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Shoreline dynamics of Nagapattinam coast by natural intervening geomorphic system and artificial structures

Balasaraswathi, P & Srinivasalu S.

Institute for Ocean Management, Anna University, Chennai-25., India
[Email: balasaraswathi19@gmail.com]

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Shoreline changes are identified and analyzed using Geomatics techniques coupled with Digital shoreline analysis system (DSAS) for knowing the impacts on Nagapattinam coast. Shoreline change rates (m/yr) are estimated with respect to End point rate (EPR) and Linear regression rate (LRR) that depict considerable changes on the north and south side of intervening rivers and artificial structures on the adjacent shorelines (between 1991 and 2014). Present study explains the erosion observed at northern side of the Uppanaru river, Vettaru river and Seruthur river. Both erosion and accretion noticed on the northern side of the Vettaikaraniruppu river is discussed. This also indicates the drastic accretion noticed on northern side of the Karaikkal port and Nagapattinam port and examined the erosion at the southern side of both ports.

[Keywords: Shoreline dynamics, intervening geomorphic system, End point rate (EPR), Linear regression rate (LRR)]

Introduction

In many countries, the coastal erosions have predominantly occurred owing to natural and man-made factors(1-4),Coastal erosion is mainly influenced by the movement of river mouth and estuaries[5]. Severe erosion has occurred along the coast of Chennai, Vedaraniyam, Karaikkal due to the construction of port, harbors, groynes, seawall etc.[6] Shoreline change analysis in both long and short term changes were derived for Tamilnadu coast by several researchers viz.(7-12) Shoreline dynamics, in specific the threat of coastal erosion, is the main concern of both state and national level work. These works suggested a numerous compelling factors and identified mitigation measures. Despite these attempts, there is an absence of information from the intervening natural geomorphic systems and artificial structures as they affect coast and coastal environment. This work attempts on identification of the risks from the shoreline dynamics due to intervening systems and structures.

Hence, the analysis of shoreline dynamics for Tamilnadu coast along with considering the impacts of intervening ports and rivers will give an additional support for forthcoming ports, harbors and coastal related works. The behavior of rivers that includes the migration of rivers is also monitored. Protection of natural resources and artificial structures give important information to coastal planner and managers.(13-14)

Materials and Methods

The coastal stretch from Karaikkal port to Point Calimere is a Nagapattinam coast of Tamilnadu, India, and it extends approximately 73km (Lat: 10°51' 17" N, Long: 79°51' 07" E and between Lat: 10°16' 26" N, Long: 79°48' 28" E). This coastal stretch is comprised of adjoining rivers namely, Uppanaru river, Vettaikaraniruppu river, Seruthur river and Vettaruriver and also man-made intervening structures such as Karaikal and Nagapattinam port. Such, intervening systems and structures in this coastal stretch influence the shoreline dynamics. More details about the intervening structures and systems follows:

Nagapattinam coastal stretch comprises of number of rivers and two man-made structures connecting the Bay of Bengal. Erosion occurs in regions adjacent to the river mouths and artificial structures (Karaikal port and Nagapattinam port) along the Nagapattinam coast. Due to the migration of rivers and the presence of coastal structures, accretion occurs.

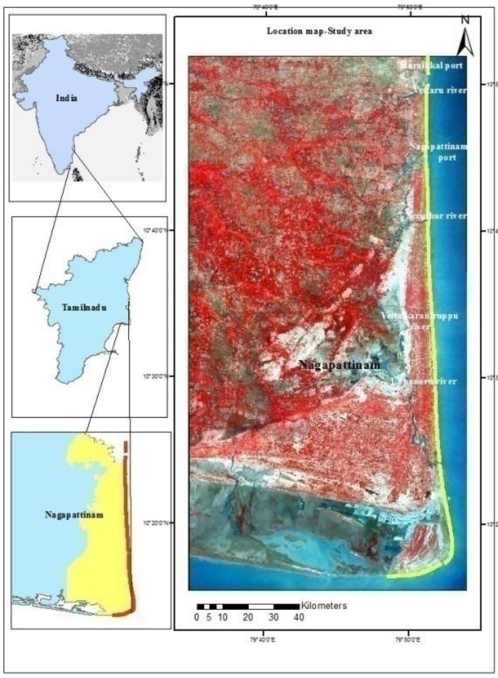

Fig. 1 Location of the study area in the map of Tamilnadu India with its intervening natural geomorphic system/man-made structures.

Region I – Karaikal port (Man-made structure): Karaikal port is one among the major ports in india. It started its operation since 2009. It is situated on eastern coast of india in Karaikal. It is around300km along the south coast of chennai port and its area extends nearly 2km which includes north and south side of breakwaters of Karaikal port.It was developed on the river banks between Pravadayanar and Vettaru rivers .

Region II – Vettaru river (Minor river): The Vettaru river flows into the Thiruvarur districts and it drains in Nagore. It lies nearer to the Karaikal port. The corresponding shoreline stretch is 1.7km.

Region III – Nagapattinam port (Man-made structure): It is one among the minor ports of Tamilnadu. It is located at the Kuduvayar river mouth of Nagapattinam district. It consists of two jetties. And its stretch is about 1.5km.

Region IV – Seruthur river (Minor river): It flows in Keelaiyur taluk in Nagapattinam district ofTamilnadu. It lies very nearer to the Shrine Velankanni temple. The corresponding shoreline length includes both the banks upto 1.8km.

Region V – Vettaikaraniruppu river (Minor river): It lies in between the Kovilpathu and Vizhunthamavadi villages. The shoreline length s about 1.6km is taken into consideration.

Region VI – Uppanaru river (Minor river): It lies in the southern side of Nagapattinam town which is connected to the Akkaraipettai village. It lies in the middle of the Vellapallam and Pushpavanam villages. The corresponding shoreline stretch is about 1.7km

A series of different Landsat sensor Thematic scanner(TM), Enhanced thematic scanner(ETM) and object linear imageries(OLI)imageries(15-20) for the years like 1991, 2000, 2010 and 2014 were adopted to calculate and analyze the influence of intervening geomorphic system and man-made structures on adjacent shorelines. The adjacent shoreline change rate was found out using the parameter like EPRand LRR(21-23) which were arrived with ArcGIS extension tool called DSAS.

The intensity value of those parameters were estimated on both the banks of every intervening structures along the shoreline. Those sensor images were changed to false colour composite(FCC) imagesthat gives the clear water and land boundary(24). Image geometric registration was done with the help of Ground Control Points (GCPs) using ERDAS IMAGINE software(25) .Finally it was projected in Universal tranverse mercator projection in a WGS84 reference datum respectively.From those imageries, the wet/dry line boundary of previous tides was delineated which easily gives the shoreline changes(26). It leads to digitize those shoreline bounday in ArcGIS 10.2.1 software by ordinary delineation techniques.

Two ways of dealing are taken up to estimate the impacts of intervening geomorphic systems/structures on shoreline dynamics i.e., EPR which are used for short term change studies (1991 to 2000; 2000 to 2010; 2010 to 2014) and both EPR and LRR are adopted for long term change studies (1991 to 2014).[27-28]

Results and Discussions

Impacts of natural geomorphic intervening Systems on adjacent shorelines

The impacts of rivers were calculated using DSAS tool by giving the aforesaid temporal shoreline layers as an input, that generated the 1458 transects. The Details of shoreline, transects and artificial structures that found and considered through the GIS analysis were furnished in the below table (Table.1).

Most of the remarkable changes were identified in the both banks of the intervening river/structures. The selection of number of transects was influenced by the width of the intervening structures and systems.

Table: 1. Parameter considered for the analysis

Year	1991	2000	2010	2014
Total length of shoreline stretch (km)	69.92	69.71	72.98	72.63
Number of Transect	1458	1458	1458	1458
Length of baseline (m)	2200	2200	2200	2200
Spacing of transects (m)	50	50	50	50
Length of breakwater in Karaikal port (in m)	N/A	N/A	484 (North side) 541 (south side)	948 (North side) 917 (South side)
Spacing between the breakwaters of Karaikal port (in m)	N/A	N/A	416	429
Length of Karaikal Port (km)	-	-	1.31	1.40
Length of jetty in Nagapattinam port (m)	N/A	N/A	217	180 (North side) 268 (South side)
Spacing between the jetties of Nagapattinam port (in m)	N/A	N/A	60	60

The shoreline change rate in both banks of four intervening rivers such as Uppanaru river, Vettaikaraniruppu river, Seruthur river and Vettaru river were calculated and illustrated in the following figures (fig. 2 a, b, c and d) and they show the change in plus (accretion) and minus (erosion) rate of the shoreline correspondingly.

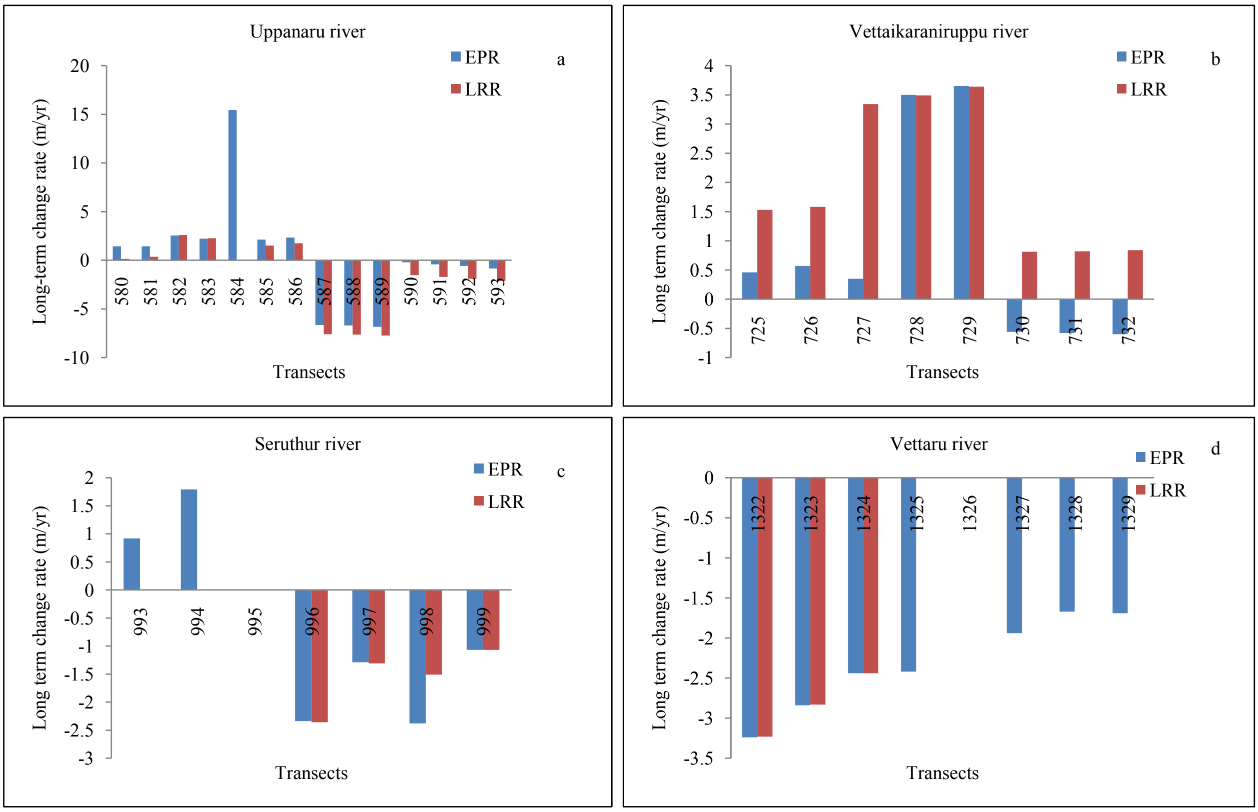

Fig. 2(a), (b), (c) and (d) depict the Long term change rate of shoreline for the intervening rivers

Figure 2a indicates the rate of change on north and south banks of Uppanaru river. The transects considered for this river from 580 (north bank) to 593(south bank).The northern portion (580 to 586) of this river undergone accretion and it experiences the erosion on the southern bank (587 to 593) of the Uppanaru River. The maximum EPR erosion and accretion value was -6.84 and +15.43 m/yr likewise the maximum LRR erosion and accretion value was estimated as -7.74 and 2.6m/yr. In figure 2b represents the shoreline changes of both banks of the Vettaikaraniruppu river. It experiences the accretion in the northern bank (725-729) with respect to the EPR and LRR parameters and undergoes low erosion were only erosion occurred in both banks with respect to EPR and LRR and the estimated maximum EPR erosion and LRR erosion value was -3.24m/yr and -3.23m/yr.

a) *Short term change studies:*

noticed in the southern bank (730-732) of the river. The calculated maximum EPR erosion and accretion range was -0.6 and 3.65m/yr. With respect to the LRR value, only low accretion was noted in south bank of the river. In case of Seruthur river (fig 2c), the erosion happened in the southern bank (from 996 to 999) and the maximum EPR erosion value was estimated as-2.38m/yr (minus value).The accretion occurred in the northern bank (993 to 994) of the river with respect to EPR parameter and accretion was estimated as 1.79m/yr. As per the LRR parameter is concerned, the southern bank was undergone only erosion. But for the Vettaruriver (fig.2d),

The short term change studies were carried out for the intervals such as 1991 to 2000, 2000 to 2010 and 2010 to 2014. The figure 3 a, b, c and d illustrate the short term change rate due to intervening geomorphic systems.

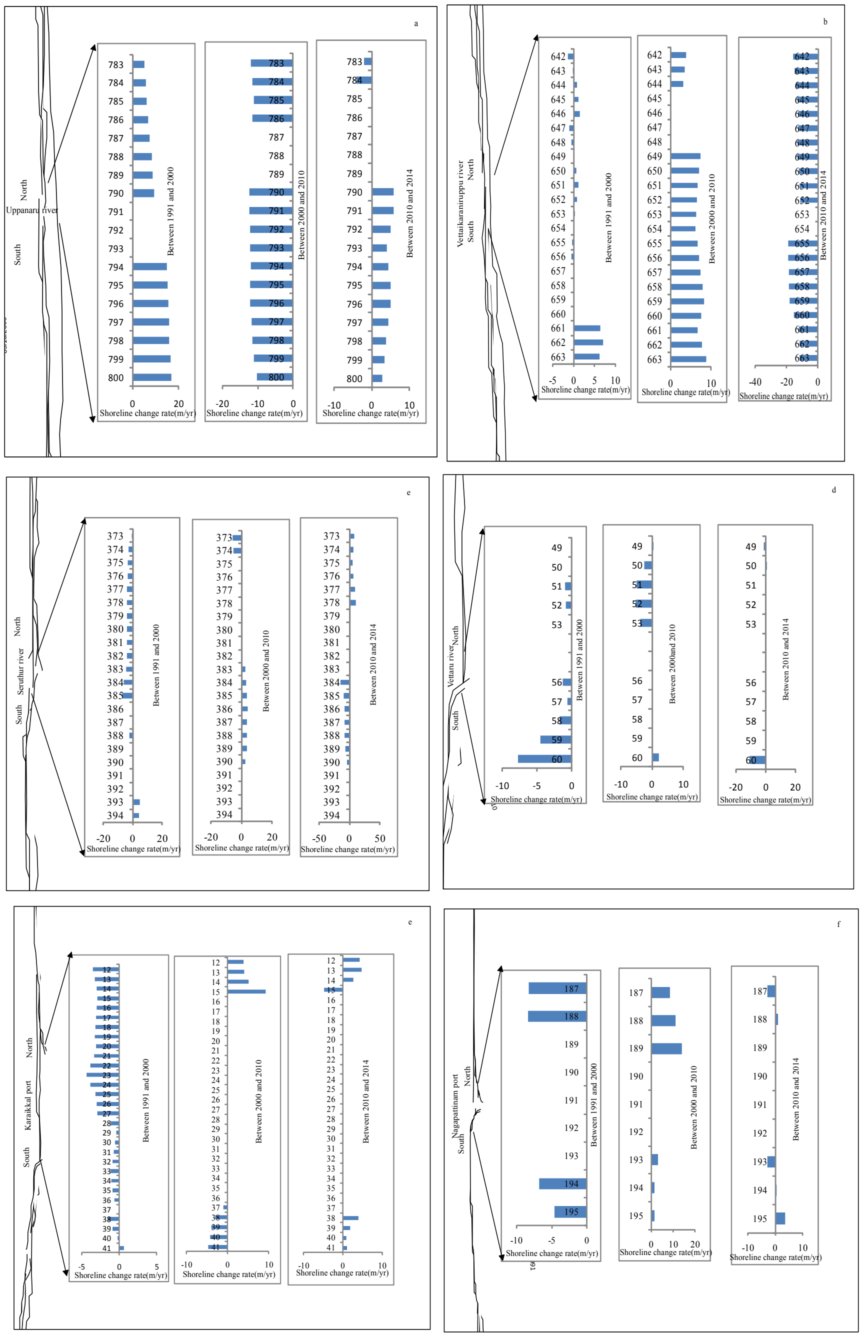

Fig. 3 a, b, c, d,e and f represents the intensity of EPR values at both banks of river/ports during 1991-2014

The shoreline change rate in both banks of Uppanaru river during the period of 1991-2000(fig.3a) displays remarkable accretion at both northern and southern banks of the Uppanaru river. It is also noticed that the river mouth has slightly moved about 107m towards south. During the period of 2000-2010, the northern and southern bank of the Uppanaru River is experienced only erosion. The estimated maximum EPR on northern and southern bank was -12.26 and -12.86m/yr and the river mouth has shifted further of about 85m towards south .In between 2010 and 2014, the northern side of the Uppanaru river undergone an erosion and the southern side of the river is affected by accretion. The maximum accretion and erosion EPR values were estimated as 5.9 and -3.95m/yr.

In the Vettaikaraniruppu river(fig. 3b), both erosion (transects number: 642, 647, 648, 655 and

656) as well as accretion (transect number: from 644 to 646, from 651 to 652) has happened on the northern bank but only the accretion occurred in the southern bank (from 661 to 663)during the 1991-2000. The estimated maximum EPR accretion on southern side was 6.94m/yr. In the year of 2000-2010, the accretion took place in both the banks of the river. The maximum accretion value on north and south side was 3.78m/yr and 8.69m/yr. It is also noticed that the river mouth has shifted about 290m towards south. During the year 2010-2014, the shoreline, corresponding to river has experienced the erosion on the both sides of the river. The estimated maximum EPR values on northern and southern bank of the river were -15.91m/yr and -19.26m/yr respectively.

The erosion and accretion EPR of Seruthur river, during 1991-2000(fig. 3c), indicates that the river mouth was shifted to 230m towards the south and the width of the river also changed from 71m to 110m. The northern bank (transect no.374 to 385 and 388) of the river undergone erosion and on the southern bank(393-394)it experienced accretion. The calculated maximum erosion and accretion EPR value were -7.35 and 4.54m/yr. The river mouth was further shifted to 290m towards north side during 2000-2010. In the north bank (373 to 374) of the river, erosion occurred and in the south bank (383 to 390), accretion undergone. In the year 2010-2014, the river mouth was moved to 110m towards the south. In the north bank of the river, accretion occurred and the south bank, experienced erosion (2010-2014). The maximum EPR erosion and accretion was calculated as-14.71m/yr and 9.63m/yr respectively.

The Vettaru river mouth was moved remarkably (nearly 690m) towards south during 1991-2000(Fig. 3d). The north (transects no.: 51 to 52) and south banks(transects no.: 56 to 60) of the river mouth undergone erosion and the estimated maximum EPR on northern and southern side was -0.99 and -7.69m/yr. Majority of the transects in the northbank (from 50 to 53) of the river mouth showed erosion during the year 2000-2010 and in the south bank(transect no. 60) of the river mouth showed accretion because of the construction of the Karaikal port was commissioned during that period(2009) which is very close to the Vettaru river mouth (north bank). The width of the river mouth was reduced from 290m to 190m in the interval of 2010 to 2014.

Impacts of man-made structures on shoreline changes.

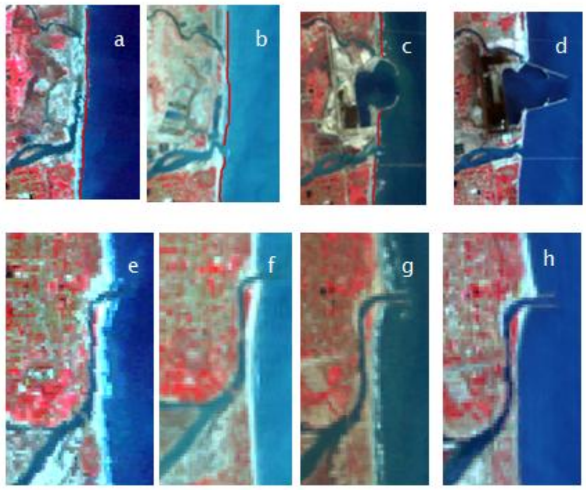

Fig 4.Spatio-temporal changes of Karaikal (a,b, c & d)) and Nagapattinam port (e, f, g & h)

The Karaikal port and Nagapattinam sea port are located at latitude 10°50.23'N and longitude 79°51'E/ 10°45'N and 79°51'E along the Nagapattinam coast, south east of India. Karaikal port was constructed with two breakwaters in 2009[29]. Recently, it undergone some modification of breakwater extension in order to improve the access in the port (Fig. 4 a, b, c and d). Its stretch is about 17.3 km including river mouth and port of which erosion and accretion were occurred in the north and south bank of the Karaikal port[30]. Nagapattinamport is the oldest port and it came to prominence during the 12th century. But, the oil jetties were commissioned during the year of 2003 to meet the demand for petroleum products in the hinterland of the Tamilnadu (Fig. 4 e, f, g & h). Such oil jetties/breakwater acts as a barrier for the northerly current, hence accretion is noticed in the south banks of both ports.

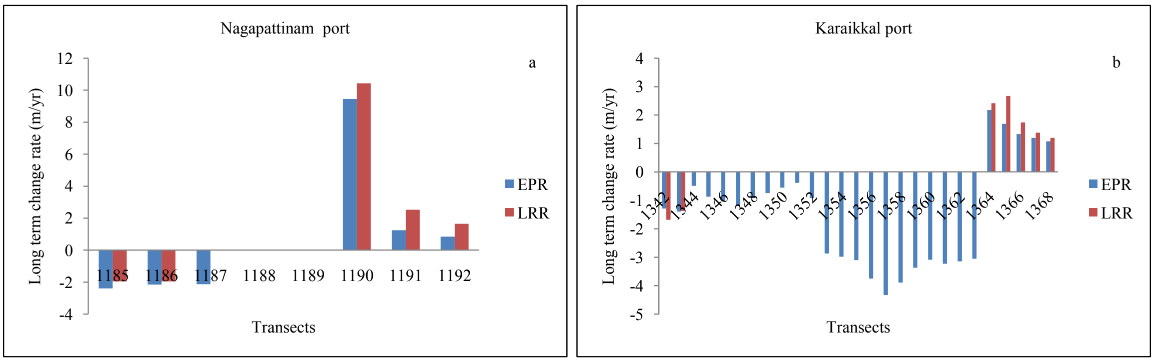

Fig.: 5. a) and b) Shoreline change rate in m/yr in both the ports(1991-2014)

a) Long term change analysis:

From the fig 5 a, the north bank (transects no.:1185 to 1187) of the Nagapattinam port (i.e., north jetty) experienced erosion and the south bank (transects no.: 1190 to 1192) undergone accretion. The change rate accretion value was 10.43 (LRR) and 9.45(EPR) m/yr. The maximum erosion rate value was calculated as -2.39 (EPR) and -1.96 m/yr (LRR). In Karaikal port (fig. 5b), the north bank (from 1342 to 1364) of the port undergone complete erosion and the maximum erosion value was estimated in both EPR and LRR Parameter was -4.33 and -1.68 m/yr respectively. Likewise the south bank (transects no.: 1365 to 1368) of the port was completely subjected to the accretion and the maximum accretion was calculated as 2.67m/yr.

The figure 3f, depicts the shoreline change rate with respect to time on both the banks of ports. The transects that were considered for the Nagapattinam port was 187 to 195. During the year of 1991 to 2000, the north and south banks of the port undergone erosion and the maximum

was -4.73m/yr. The accretion occurred during 2010-2014 in both the banks (12 to 14-north bank and 38 to 41- south banks) of the port. The below figure 6., illustrates the overall shoreline change rate for the chosen stretch. Nagapattinam port (Fig. 4 e and f) is constructed with oil jetties, and its effects are considerably low when compared to Karaikal port. A side of north jetty in Nagapattinam port show erosion, an accretion is noticed in the side of south jetty during the estimated EPR value was -8.38m/yr, and it was the pre-construction period of oil jetties of Nagapattinam port. Between 2000 and 2010, in both banks of the Nagapattinam port, an accretion occurred and maximum accretion value was noted as 13.84m/yr (transect no. 189) which is in the side of north oil jetty. During 2010-2014 analysis, both accreted (no. 188) and eroded transects (187) were noticed in the north bank. Similarly, accreted transects (no. 195) and eroded transects (no. 193) were seen in the south bank of this port. The maximum erosion and accretion values were calculated as -3.05m/yr and 3.6m/yr respectively.

Similarly, the number of transects considered for the Karaikal port (fig 3e) was 12 to 41. At Karaikal port, pre-construction time of breakwater (1991-2000) indicates negatives values on both banks of the port and the maximum erosion value was -4.36m/yr. During the year 2000-2010, the drastic increase in accretion was noted in the north bank (from 12 to 15) of port, the maximum value was 9.17m/yr. In the south bank (from 37 to 41) of the port, the erosion occurred and the estimated maximum EPR value

present analysis(Fig.5a). Karaikal port was built with two extended breakwaters and therefore it causes considerable shoreline changes in the post-construction of breakwaters (fig.4c and d). Therefore, the shoreline dynamics of Nagapattinam coast is influenced by the long shore sediment transport is towards the northerly direction[31].The intervening natural geomorphic systems and artificial structures are also indicated in the same figure(Fig. 6)

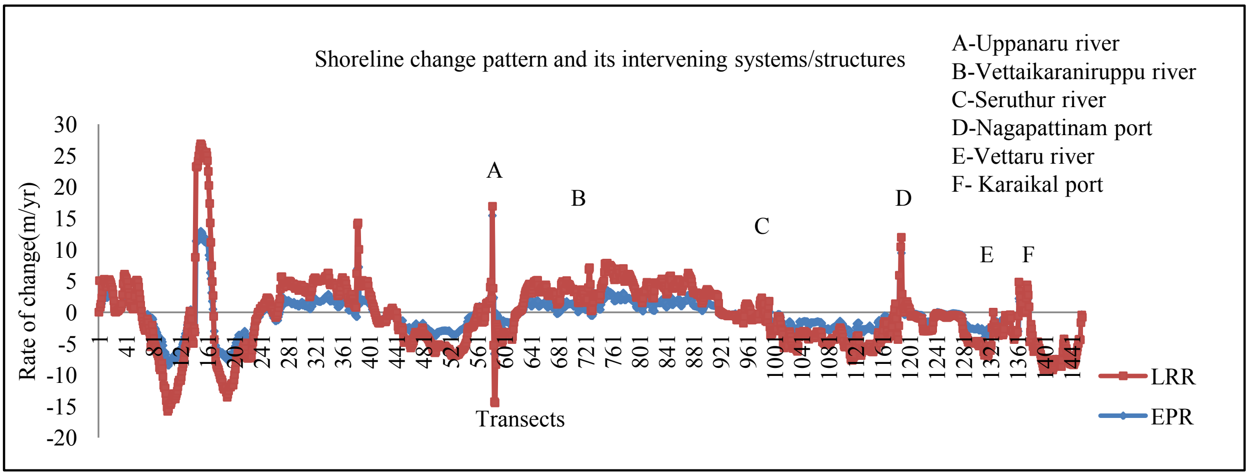

Fig.6 The select stretch of shoreline change and its intervening systems and structures of Nagapattinam coast

Conclusions

Through the analysis of the shoreline dynamics in the Nagapattinam coast from Karaikkal port to Point Calimere, Tamilnadu, India, the following conclusions are arrived.

A significant shoreline dynamics was observed between 1991 and 2014. Migration of intervening river mouths were also identified (from 1991 and 2014). Impacts of the port and intervening rivers on shoreline change were understood. It is anticipated that the outcome of this study will provide essential information for both coastal structure and shoreline management of Tamilnadu coast.

However, the nature and intensity rates of shoreline dynamics change are different from each other. Shoreline corresponding to Uppanaru river, Vettaikaraniruppu river, Seruthur river and Vettaru river is migrated towards the land (erosion) on south bank and towards the sea (accretion) on north side except Vettaru river. Because it is eroded on both banks. Due to the considerable movement of the river mouths, the Vettaikaraniruppu river is more accreting and Vettaru river which is completely eroding in nature on both banks (due to the emergence of Karaikal port nearby). Hence, the dominant northerly long shore current is responsible for accretion on north banks of the intervening rivers(Uppanaru river, Vettaikaraniruppu river and Seruthur river). But in the case of these ports, the north breakwater/oil jetty is acts as a barrier, so accretion is happened in south banks of both ports. Also, the impacts are also not the same between Nagapattinam and Karaikal ports. The intensity of erosion EPR is noticeably more (-4.33m/yr) in north bank of the Karaikal port compared to the Nagapattinam port (-2.39m/yr).

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