

Current Status and Decadal Growth Analysis of Krishna - Godavari Delta Regions using Remote Sensing

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Abstract

Demarcation and continuous monitoring of shoreline are essential for understanding the dynamic nature and processes of the coastal area. Shorelines of delta regions are ecologically and economically sensitive and dynamic. Changes in the environmental conditions and human interference affect the balance of delta's morphology. As delta areas are severely disturbed by natural as well as anthropogenic factors, it is essential to study the current status and their growth pattern. This study focuses on the decadal change analysis of Krishna-Godavari delta region in the east coast of India from 1972 to 2014 using satellite data. Advanced remote sensing and GIS technology along with statistical tools are efficient to study the changes in the delta. Results show that the major accretion over these areas is due to the growth in the geomorphological landforms like spits and bars. It is observed from the 40years of analysis over Godavari delta river mouths; Nilarevu (781m), Vainateyam (463m) and Vasishta (320m) are under erosion. Favorable currents in monsoon and post-monsoon over Krishna delta support the growth of spit in south-western direction in Krishna delta. This study has brought out the current status and growth patterns of Krishna-Godavari delta in last few decades. This kind of study helps in proper management and planning of the coast which requires accurate knowledge about the endurance of the area.

Additional Index Words: Krishna-Godavari delta, shoreline, remote sensing, erosion, accretion

Introduction

Coastal zone, the interface between land and sea is a dynamic environment encircled with diverse features. These include deltas, beaches, dunes, ridges, spits, mangrove forest and many other coastal features (Post and Lundin, 1996). River deltas, which represents 39 percent of global discharge to coastal zone (Syvitski and Saito, 2007) are modified by the interactions of the controlling processes of hydrology, offshore, climate, disperse and sort of sediments (Coleman, 1982). Human population are preferring delta region because of its high biodiversity and productivity (Syvitski, 2008). Human activities in these low gradient regions such as the construction of dams, mining, irrigation and natural factors including land subsidence, sea level rise and other climate extremes play a major role in the transformation of high sensitive delta (Overeem and Syvitski, 2009) and will thereby led to destruction in delta.

Background and Goal

Shoreline change studies in dynamic regions are major concern of the coastal zone management (White and Asmar, 1999) and are identified as one among the twenty-seven features by International Geographic Data Committee (Mujabar and Chandrasekar, 2011). Most of the deltas are under threat and protection of coastal areas requires understanding the nature of delta and river mouths, which is important for finding measures to restore, maintain and strengthen the delta's capacity to survive the climate change effects (IADC, 2009).

The sediment discharge supplied by the rivers, Yellow River, Yangtze River, Pearl River, Red River the Mekong, the Chao Phraya and the Irrawady which forms the major mega deltas of the south-east and east region has reduced as a result of human activities (Saito *et al.*, 2007). Syvitski *et al.*, 2009 reported from the thirty three major deltas of the world including Indian deltas that sinking of deltas are mainly due to the reduced aggradation and accelerated compaction. Out of which Krishna delta is affected from both these factors. Krishna, Ganges, Brahmaputra and Godavari delta shows the high-risk trend among the 48 deltas of the world under the anthropogenic aspect (Tessler *et al.*, 2015).

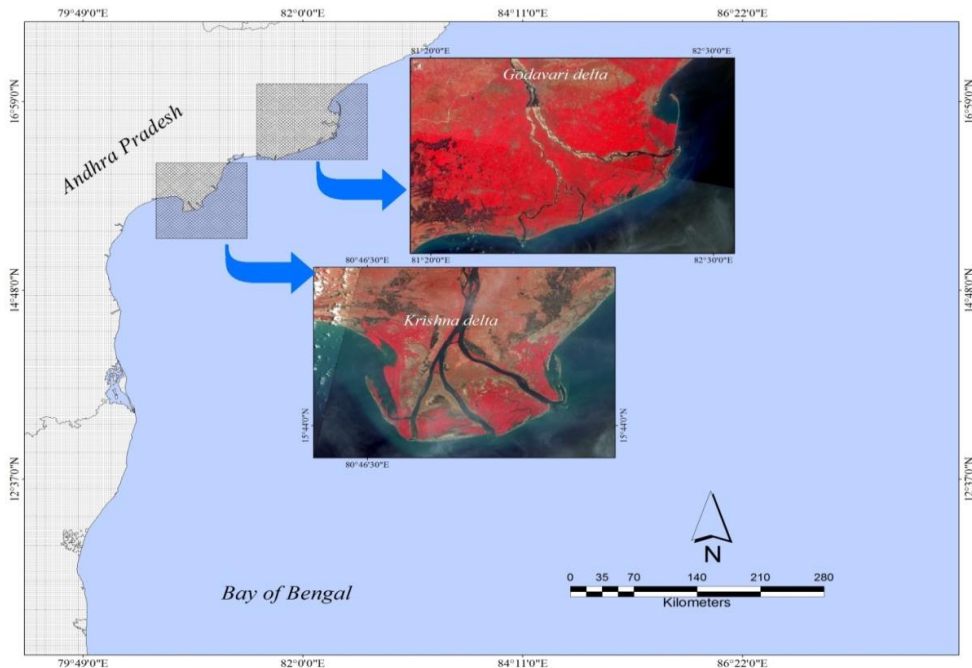
Several shoreline studies were carried out in Krishna-Godavari delta. Kankara *et al.*, 2015 studied the shoreline change along 974km long coastline of Andhra Pradesh for the last 22 years (1990-

2012). Studies carried out by Kallepalli *et al.*, 2017 showed 42.1km² of erosion between 1977 and 2008 in Krishna-Godavari delta. Similarly, Hema Malini and Nageswara Rao, 2004 reported 18.36km² of erosion in Godavari delta for the past two and half decades resulting in the destruction of mangroves and displacement of habitat. Nageswara Rao, 1985 studied the progradation of the Krishna delta through submarine topography, delta morphology and marine forces in which he concluded that the progradation is mainly due to the spit –lagoon growth and followed by lagoon filling.

Spits are geomorphic depositional landform in which one end is attached to the mainland and other to the open water. Longshore drift, tidal, fluvial currents and sediment supply, wave refraction and its angle, sea level rise are some of the factors controlling the growth of spits (Avinash *et al.*, 2013). Kunte *et al.*, 1993 studied the net shore drift direction of east coast of India through the offshore turbidity pattern as well as coastal landforms. In this study, an attempt has been made to understand the growth of the spit formed in the Krishna delta in a southwest direction and its contributing factors. Hegde *et al.*, 2015 reported that reversal of alongshore drift direction is common in tropical coast. Continuous monitoring of delta is essential to understand the morphology as it is severely affected by the natural as well as anthropogenic factors and also sustains major population.

The present study focuses on the decadal change analysis of Krishna-Godavari delta region in the east coast of India during 1973, 1993, 2003 and 2014 using satellite data. The study area, Krishna and Godavari delta (Figure 1) lie on the eastern coast of India built by the peninsular rivers; Krishna and Godavari. Arcuate shaped Godavari delta has its apex near Rajahmundry and stretches from Upputeru in the south to Uppada in north-east (Sarma *et al.*, 2001) whereas lobate Krishna delta extends from Nizampatnam in the south to Machilipatnam in the state of Andhra Pradesh. These semi-arid regions are influenced by both south-west and north east monsoon and receive an average rainfall of 840mm in Krishna and 1100mm in Godavari basin (Selvam, 2003; Trent *et al.*, 2007). Godavari River has mainly four distributaries namely, Gautami, Vasishta, Vainateyam and Nilarevu and three distributaries of Krishna river forms the major Krishna delta front (Rao *et al.* 2010).

Figure 1. Study area Krishna-Godavari delta



Methods

Landsat satellite datasets from USGS Earth Explorer for four different decades mainly; 1973-1993, 1993-2003, 2003-2014 and 1973-2014 were used for shoreline extraction of the Krishna-Godavari delta. This study has restricted to decadal scale analysis for the past 40 years and because of the unavailability and cloud covered scenes in 1983, 1983 has not considered for this study. All the scenes were geo-referenced and projected to WGS 1984 UTM coordinate system. Detailed specifications of the datasets used were listed in the Table1. Downloaded geo-referenced datasets were enhanced, mosaicked and subsetting to the area of study in ERDAS Imagine software for extraction of shoreline.

Coastal investigators followed the use of shoreline indicators because of the dynamic nature of shoreline position (Elizabeth and Ian, 2005). Waterline (dune line) (Stafford and Langfelder, 1971) was used as the shoreline indicator for the present work. Tidal conditions were noted from the acquisition time of the datasets to reduce the tide influenced errors. After the extraction of shorelines

in Arc GIS, statistical shoreline change was computed using Digital Shoreline Analysis System (DSAS), an Arc GIS software extension (Himmelstoss, 2009). An uncertainty value of 10m was also specified for each shoreline to compute the reliability of rates in a better way (Himmelstoss, 2009). Shorelines are appended in a single feature class, and baseline was constructed 3000m offshore side. Transects were created perpendicular to the trend of shorelines with an interval of 50m to calculate the change statistics. Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), End Point Rate (EPR) and Linear Regression were the major statistical methods for shoreline change calculations. For the present study, NSM was considered for computation of shoreline change which will measure the distance between the oldest and youngest shoreline. Accretion and erosion values were indicated in positive and negative values respectively.

Areas of the Krishna delta spit were calculated for the same years, and currents are plotted for the particular region for the acquisition date of the years 2003 and 2014. HYCOM + NCODA Global 1/12° Analysis Current data for the year 2014 and OSCAR Third Degree Resolution Ocean surface currents for the year 2003 from Asia-Pacific data research center were used. Monthly results of the current data for 2013 and 2014 of Krishna delta is also plotted to support the study.

Table 1. Datasets used

Year s	Date of pass	Satellite/se nsor	Path and row	Acquisiti on time
1973	20/01/1973	Landsat 1/MSS	152/48	04:26
	20/01/1973	Landsat 1/MSS	152/49	04:26
1993	03/05/1993	Landsat5/TM	141/48	04:13
	03/05/1993	Landsat5/TM	141/49	04:13
	26/05/1993	Landsat5/TM	142/49	04:20
2003	04/03/2003	Landsat7/E TM	141/48	04:39
	04/03/2003	Landsat7/E TM	141/49	04:40
	11/03/2003	Landsat7/E TM	142/49	04:46
2014	29/05/2014	Landsat8/OLI	141/48	04:50
	29/05/2014	Landsat8/OLI	141/49	04:51
	20/05/2014	Landsat8/OLI	142/49	04:57

Results

Shoreline mapping was carried out for Krishna and Godavari delta for the four decades namely 1973-1993, 1993-2003, 2003-2014 and 1973-2014 respectively. Net shoreline Movement was calculated for the respective years which give the distance between oldest and youngest shorelines (Figure 2 and 3).

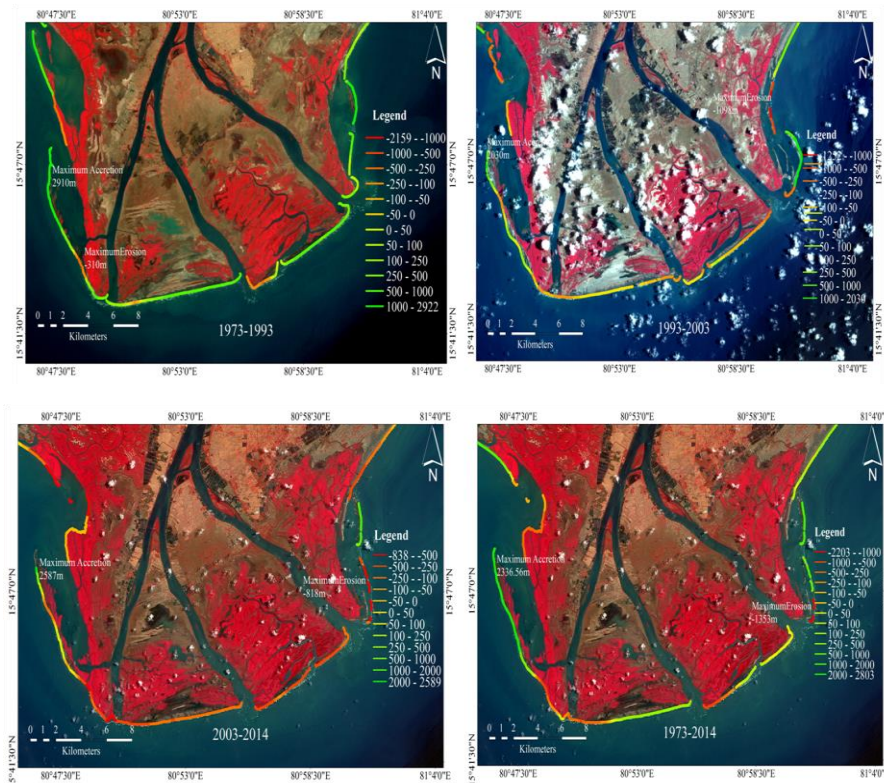
Shoreline Change of Krishna Delta

Maximum erosion of 310m and accretion of 2.9 km near Uppu Revu was observed for the period between 1973 and 1993. In overall observation, 1973-1993 shows a phase of accretion in Krishna

delta region in comparison with the erosion. The higher NSM was due to the growth of spit in this region, and less value was found at the foot of the spit. This was due to the shift in the foot of the spit towards the coastal side. Well developed bars were found in the northern part of the Krishna delta in 1993. These bars were fragmented and shifted towards the coastline in 2003 which indicates the high marine action. Head of the spit has widened by 2km near Uppu revu by 2003. The periods between 2003 and 2014 was pertaining to erosion. The head of the spit which was growing towards the coast has changed its position by 2.5 km to the seaward. In overall, there was high erosion in the northern part of the Krishna delta due to the reduction in the size of the spit and high accretion in the southern part of the delta during the period between 1973 and 2014.

Unlike the growth of the spit and bars, the mouth of the three lobes of Krishna delta exhibited dynamic changes. Though 1973-1993 was an accretion phase, the middle lobe showed an erosion of 186m. During 1993-2003, all of the three lobes were under the category of erosion with a higher value of 382m in the northern lobe. The same trend of erosion was followed between 1973 and 2014 with a high erosion of 545m in the middle lobe of Krishna.

Figure 2. Shoreline change of Krishna delta



Shoreline Change of Godavari Delta

Gautami and Vasishta river mouths showed higher erosion of 1.6 and 1.4 km and Nilarevu mouth marked 972.6 m of accretion during 1973-1993. NSM of 1993-2003 of Godavari delta showed a maximum of 689m. Formation of bars parallel to the Vasishta river mouth resulted in the higher accretion. Erosion of 853m in Gautami river mouth was observed during the same year. Reduction in the mangrove was also noticed in this region. Well developed Spit has formed in the Vasishta river mouth between 2003 and 2014 which showed a higher accretion value of 1.15km. Spits and bars formed near the mouth of Gautami have shifted towards the land. Maximum erosion of 817m was marked near the mouth. Regions near Nilarevu and Gautami mouths have shown maximum changes in accretion as well as erosion from 1973-2014. Higher accretion of 1.2km near Nilarevu and erosion of 1.01km near Gautami mouths have observed during these periods. Net shoreline movement of delta during 1973-2014 conveyed that all the mouths were under erosion with major dynamic changes over the Gautami and Nilarevu mouths.

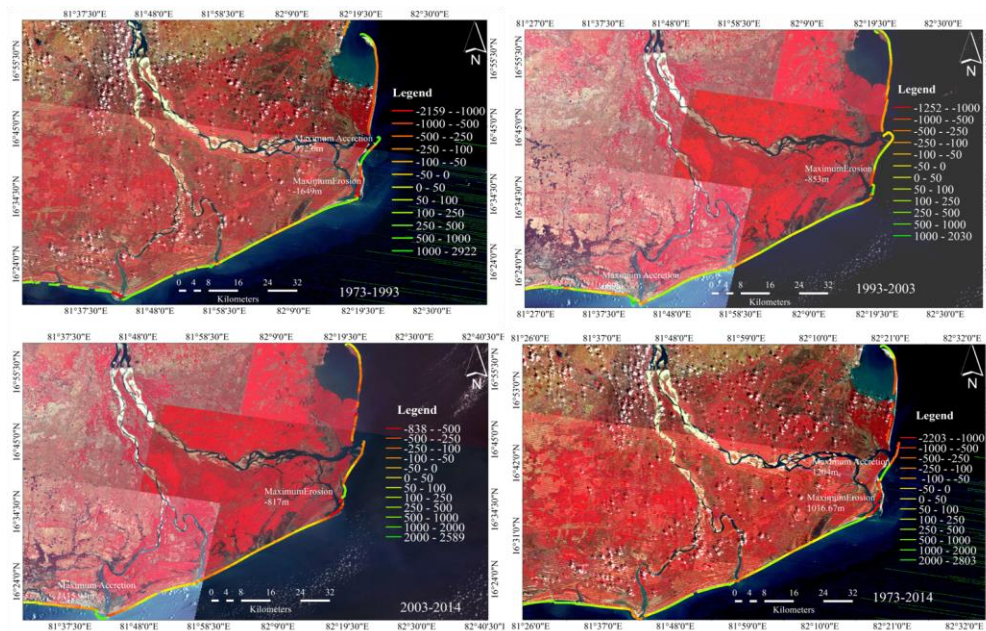


Figure 3. Shoreline change of Godavari delta

Formation and Growth Pattern of Spit in Krishna delta

The pronounced growth of the spit in south-western direction was noteworthy near the southern river mouth of Krishna delta. The pattern of the growth of the spit and its changes in area for the periods 1973-1993, 1993-2003, 2003-2014 and 1973-2014 were calculated (Figure 4). Current data for the years 2003 and 2014 were also plotted to understand the role of prevailing currents for the growth (Figure 5 and 6).

Area changes and Hydrodynamics

Areas of the spit in Krishna delta were calculated for the same years where shoreline changes were analysed. Changes in area were calculated for 1973-1993, 1993-2003, 2003-2014 and 1973-2014. Small spit was observed during 1973 near the mouth of Krishna. An increase in the area (2sq.km) towards the south west direction was noticed by 1973-1993. Major increase in the length of the spit happened during 1973-1993. Widening of the spit (2sq.km) at its head occurred between the years 1993-2003. Accretion phase was reduced by the year 2014. Only one sq.km change in area was examined during 2003-2014. In over all, area of the spit was increased by five sq.km from 1973-2014. It was also observed that the position of the head of the spit was shifting towards and away from the coastline in different years. Also, presently this spit has enriched with mangroves from the foot to the head.

Spit growth in the north east direction was common in these delta regions especially the 21km long Kakinada spit of Godavari delta. South-west growth of the Krishna spit led to study the current over the area. Current data were plotted for the particular region for the periods of 2003 and 2014 to understand the contributing factor for the growth of spit in a south-west direction. Data was collected from the Asia-Pacific Data Research Centre.

Data has been plotted for pre-monsoon, monsoon, post-monsoon and date of satellite pass. The satellite pass for the years 2003 and 2014 was during the end of post monsoon and summer season. The current was towards the north-east direction during these months. During monsoon season, south-west direction of the current was observed for the respective years and vice versa in post monsoon and pre monsoon seasons.

Figure 4. Changes in area of spit in Krishna delta

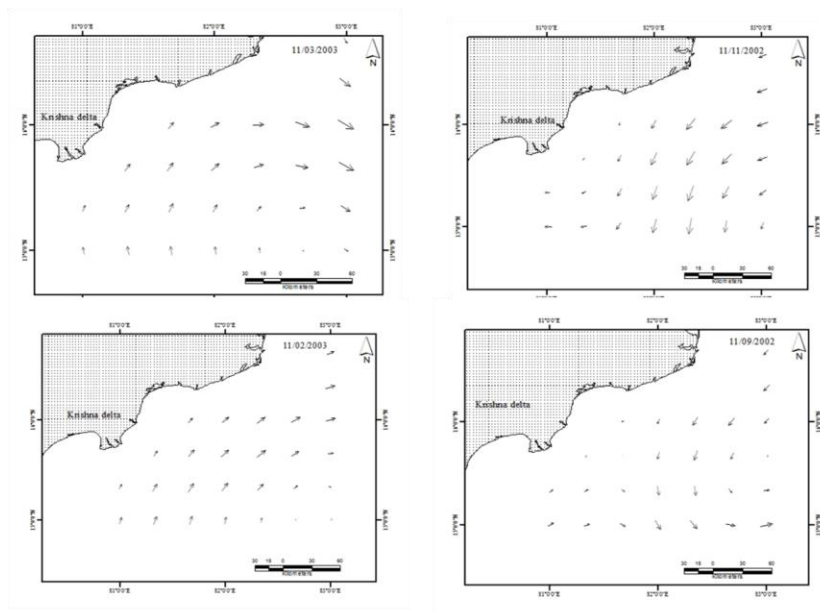
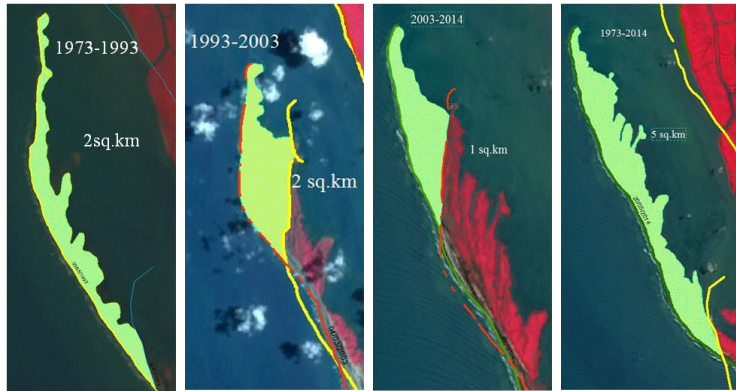
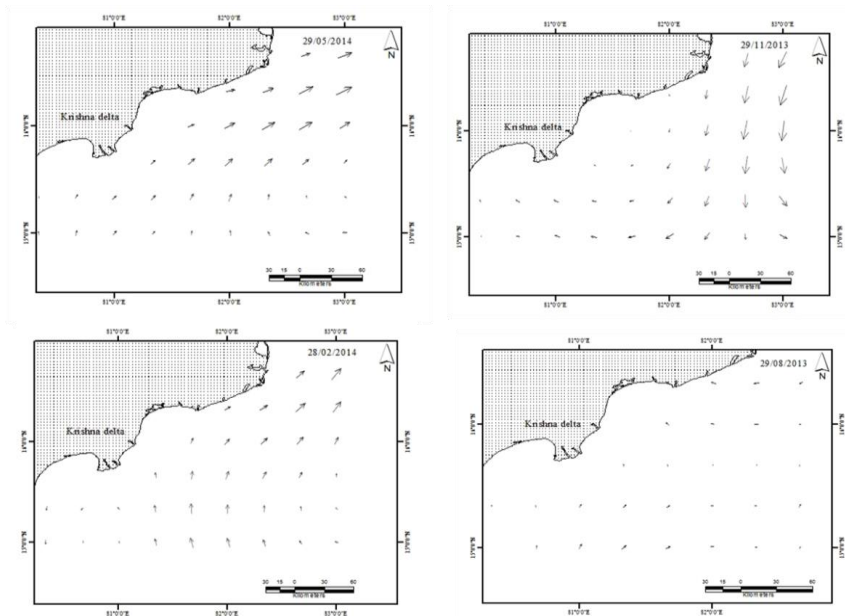


Figure 1 Current patterns during the date of satellite pass, monsoon, post-monsoon and pre-monsoon in 2003

The current direction is along the south-west during November and February in 2003 and 2014 which led to studying the monthly observations of current data for the years 2013 and 2014 in Krishna delta region. Monthly plots of current data for the year 2013 and 2014 were made. It is

inferred that currents during monsoon and post-monsoon are favoring the growth of spit in a south-west direction

Figure 2 Current patterns during the satellite pass, monsoon, post monsoon and pre monsoon in 2014



Discussion

The present work discussed the shoreline change of Krishna-Godavari delta for four different decades. It is clearly portrayed that the major accretion in Krishna and Godavari delta was due to the growth of the geomorphological landforms over these regions. An earlier study (Nageswara Rao, 1985) reported that wave power is dominant in Krishna delta in comparison with the sediment discharge from rivers which will lead to the quick moulding of river-borne sediments into marine-dominated coastline landforms. Change in the position of spits and bars more towards the coast in the Krishna delta indicate the high marine action. Major geomorphic changes were observed in Nilarevu and Gautami mouths of Godavari delta. Erosion and accretion of spit were observed during the period 1973 -1993 in Gautami and Nilarevu mouths. Reduction in mangroves in Gautami river mouth during 1993-2003 could be due to the cyclones and depressions. 13 cyclones and depressions were tracked between 1993 and 2003 by India Meteorological department

The changes in the area of the spit showed that the major growth has happened during 1973-1993 after that the widening of the head of the spit. It is also noticed that thickening was shortened by one sq.km between 2003 and 2014. Currents of monsoon and post-monsoon were along the direction of growth of spits of Krishna delta in a south-west direction. Kunte *et al.*, 2013 reported that the coast experiences bi-directional sediment transport. The growth of the spits in the south-west could be due to the favorable current in monsoon and post-monsoon season.

Conclusions

Continuous monitoring of shoreline changes in the highly sensitive regions is very important for the proper planning measures and management. The present work concludes that the shoreline of the delta is very dynamic showing the divergence in the geomorphological landforms such as spits and bars. It is suggested that favorable currents during monsoon and post monsoon season could be the reason for the growth of spit in a south-west direction. The detailed understanding behind the erosion of river mouths is recommended for the future study. Dynamics of sedimentation, hydrodynamic regime, extreme events and other parameters should be considered for the better understanding of the formation and fragmentation of the landforms in delta fronts.

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