Science of the Total Environment 637–638 (2018) 717–729

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Threats to coastal communities of Mahanadi delta due to imminent consequences of erosion – Present and near future

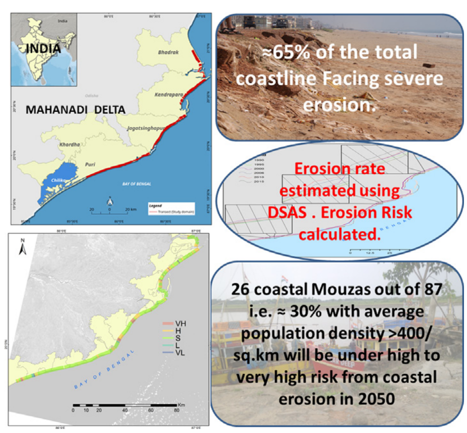
Anirban Mukhopadhyay *, Pramit Ghosh, Abhra Chanda, Amit Ghosh, Subhajit Ghosh, Shouvik Das, Tuhin Ghosh, Sugata Hazra

School of Oceanographic Studies, Jadavpur University, Kolkata, West Bengal, India

HIGHLIGHTS

- Coastal districts of Mahanadi delta suffering from coastal erosion for decades
- Rate of coastal erosion has been estimated from 1990 to 2010 using DSAS tool.
- Most of the coastline (≈65%) is facing erosion at present and the trend will continue.
- More than 8000 households are under very high risk from coastal erosion.
- ≈30% coastal mouzas would be under very high risk from coastal erosion in 2050.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 10 January 2018
Received in revised form 19 April 2018
Accepted 6 May 2018
Available online xxxx

Keywords:
Coastal erosion
Coastal communities
DSAS
EPR
LRR
Mahanadi Delta

ABSTRACT

Coastal erosion is a natural hazard which causes significant loss to properties as well as coastal habitats. Coastal districts of Mahanadi delta, one of the most populated deltas of the Indian subcontinent, are suffering from the ill effects of coastal erosion. An important amount of assets is being lost every year along with forced migration of huge portions of coastal communities due to erosion. An attempt has been made in this study to predict the future coastline of the Mahanadi Delta based on historical trends. Historical coastlines of the delta have been extracted using semi-automated Tasselled Cap technique from the LANDSAT satellite imageries of the year 1990, 1995, 2000, 2006 and 2010. Using Digital Shoreline Assessment System (DSAS) tool of USGS, the trend of the coastline has been assessed in the form of End Point Rate (EPR) and Linear Regression Rate (LRR). A hybrid methodology has been adopted using statistical (EPR) and trigonometric functions to predict the future positions of the coastlines of the years 2020, 2035 and 2050. The result showed that most of the coastline (≈65%) is facing erosion at present. The predicted outcome shows that by the end of year 2050 the erosion scenario will worsen which in turn would lead to very high erosion risk for 30% of the total coastal mouzas (small administrative blocks). This study revealed the coastal erosion trend of Mahanadi delta and based on the predicted coastlines it can be inferred that the coastal communities in near future would be facing substantial threat due to erosion particularly in areas surrounding Puri (a renowned tourist pilgrimage) and Paradwip (one of the busiest ports and harbours of the country).

* Corresponding author.
E-mail address: anirban_iirs@yahoo.com (A. Mukhopadhyay).

https://doi.org/10.1016/j.scitotenv.2018.05.076
0048-9697/

1. Introduction

Shorelines are defined as the interface between sea and land. Due to various natural (like storm surges, sea level rise, flood etc.) and anthropogenic factors (like construction of jetties and ports, clearing of coastal vegetation etc.), shorelines are undergoing unprecedented change throughout the world. Around 70% of the world's shorelines are undergoing coastal erosion, resulting in instability in these regions and affecting the socio-economic setup of the regions concerned (IPCC, 2001). Whenever any natural processes taking place in these shorelines threatens human life and infrastructure it leads to natural hazards and in order to prevent the impact of such hazards coastal managers should know the intrinsic physical, ecological and coastal features, human occupation, population, demographic details along with past and present shoreline trends (Jana and Bhattacharya, 2013). This demands an assessment of the coastal dynamics especially at regional levels so that stability can be reinstated and natural disasters like floods could be avoided in the future.

Most research on coastal management principally relies upon historical shoreline data (Addo et al., 2008). Natural causes of shoreline change include storms, floods, morphology and geology of the catchment areas, their size and the nature of the sedimentation basin – all of which affects coastal erosion (Kumar et al., 2010a, 2010b). According to Albert and Jorge (1998), climate change induced rainfall along with the coastal hydrodynamics such as waves, tides and currents also result in shoreline change. Changes in hydrodynamics of near-shore environment like river mouth processes, storm surges and the nature of coastal landforms also regulate the degree of shoreline change (Scott, 2009; Narayana and Priju, 2006; Kumar and Jayappa, 2009). Man-made factors include construction of jetties, groins, ports, industries, sea-walls and aquaculture farming which usually lead to widespread erosion by altering the sediment movement along the coast (Kumar et al., 2010a, 2010b). Sea-level rise is also a major cause of coastal erosion. Although it may not be perceptible to the human eye mainly because of its slow rate, its effect is prominent when shorelines are compared after a long time interval (Hazra et al., 2002; Feagin et al., 2005).

Vulnerable coastal ecosystems such as mangroves are rapidly undergoing loss all over the globe (Lovelock et al., 2015). Shoreline erosion due to sea-level rise is directly affecting these ecosystems (Huq et al., 1995). Sea-level has increased globally at the rate of approximately 1.8 mm/year between the years 1950 and 2000 (Church et al., 2004) although this rate was found to vary in different parts of the world (Church et al., 2008). By the end of the 21st century, sea-level is projected to increase by 0.18–0.59 m compared to 1980–1999 levels according to IPCC (Solomon, 2007). Rahmstorf (2007) expects sea-level rise, mainly due to global warming, will continue for centuries. In fact, some researchers are assuming that this change would be more than that predicted by IPCC (Pfeffer et al., 2008; Rahmstorf, 2007; Kay et al., 2015; Lovelock et al., 2015).

Hence it is of paramount importance to assess these changes in the coastlines so that their effects on the ecology as well as human society can be attenuated. Taking proper measures to stop the rapid erosion occurring due to various factors by immediate implementation of policies also require identifying the most vulnerable areas and the magnitude of the rate of erosion. It is also important to measure the coastal erosion/accretion for a wide-range of studies, like development of setback planning, hazard zoning, erosion-accretion studies, and predictive modelling of coastal morphodynamics (Sherman and Bauer, 1993; Al Bakri, 1996; Zuzek et al., 2003).

Remote sensing data has been used widely in many previous studies in order to analyse the temporal variability of shoreline positions (Dolan et al., 1991; Fletcher et al., 2003; Thieler and Danforth, 1994; Ford, 2013). A popular shoreline assessment tool namely Digital Shoreline Analysis System (DSAS) developed by Woods Hole Coastal and Marine Science Center, USGS was implemented in this study to assess the coastline change in one of the most vulnerable shorelines in India, namely Mahanadi delta. Keeping in view the above mentioned background, it was hypothesized that the shoreline of Mahanadi Delta facing the Bay of Bengal underwent substantial erosion at par with the global erosion rate (Ericson et al., 2006; Syvitski et al., 2009). The main aim of the study was to understand the existing and future risk of coastal erosion in the Mahanadi Delta. Based on the proposed hypothesis the following objectives were formulated for the present study. The first objective of the study was i) to measure the erosion rates of this shoreline (between the years 1990 and 2015 using satellite images) (Table 1) by means of two statistical techniques namely End-Point Rate (EPR) and Linear Regression Rate (LRR) and identify which method is suitable for the present study area, ii) to predict the future position of shorelines for the years 2035 and 2050 and iii) to prepare a risk map for the years 2035 and 2050 keeping in view the demographic factors in addition to shoreline change scenarios, in order to identify the areas which will be hard hit due to erosion activities.

2. Materials and methods

2.1. Study area

Flowing for over 900 km, the Mahanadi River basin is over 1,40,000 km^2 in area and extends over seven states of India (Fig. 1). It is known to deposit the most silt than any other rivers in the Indian subcontinent (Mahalik et al., 1996; Mahalik, 2000). The delta's fluvial upper portion is primarily composed of sediments deposited from the rivers in the region. The fluvial features can be segmented into major active river systems – Birupa, Mahanadi and Kathjodi-Debi systems. The drainage channels and the flood plains are the other major geographical features of the fluvial portion of the delta. Apart from the fluvial portion, there are ancient beach ridges, tidal flats along the coast with mangroves. These fluvio-marine features are found running parallel to the coastline (Somanna et al., 2013). The Mahanadi delta is a *meso* tidal delta and the tidal range varies from 2 to 3 m. (Mahalik et al., 1996; Kumar and Bhattacharya, 2004).

Mahanadi Delta, while being vulnerable on one hand, is also one of the most populated river deltas of India. The area has one of the most fertile agricultural lands and contributes positively to the national economy. Rice, oilseeds and sugarcane are the main crops produced in this delta. Good transportation network of the state helps in trading of these crops through the nearby well-developed cities of Cuttack and Sambalpur. This trading facilitates the welfare of the local agricultural community who earn their livelihood mainly through the sale of their crops in these cities. Floods have been a perennial problem in this delta. Puri, a city in the Mahanadi delta, being an active pilgrimage site, attracts a voluminous footfall in the region. Coastal erosion is, therefore, a threat to historically and culturally important buildings such as the centuries-old Puri temple.

2.2. Subdivision of the entire coastline into smaller sections

The coastline under study was divided spatially into 9 smaller sections, namely 'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H' and 'I' (Fig. 2). These divisions were made in such a way so that each division starts from a specific

Table 1
The list of satellite imageries used along with the date of acquisition and the tidal condition.

Year	Satellite imagery type	Date of acquisition	Spatial resolution	Tide (m)
1990	Landsat TM	1990-12-23	30 m	2.26
1995	Landsat TM	1995-12-21	30 m	2.30
2000	Landsat TM	2000-12-02	30 m	2.49
2006	Landsat ETM+	2005-12-24	30 m	2.21
2010	Landsat ETM+	2010-11-04	30 m	1.90
2015	Landsat OLI	2015-12-28	30 m	2.83