

Morpho-dynamic evolution of Ekakula spit of Odisha coast, India using satellite data

R. Mani Murali* & P. Vethamony

CSIR- National Institute of Oceanography, Dona Paula, Goa – 403 004, India.

*[Email: mmurali@nio.org]

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Ekakula spit is at the northern end of Gahirmatha coast in the state of Odisha, India. This spit is located at the mouth of Maipura river, which is falling in the northern side of Mahanadi delta region. This spit is a prominent and important for many reasons because it triggers interests to the coastal managers and environmentalists because of its nature. Multi-temporal satellite images (1999–2009) were used to study the Morpho-dynamic evolution of this spit. Results show that the spit grows towards northeast mainly by the deposition of sand brought by the littoral drift from the south. In the past, it got fragmented and detached portion moved away towards the offshore. Temporal satellite images revealed the progressive evolution of the spit. Spit appears to have undergone growth and fragmentation over the years and accordingly the Maipura river mouth shifted back and forth. The growth of the spit forces the river to shift its mouth and the river causes the fragmentation by breaching the spit during heavy floods. Ekakula spit lost about 306 m when compared its position in 1973 (SOI toposheet) to the satellite image of 1999. The year-wise length of the Ekakula spit was estimated using satellite data for the period 1999-2009 from a base point selected for this purpose. Ekakula spit length increased since 1999 by 2710 m by 2008 and little reduced to 2431 m during 2008-2009. Spit appears to be growing steadily by the deposition of sediment brought from south by the littoral drift except during 2003 and 2009 when it suffered some erosion. Maximum increase in length was during 2004-2005 followed by 2000-2001 and 1999-2000. Minimum was during 2004-2005. Erosion was minimal during 2002-2003.

[**Keywords:** Gahirmatha coast, Erosion, Ekakula spit, Odisha, Mahanadi delta.]

Introduction

Odisha coast of India is about 476 km long¹ stretching from Ichchapuram in the south to the west of Subarnarekha river mouth on the western shore of the Bay of Bengal. In general, Odisha coastline is oriented in a SW-NE direction. Murali et al (2009) studied accretion and erosion processes in parts of Orissa coast.² There are several major and minor rivers joining the Bay of Bengal at several locations along the coast. From south up to Dhamara, the rivers and creeks opening to the sea are Rushikulya, Chilka lake, Bhargavi, Kushabhadra, Prachi, Devi, Jatadharmohan creek, Mahanadi, Jambu, Hansua, Bansgarh, Maipura and Dhamara. North of Dhamara coast, the Budhabalanga and Subarnarekha rivers enter the sea at the northern most part of Odisha coast. The sediment

contributions from all these rivers spread all along the coast and make the Orissa coast depositional in nature³. The coast bulges out in the central portion, from Chilka Lake to Dhamara, where Mahanadi, Brahmani, and Baitarani river systems form a combined delta. The coast is concave in shape between Dhamara and the Subarnarekha river mouth as no major river pushes the shoreline into the Bay of Bengal. The Rushikulya river in the south and the Budhabalanga and Subarnarekha rivers in the north have very little or no delta formation⁴. The lone Hukitola bay off Jambu has been formed because of the huge complex spit to the north of the Mahanadi estuary⁵. There are only three islands off the Orissa coast - Outer Wheeler Island, Long Wheeler Island, and Coconut Wheeler Island off Dhamara and Maipura river mouths.

The net littoral drift along the coast is northerly⁶. This littoral drift together with the river-discharged sediments make the river mouths a depositional environment⁷. Hence, the river mouths protrude in to the sea. The littoral drift deposition builds spits and bars at the river mouths especially at the southern side of the river mouths. Most of the river mouths have well developed spits. This causes the coastline orientation shifting towards west or northwest at the immediate vicinity of the northern side of the openings. Again, after a stretch, the coastline tends to orient itself towards northeast. The Gahirmatha coast (Fig. 1) lies about 10 km northwest of the Paradip coast on the northern side of Mahanadi river. Dhamra and Maipura rivers are at the northern side of Gahirmatha coast discharge into the sea.

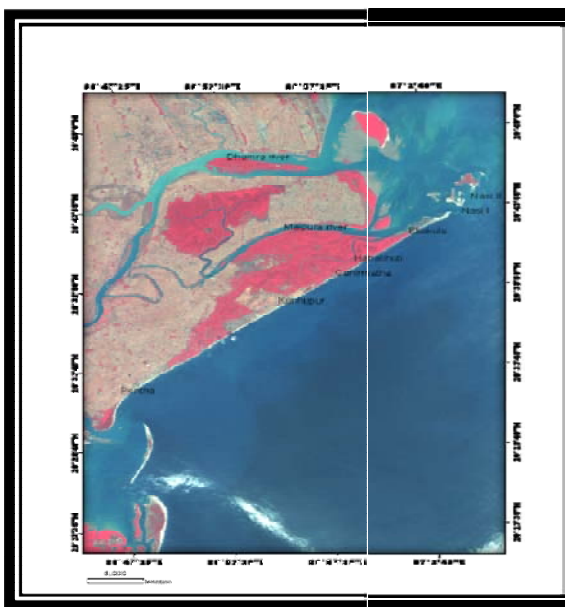


Fig 1—Study region

Table 1—Details of satellite images

Year	Path/row	Satellite ID	Date
1999	107-58	1D	28/2/99
2000	107-58	1D	19/1/00
2001	107-59	1D	22/2/01
2002	107-60	1D	13/1/02
2003	107-61	1D	17/2/03
2004	107-62	P6	13/1/04
2005	107-63	P6	24/2/05
2005	107-64	P6	09/12/05
2007	107-64	P6	21/01/07
2008	107-64	P6	16/1/08
2009	107-64	P6	10/01/09



Fig 2. Field photos showing the deposition at the spit

Ekakula spit (Fig. 2) is an extension of the Gahirmatha coast at the Maipura river mouth. This elongated spit extending towards north from Ekakula owes its origin mainly to the deposition of sediments brought by the northerly long shore sediment transport from south and partly to the sediments deposited by the Maipura-Dhamara river system⁸. A close inspection of the temporal satellite images of the area (Table 1) reveals the progressive evolution of the spit. This spit was visited during the field trip in December 2008 (Fig. 2). Spit appears to have undergone growth and fragmentation over the years and accordingly the Maipura river mouth shifted back and forth. Growth of the spit forces the river to shift its mouth and the river causes fragmentation by breaching the spit during heavy floods and cyclones⁹.

Materials and Methods

Available data and information pertaining to the study area from different sources were collected and used here. Satellite data pertaining to the study area were procured from the National Remote Sensing Centre, Hyderabad, after atmospheric correction. Linear Imaging Self-scanning Sensor (LISS) III sensor data from the Indian Remote Sensing Satellite (IRS) were

used in this study. Cloud free data pertaining to January-February months for the years 1999 to 2009 were processed and analysed. Spatial resolution of these data is about 23 m. Georeferencing was carried out using the reference points from toposheets. Details of data sets, image characteristics are presented in Table 1. Digital image processing of satellite imagery and the spatial mapping was undertaken using commercial digital image processing software. The accuracy was less than 1.0 RMS error. Then the coastlines were digitized using common data interpretation techniques. They were superimposed on registered toposheet published by Survey of India in 1975 (Survey period, 1973-73) to study the long-term changes occurred on the spit.

Apart from these, a field survey of the coastline using a DGPS (Accuracy is 2 m) was carried out in December 2008. The positions along the Ekakula spit to Maipura River mouth were taken to demarcate the high water line and to compare with the other data sets.

Results & Discussion

This spit grew towards northeast and reached closer to the Outer Wheeler Island by 1988¹⁰. A comparison of satellite imageries in November 1988 and March 1989 showed that the spit was breached near the northern end near Wheeler Island during this period. It appears that the spit was again breached and fragmented at its Ekakula end in the south during a cyclone in 1989 and the Maipura river mouth shifted back towards south.

The detached portion of the spit remained as a barrier offshore bar known as Nasi bar towards south of Maipura mouth. This bar extended further north easterly in the later years under the influence of long-shore current. However, the Nasi bar got further fragmented into two parts in May 1997 during a cyclone and since then it was subject to further fragmentation. Accelerated long shore transport of sands helps building and prolongation of this spit system. The continued prolongation of the spit may lead to the withdrawal of material from the proximal end of the spit causing thinning and deposition at the distal end causing widening. During high

episodic floods or extremely high wave conditions and storm surges associated with cyclones, the river tends to breach the spit in between especially at the thinned locations.

Table 2—Year-wise variation in length of the Ekakula spit from a base point

Base point position: 87° 2' 3.12'' E, 20° 42' 15.6'' E

Year	Distance from Base point (m)	Difference from previous year (m)	Difference from 1999 (m)
1973	1775	-	-
1999 Jan	1469	306	0
2000 Feb	2066	597	597
2001 Jan	2753	687	1286
2002 Feb	2811	058	1342
2003 Jan	2748	- 63	1279
2004 Feb	3212	464	1743
2005 Feb	3924	712	2455
2005 Dec	4070	146	2601
2007 Jan	4083	13	2614
2008 Jan	4179	96	2710
2009 Jan	3900	-279	2431
Net increase during 1999 – 2008 : 2710 m			
Net increase during 1999 – 2009: 2431 m			

Ekakula spit lost about 306 m when compared its position in 1973 (SOI toposheet) with that in the satellite image of 1999. However, a comparison between the images in 1989 (before it was breached and the detached part remained separately as Nasi bar) and 1999 showed that the loss was about 6 km. Since 1999, the spit has been growing again towards northeast. The year-wise length of the Ekakula spit was estimated using satellite data for the period 1999-2009 from a base point selected for the purpose. The details are presented in the Table 2. The Ekakula spit length increased since 1999 by 2710 m by 2008 and 2431 m during 2008-09 towards northeast (Fig. 3). The spit appears to be growing steadily by deposition of sediment brought from south by the littoral drift except during 2003 and 2009 when it suffered some erosion. The maximum increase in length was during 2004-2005 (712 m) followed by 2000-01 (687 m) and 1999-2000 (597 m). Erosion was minimal during 2002-03 by 63 m.

Spatio-temporal changes of the detached Nasi bar for the period 1988-2001 revealed interesting features¹⁰. The change positions of the barrier bar centroid clearly depicted the

migration of Nasi barrier along a north-east direction during the period 1989–1996. Within seven years, the sand bar had migrated about 6.85 km from the point of origin or breaching. The evolutionary trend of the spit had undergone five predominant cycles of mass erosion and post-cyclone rebuilding in a span of 14 years from 1988 to 2001. Each of the major erosion processes was invariably linked with the incidence of cyclones in the region. In the early stage of migration after the separation from the spit, the barrier bar was in the shallow water regime of the estuary and hence the sediment deposition was significant under the influence of littoral current. On the other hand, during the same period, the region had experienced three major cyclonic events that resulted in mass erosion of the spit successively and the transported sediments were re-distributed in the barriers. However, due to the absence of cyclones during 2000–2008, the spit dimension had progressively increased in spite of minor changes in between.

Ekakula spit and the Nasi bars are known for providing mass nesting sites for the Olive Ridley turtles. Satellite images of the area revealed that spit underwent marked temporal changes. In general, the spit grows towards northeast but were fragmented during the heavy floods and cyclones. Accordingly the Maipura river mouth shifts to and fro. The build up and subsequent fragmentation processes of the spit created different landforms in the offshore. The Ekakula spit grew towards northeast and reached closer to the Outer Wheeler Island by 1988 and hence the Maipura river mouth shifted progressively towards north.

It appears that the spit was breached and fragmented during a cyclone in 1989 and the Maipura river mouth shifted back towards south by about 6 km. The detached portion of the spit remained as an offshore sand bar known as Nasi bar. This bar extended further north-easterly in the later years under the influence of littoral drift from south. The migration rate of Nasi barrier bar was found to be substantial during the period 1989–1997.

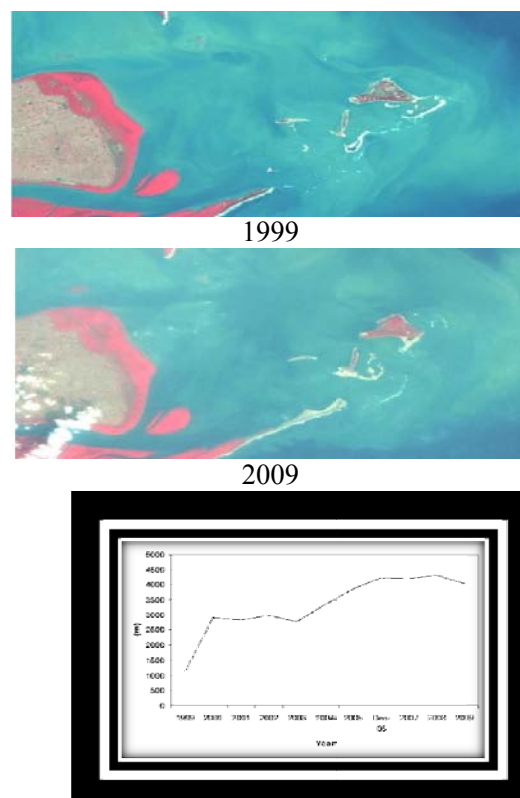


Fig 3. Year-wise variation in length of the Ekakula spit from a base point

The Ekakula spit lost about 1.8 km when compared its position in 1973 with that in the satellite image of 1999. But a comparison between the images in 1989 (before it was breached and the detached part remained separately as Nasi bar) and 1999 showed that the loss was about 6 km. Since 1999, it has been growing again towards northeast. The year-wise length of the Ekakula spit estimated from satellite data for the period 1999–2009 showed that the Ekakula spit length increased from 1999 by 2710 m up to 2008 towards northeast. The spit appears to be growing steadily by deposition of sediment brought from south by the littoral drift except during 2002–03 and 2008–09 when it suffered some erosion. This erosion may be due to the severe monsoon, heavy runoff from the rivers, etc, but need to be explored in detail. The prolongation of the spit growth could cause erosion and narrowing of the proximal end of the spit.

Severe floods and/or extremely high wave conditions especially during cyclones cause the breaching of the spit at the narrow and weak spot. The reasons for the erosion may be due to natural processes and manmade interventions. This coast is prone to cyclones, storm surges, and floods, which cause episodic changes in the morphology of the coast.

As described earlier the Ekakula spit grows towards northeast mainly by the deposition of sand brought by the littoral drift from the south. However, over the years, the spit was fragmented and the detached portion moved away towards the offshore. After some time, some fragmented portions were dispersed in the sea. This episodic fragmentation of the spit leads to loss of large quantum of sand that was deposited earlier on the spit. This loss of sand caused reduction in the quantum of the littoral drift towards south, which normally happens during the NE monsoon season. This in turn reduced the sand replenishment towards south along the Gahirmatha coast adversely affecting the extent of building up of beaches normally taking place on the coast during NE monsoon.

Conclusion

However, for a better understanding of the seasonal and annual cycles of the coastal geomorphologic changes, we need regular monitoring of the Gahirmatha coast with measurements of beach profiles and littoral parameters on a monthly basis. As the inaccessibility of the coast by roads makes the data collection difficult and cumbersome, remote sensing images were used to find out the variations of spit growth in this study. It is found that during the period 1999-2008, the Ekakula spit length increased to 2710 m towards northeast. It lost about 306m upto 1999 when compared its position in 1973. The spit appears to be growing steadily now by deposition of sediment brought from south by the littoral drift after facing erosion. The delta advance and retreat depend on the critical factor of sediment supply to the shore face. When sediment supply to the shore face reduces, erosion will dominate on the shore. This region is experiencing reduced sediment input from rivers under natural

forcing and manmade interventions in the river course from catchment area to the river mouth. Factors such as sea level rise due to global warming, local subsidence/tectonic causes, and occurrence of more frequent cyclones and floods are controlling the significant changes along these coastal regions, which needs to be studied in detail for the proper coastal zone management.

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