and management.

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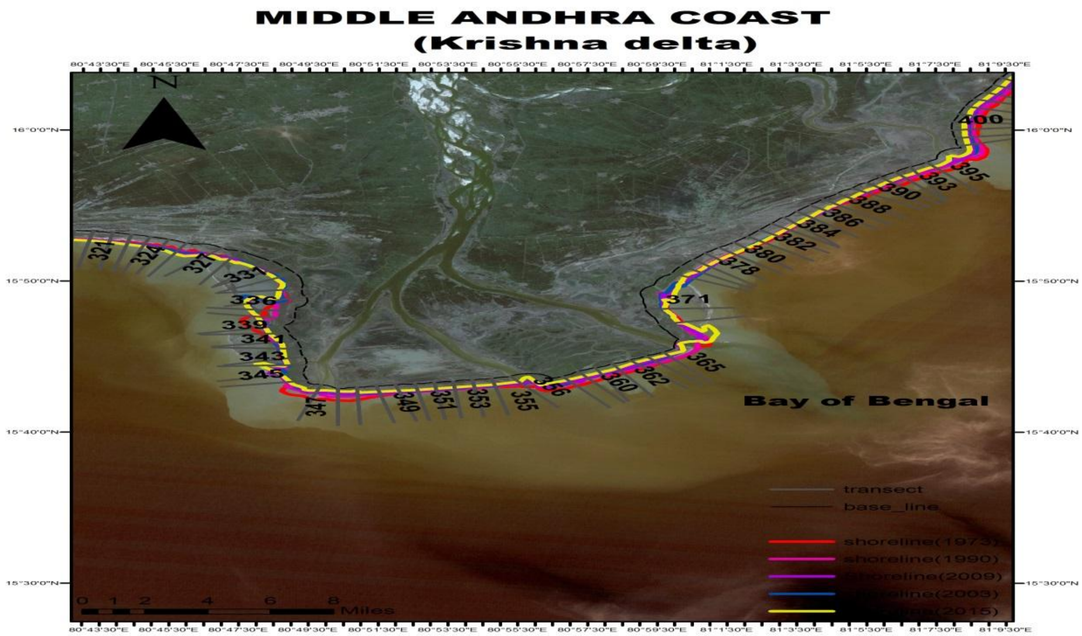

Krishna delta

Data

For this study, Multiresolution satellite data of Landsat for the time period of 1973, 1990, 2003, 2009, 2015 and average monthly/Annual mean value of sea level data for nearby two station one is Chennai and another one is Vishakhapattanum has been taken from the database of the Permanent service for Mean sea level (PSMAL). For the shoreline change analysis, ERDAS, ARCGIS and DSAS (Digital shoreline analysis system) have been used**.**

9.4 Methodology

For the shoreline mapping, we have followed following method which is given in fig.2

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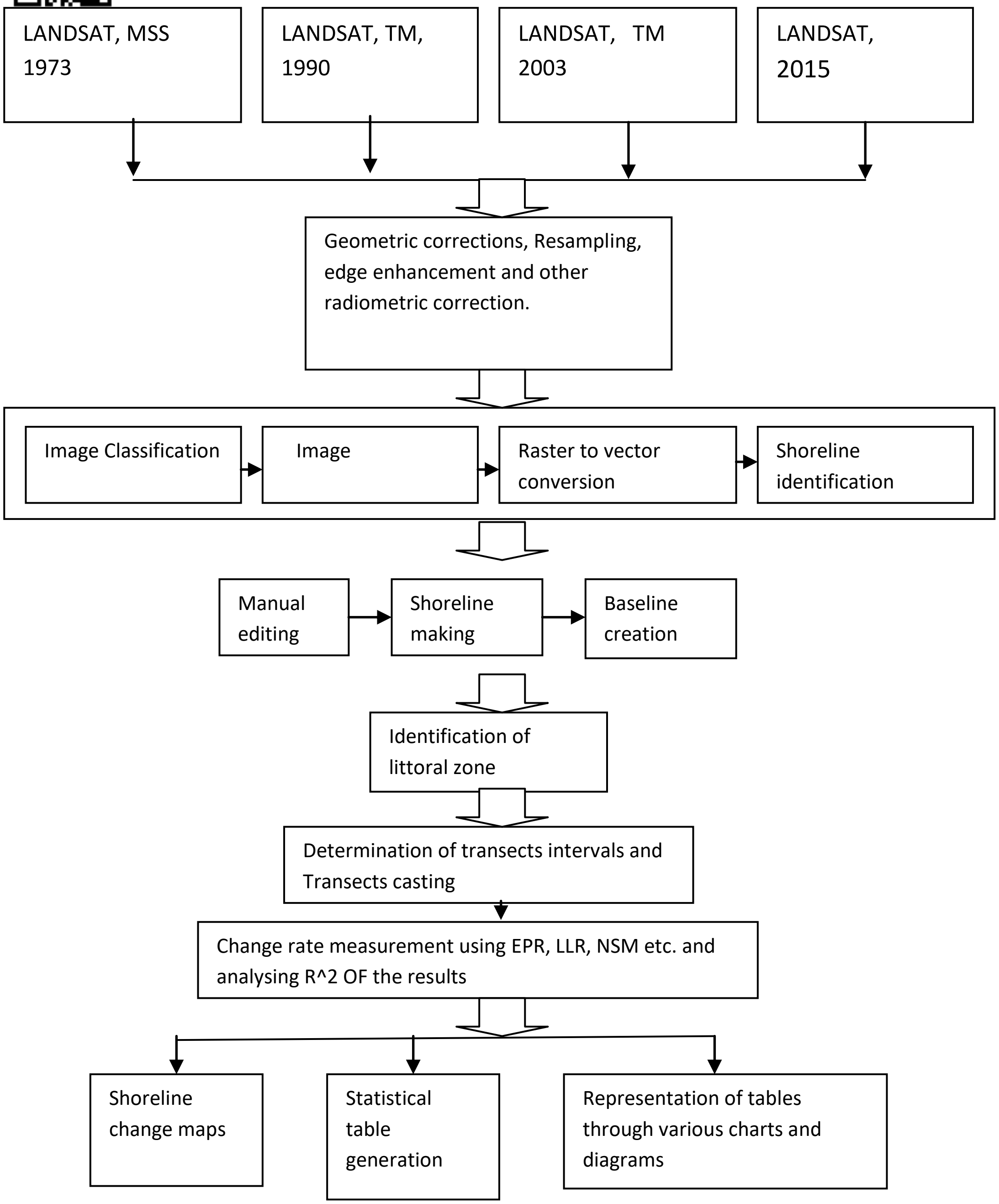


Calculation of Rate of Shoreline Shift

To measure the amount of shoreline shift, it has been measured by quantifying the amount of shoreline shift along transects from baseline. This procedure involved the establishment of the baseline in the direction of general orientation of shoreline and transects established perpendicular to baseline in the desired spacingby using DSAS.DSAS is an extension of ArcGIS software developed by USGS. This extension contains three main components that define a baseline, generate orthogonal transects at a user defined separation along the coast, and calculate rates of change (linear regression, endpoint rate, jackknife, net shoreline movement etc.).

For this study, Transects perpendicular to the shoreline have been draw at the interval of 1000 m. and baseline created at 2000 m distance from the shoreline derived from 1990s Landsat data has been taken as reference line. Movement of all shoreline over the period 1973-2015 has been detected in reference to the baseline which is casted on onshore direction. In this context there are the 326 to 415 transect along the coast. The movement of shoreline with respect to the baseline is considered erosion where it is move toward land at each transects and statistical value have been denoted as negative and accretion where it is move seaward at each transects and show through positive sign.

The first step in the analysis quantified changes and change rate for each period of observation. Change rate has been calculated by using End Point Rate (EPR) (Crowell *et al.* 1997) and net changes by the net shoreline movement. The end point rate has been calculated by dividing the distance of shoreline movement by the time elapsed between the earliest and latest measurements (i.e., the oldest and the most recent shoreline). The major advantages of the EPR are the ease of computation and minimal requirement of only two shoreline dates. The major disadvantage is that in cases where more data are available, the additional information is ignored. Net shoreline movement is distance between youngest and oldest shoreline.

EPR = Distance between youngest and oldest shoreline/ Time between the oldest and youngest shoreline

NSM= Distance between youngest and oldest shoreline

The coefficient of determination (R^2) is a measure of goodness of fit of the equation to the present data.

Shoreline and Sea level Change

For showing the relation between shoreline and sea level change we have chosen correlation method. The correlation is defined as the measure of linear association between two variables.

Result

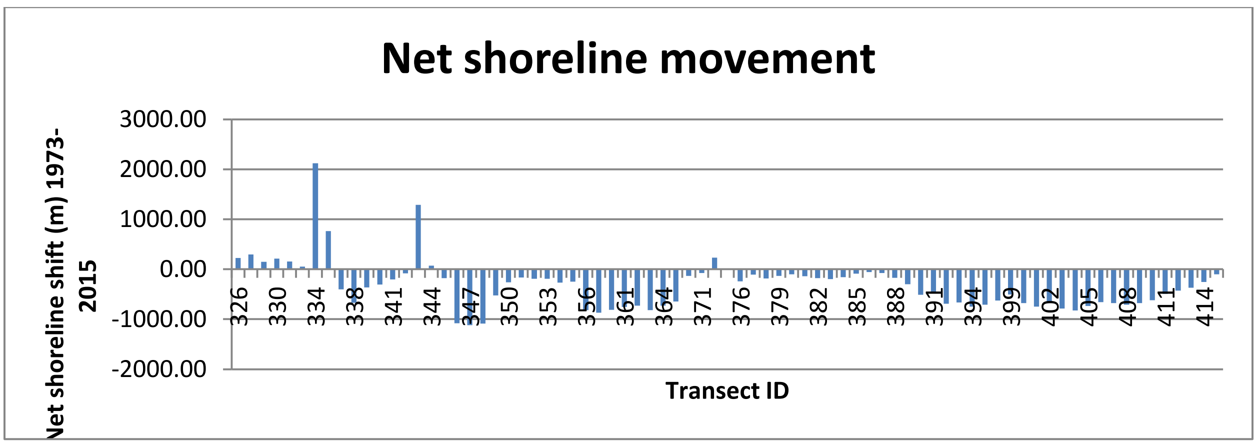
All statistical results derived from digital shoreline analysis system along the 140 km long shoreline for every transect has are presented through different figure and table and they are analyzed on perspective of major determining factors like exposure of shoreline, wind and wave action, slope of the beach, sediment supply and transport and anthropogenic factors like sand extraction, construction of seaport etc.

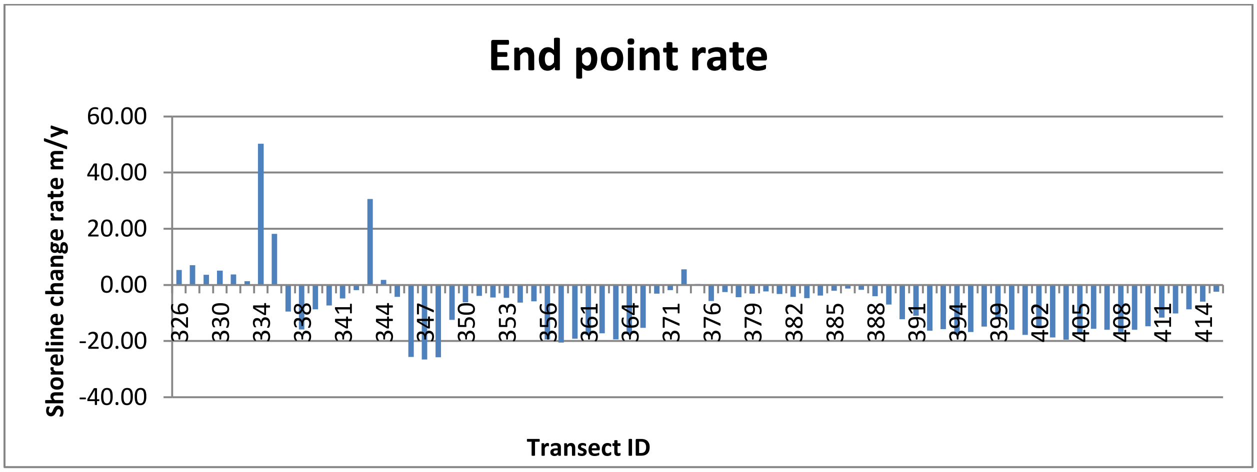
All transects except 326 to 329, 330, 331, 333, 334, 336, 343, 344, 373, and 375 along the shoreline under littoral cell-1 fall within erosion regime. Average erosion rate (which is represented by end point rate) of transects 326 to 415 varies between -26.60 to 50 meter per year which is along to transect 347 and 334 respectively. As the same, net shoreline movement during the time period of 1973 to 2015 along transect 326 to 415 varies between -1121.85 m. to 2119.92 along the same transect id. Data shows that the southern part of the Krishna river delta experience advancing shoreline along the transect id 326to 336, Where substantial amount of sediment load is been transferred by the river Krishna. Table 2. Summaries the shoreline change and change rate along each transect id

Transect ID	EPR	NSM	LRR	LR2	Transect ID	EPR	NSM	LRR
326	5.30	223.52	4.13	0.62	373	5.51	232.61	4.22
327	6.96	293.63	4.92	0.44	375	0.24	10.14	1.39
329	3.60	151.90	3.52	0.74	376	-5.69	-240.15	-1.58
330	5.07	213.78	4.75	0.75	377	-2.59	-109.31	0.63
331	3.74	157.78	2.85	0.26	378	-4.41	-186.07	-1.06
333	1.30	54.97	0.92	0.10	379	-3.15	-132.67	-0.39
334	50.26	2119.92	60.85	0.83	380	-2.32	-98.01	-0.95
336	18.16	765.96	25.76	0.55	381	-3.29	-138.78	-3.27
337	-9.50	-400.73	-0.97	0.00	382	-4.22	-178.15	-4.19
338	-15.89	-670.12	-15.81	0.73	383	-4.74	-199.95	-4.08
339	-8.65	-365.05	-7.89	0.69	384	-3.80	-160.22	-2.31
340	-7.33	-308.97	-5.65	0.71	385	-2.10	-88.46	-0.97
341	-4.83	-203.88	-3.77	0.43	386	-1.35	-56.86	-0.72
342	-1.87	-79.02	-1.65	0.57	387	-1.79	-75.70	-0.74
343	30.59	1290.39	22.43	0.45	388	-4.05	-170.74	-3.16
344	1.76	74.42	2.97	0.16	389	-7.04	-297.14	-6.58
345	-4.29	-180.89	-3.63	0.83	390	-12.18	-513.56	-11.44
346	-25.64	-1081.56	-22.91	0.86	391	-11.03	-465.27	-11.42
347	-26.60	-1121.85	-24.87	0.97	392	-16.31	-687.75	-15.55
348	-25.75	-1085.94	-23.47	0.96	393	-15.78	-665.66	-15.42
349	-12.42	-523.80	-11.91	0.99	394	-17.68	-745.83	-17.26
350	-6.21	-262.02	-5.92	0.82	395	-16.81	-708.94	-17.02
351	-3.92	-165.31	-3.59	0.50	398	-14.82	-625.12	-15.03
352	-4.47	-188.44	-4.04	0.63	399	-11.90	-502.03	-12.50
353	-4.58	-193.17	-4.33	0.62	400	-16.03	-676.05	-15.71
354	-6.31	-266.15	-6.44	0.95	401	-17.80	-750.59	-17.06
355	-5.88	-247.87	-6.06	0.81	402	-15.25	-643.39	-15.71

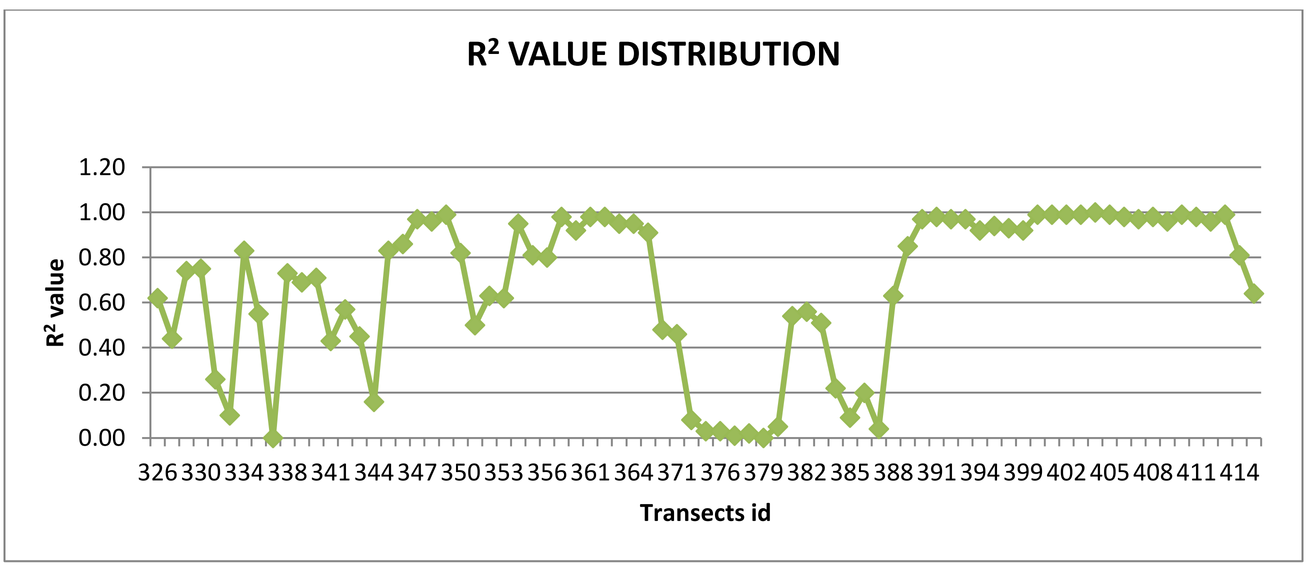
356	-19.35	-815.95	-16.61	0.80	403	-18.67	-787.28	-18.67
359	-20.60	-868.94	-20.20	0.98	404	-19.53	-823.70	-19.41
360	-19.19	-809.55	-17.18	0.92	405	-17.40	-734.01	-16.87
361	-17.92	-755.74	-17.09	0.98	406	-15.61	-658.20	-15.43
362	-17.25	-727.51	-16.08	0.98	407	-16.04	-676.34	-16.20
363	-19.41	-818.81	-18.14	0.95	408	-16.82	-709.58	-16.77
364	-17.33	-731.07	-17.07	0.95	409	-16.00	-674.67	-16.15
365	-15.31	-645.75	-16.23	0.91	410	-14.75	-622.18	-14.01
369	-3.11	-131.26	-3.43	0.48	411	-11.71	-494.03	-11.01
371	-1.82	-76.65	-2.59	0.46	412	-10.14	-427.82	-9.24

The average shoreline change rate (EPR), LRR and position (NSM) in the last 42 years (1973-2015) indicate that the sector are experienced Moderate erosion along the coast which are -6.06483871 m/y, -5.153870968 m/y and -255.7967742 m respectively. Maximum and minimum EPR and NSM are 50.26 m/y, -26.6 m/y, 2119.92 m and -1121.85 m/y respectively which is along the transect id 334 and 347. The estimated mean erosion rate was -10.1702 m/yr. NSM -428.9684 m and the estimated accretion rate was 11.04 m/yr. and average NSM is 465.75 m. The period between 1973 and 2015 shoreline change analysis revealed that 50 transects eroded and 12 transect accreted while the remaining show stability along the coast.





The coefficient of determination (R^2) is a measure of goodness of fit of the equation to the present data. The statistical significance is considered at the 80% level of confidence (instead of 95% confidence level) in view of small number of samples, as Suggested by Allanetal.(2003). The distribution of R^2 value for all transect line throughout the shoreline shows the distinctive distribution pattern. Transect 334-350, 354 to 359, 360 to 365 and 389 to 414 have the $R^2 > .8$ and rest of transect have the R^2 value < 0.80 based on R^2 e value entire shoreline is categorized into two zone . Zone 1 include transect 334 to 350, 354 to 359, 360 to 365 and 389 to 414 which show the higher degree of conformation with the observed position. Zone II includes transect 326 to 334, 351 to 353 and 369 to 388 which show lesser degree of conformation with observed shoreline position. This in fact emphasizes that the prediction of future shoreline position will be highly accurate for the transect line which have R^2 value (>.80) (Figure2).



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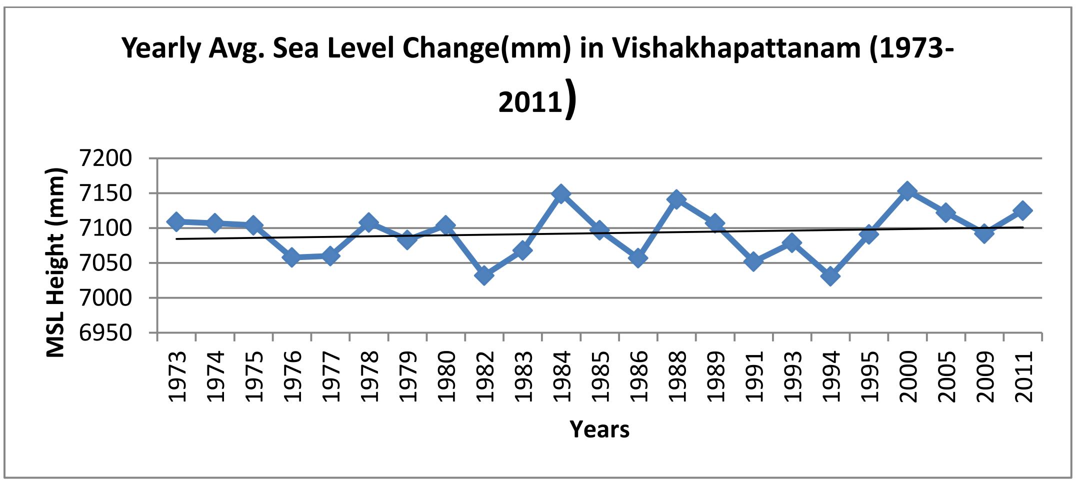
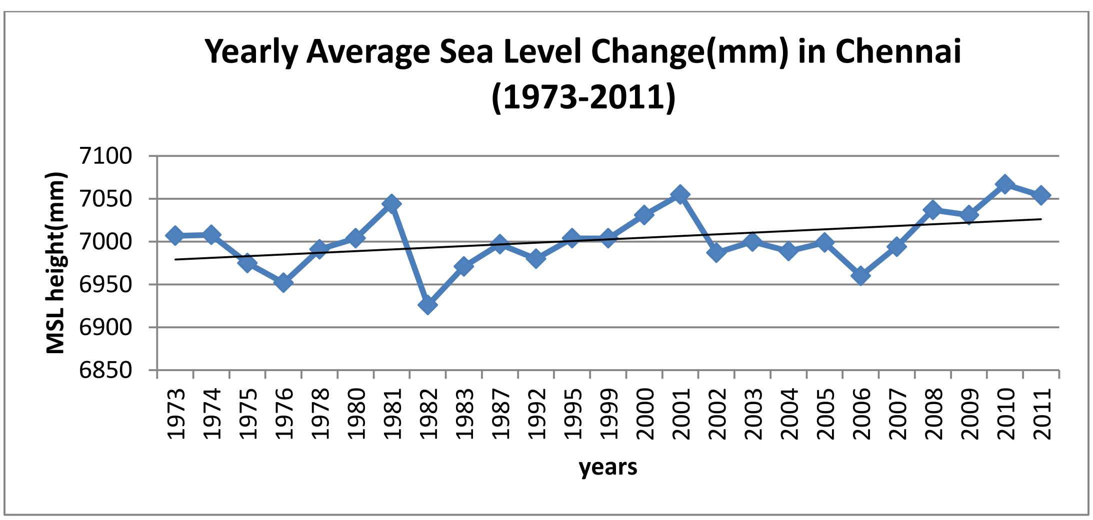
Sea level and shoreline change relation:

In order to assess the shoreline response to sea level change can be compared with the MSL data of the same year. For the comparison, get the average MSL of the both station and com. Average Shoreline shift also calculated for the each interval like 1973-190, 1990-2003 and 2003-2015 and the degree of association between MSL and Shoreline shift can well be displayed by "r" statics, show the value 0.31 which indicates a lower degree of relation between these two.

The graph shows that MSL height was in an increasing trend during the period of 1973-2011, which in fact that same time span when shoreline also experience high magnitude of shifting from its earlier position. But the correlation between the shoreline shift and sea level rise which is r = .31(weak relation) suggests the shift was more because of some other processes rather than SLR.



Yearly MSL along vishakhapattanum



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Yearly MSL along Chennai

YEAR	Avg. MSL(mt.)	Avg.	year	Avg. shoreline shift(mt.)	Avg.	r
1973	7.058		1973	0		
1987	7.049	7.064	1990	-206.12	-63.9492	0.317475
2003	7.061		2003	12.831		
2011	7.089		2015	-62.509		

Interactive relationship between sea level rise and shoreline change

Conclusion

Thus the study finds out that an extensive part of the shoreline is affected by the shore zone erosion during the time period except southern part of the Krishna River receives a substantial amount of sediment load from river. Apart from that the historic rates of shoreline change provide valuable data on erosion and accession trends which is helping in the prediction of future shoreline movement. For the interactive relationship between shoreline change and sea level rise the study find out that MSL and shoreline is in weak positive correlation in the time span. So sea level rise can be one factor for the shoreline shift but there are some other processes also are there like anthropogenic activity, storm surge etc. should be taken into account with the sea level change in order to study of shoreline behavior.

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