Morphological Change Analysis of Camorta Island, Nicobar Group of Islands, India using Satellite Remote Sensing Technique: A Case Study after 2004 Tsunami

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Abstract

The December 26, 2004, Indian Ocean Tsunami generated an undersea and megathrust earthquake with the epicentre at the west coast of Northern Sumatra that had made a very critical impact on coastal environments in the 16 Indian Ocean countries. This Massive tsunami registered a magnitude of 9.3 MW caused unexpected sea level rise and resulted in change in shoreline along most of the Andaman and Nicobar Island. Camorta Island, one of the Nicobar group of islands experienced worst damages. The study of coastline and morphology changes of Andaman and Nicobar Island was significant for understanding the damages caused by this tsunami. The delineation of shorelines and analysis of shoreline changes of Andaman and Nicobar Island for 22 years from 1992 to 2014 were done utilising the satellite imageries acquired by Landsat in ArcGIS environment. Landsat images collected on 1992, 2005 and 2014 were used for the study. The results showed that about 19 Sq.Kms of area had been eroded or submerged due to the Tsunami-genic and Non-Tsunami-genic activities. The Average Linear Regression Rate of the Eastern Coast of the Island between 1992 and 2014 is about -11.78m. The average Net Shoreline Movement is about - 239m observed on the eastern coast of the Island. In the Western Coast many regions were transgressed by the seawater and those regions show

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a High Linear Regression Rate of - 13m. Thus, this study gives an outlook of the changes that occurred due to the 2004 Tsunami.

1. Introduction

Shore line is a dynamic geomorphic feature that corresponds to the physical boundary between land and ocean (Maselli 2004). These Shore linesare being modified due to incessant waves, tides, near shore currents that results in transportation of sediments (Passeri et al. 2015). These changes may be due to unpredictable rapid or slow long-term natural processes as well as man-made involvements. In most of the cases, morphology of shoreline will change dramatically due to rapid-on set and slow-onset events like tsunami, earthquake, cyclone, sea-level changes, storm surge, flooding, wave action, tidal changes (Mukhopadhyay et al., 2011) which will have severe impact on life and livelihood of that region. The shoreline changes are analysed in terms of erosion and accretion, whereas the coastline moves towards land and ocean, (Chandramohan et al., 1993; Mahendra et al., 2017). These studies are significant and plays crucial role in designing the coastal sustainable management plan.

Andaman and Nicobar Islands drew the attention of various global communities for the huge morphological changes (Narayana et al., 2007) and losses to life and properties during the 2004 Indian Ocean tsunami triggered by the 9.3 Mw great earthquake (Bahuguna. A and Nayak. S 2008). This tsunami waves caused destruction to many countries that were associated with Indian Ocean i.e., India, Indonesia, Sri Lanka, Maldives etc. (Kench et al. 2006). Consequent to the tsunami, the Nicobar group of Islands of India which is close to the focus of the Great earthquake became first victim in India and witnessed huge damage to the coast. Moreover, it is believed that kilometres of coast were eroded and few Islands were submerged hundreds of meters below the earlier level. In current study, we have focused on Camorta Island that belongs to Nicobar group of Islands for understanding the coastal morphological changes that occurred in recent decades.

2. Study Area

Camorta Island (Kamorta Island) is part of Nicobar Group of Islands of India and located near to south-eastern coast of India (Figure 1). It is situated at 8.133°N latitude and 93.5°E longitude with highest elevation of 186 above MSL. This Island consists of about 3688 (2011 census) population and extended upto~136 km^2 in area with ~26 km length and ~8 km width. Camorta Island have ~108 km of coastline length and covered with dense forest/mangroves, wetlands, wastelands etc.

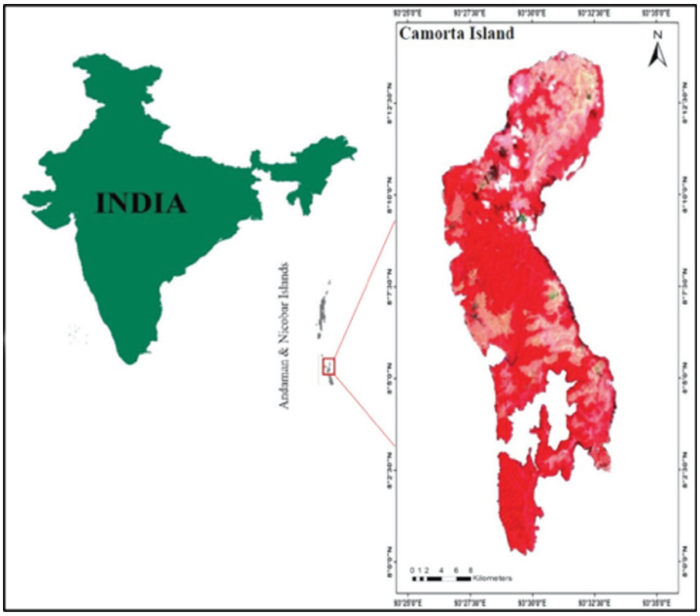

Figure 1: Study area map of Camorta Island, Nicobar Group of Islands, India.

3. Methodology and Materials

In this study, we have utilised the Landsat series satellite images for selected three years i.e., 1992, 2005, and 2014 (Table 1), from the USGS Earth Explorer for analysing the coastal morphological changes of Camorta Island that was induced by the 2004 tsunami (Figure 2) (Dolan et al. 1991; Fletcher et al. 2003; Ford 2013; White, K., and H. M. El Asmar, 1999). The selected satellite images were used to create False Colour Composite (FCC) and the shorelines changes of respective years and were digitized manually for better accuracy using Arc GIS environment. The digitized shorelines were further processed in Digital Shoreline Analyses System (DSAS) (Theiler et al. 2009) a plugin of USGS, which is added to Arc GIS. The DSAS used to estimate the rate of change of shoreline with the help of temporal data. Initially, the baseline is generated parallel to the shorelines by buffering them and followed by the DSAS manual procedures

(Himmel stoss 2009). This automated tool creates the series of lines i.e., transects perpendicular to these shorelines and baseline at our defined distance and then was used for calculating the rate of change statistics (Crowell and Leatherman, 1991). The DSAS can help us in providing the various types of shoreline change statistics such as Net Shoreline Movement (NSM), Linear Regression Rate (LRR) (Crowell and Leatherman, 1999), and End Point Rate (EPR). The detail methodology is shown in Figure 2. In addition, we also prepared the Land use and Landcover map of 1992 and 2014 for land use/land cover change analysis Figure 3.

Table 1: Data Specification and Land Area changes around Camorta Island during 1992-2014

Image acquisition date	Sensor	Source	Total Land Area (KM²)	Net Change (KM²)
1992/02/02	Landsat 5 TM	US Geological Survey	136 km²	-
2005/01/04	Landsat 5 TM	US Geological Survey	128 km²	8 km²
2014/03/02	Landsat 8 OLITIRS	US Geological Survey	117 km²	19 km²

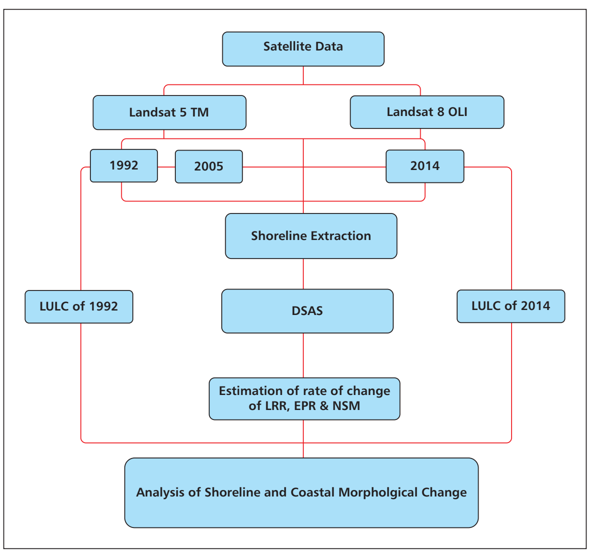

Figure 2: Methodology adopted for current study

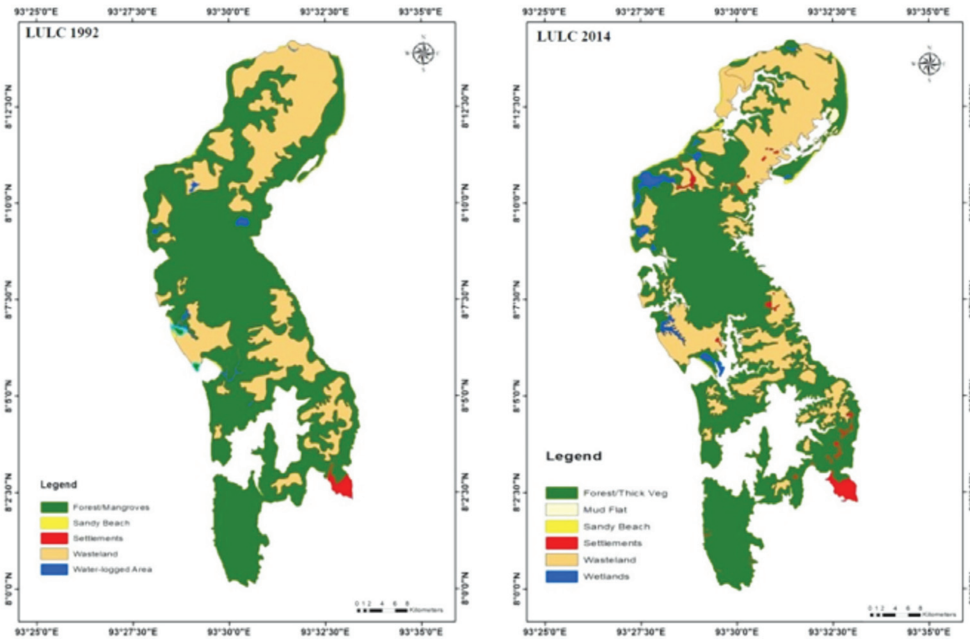

Figure 3: Land Use and Land Cover Maps for the year of 1992 & 2014

4. Results And Discussion

After processing the satellite images, the shorelines of 1992, 2005 & 2014 were digitized following the standard manual procedures and were interpreted for further analysis. The shoreline change statistics like Net Shoreline Movement (NSM) is calculated for 1992 to 2005 shorelines (Figure 4 (a)) and also for 1992, 2005, & 2014 shorelines (Figure 4(b)) of Camorta Island using the DSAS. The average NSM recorded is about -239 m/year and average LRR recorded is about the -11.78 m (Figure 5a). In addition, we also calculated the average EPR value as -11 m to understand the damages that caused by the tsunami-genic and non-tsunami-genic activities (Figure 5b). Further, we also prepared the land use and land cover map by analysing the changes that have occurred over the time (Figure 3) which clearly depicts that the West coast experienced the huge loss of land when compared with the East coast. After the 2004 tsunami, we can also see the increase in settlements inwards the Island and sandy beaches at the East coast. The results highlights the high rate of erosion occurred over all along the coastal line of

Camorta Island in 1992, 2005 and 2014. In 1992, the Island had of ~ 136 land km^2 total area. From 1992 to 2005, the total area is reduced to the 128 km^2 with Net change of 8 km^2 which means that this Island had experienced substantial reduction in land area due to the 2004 tsunami (Table 1) (Figure 6). This rapid changes have not only resulted in loss of land area but also costed its ecosystems. In continuation, we also calculated the shoreline change upto the year 2014 which again has shown the reduction of land upto 117 km^2. Again the rate of change was 11 km^2 which means that the total Net change was 19 km^2 (Figure 6). Thus, this Island has undergone significant loss of land not only due to 2004 Tsunami but also of other natural process till date. Overall, the Camorta Island lost its major portion of coast at West side than the East side (Figure 7).

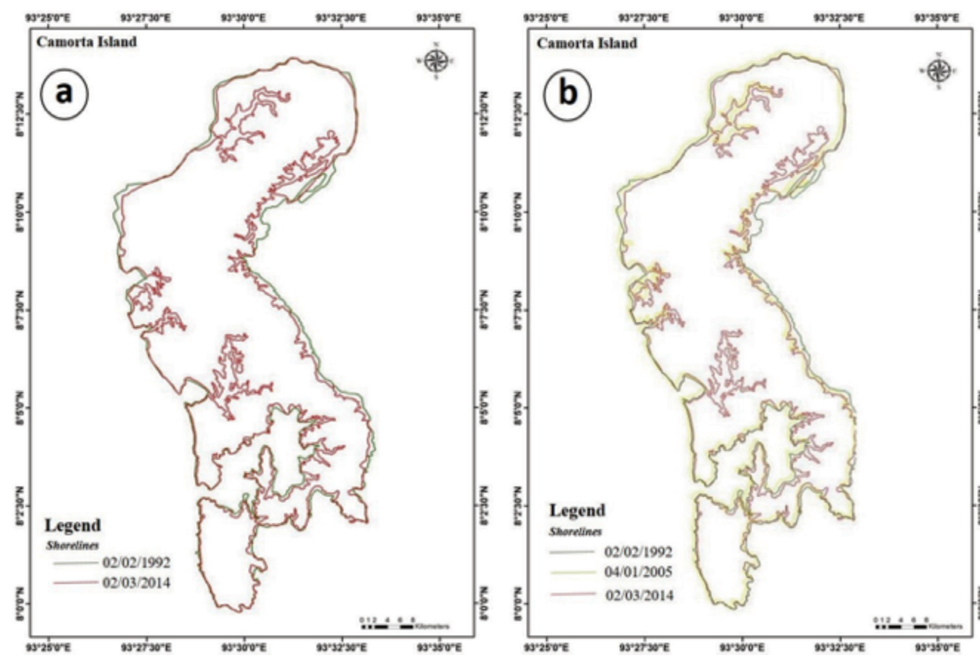

Figure 4: (a) Shorelines extracted for the year 1992 to 2014; b) Shorelines extracted for the years of 1992, 2005, & 2014

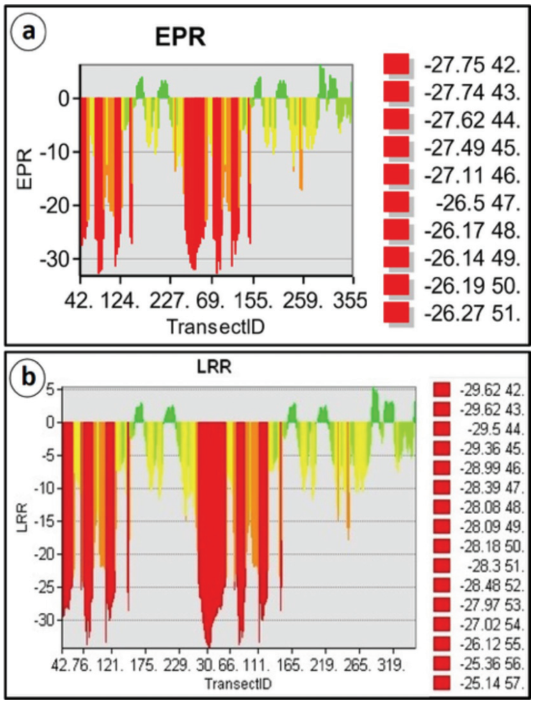

Figure 5: (a) Linear Regression Rate Graph from 1992 to 2014; (b) End Point Rate Graph from 1992 to 2014r

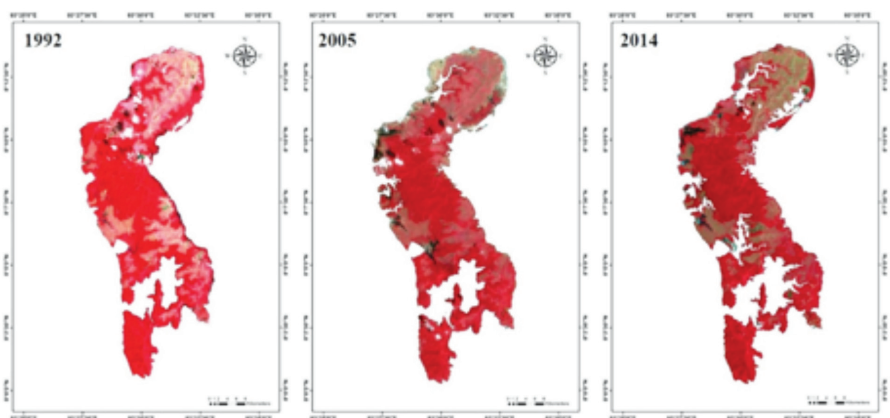

Figure 6: Shoreline and Coastal morphological change of Camorta Island before (1992), after 2004 Tsunami (2005), and latest (2014).

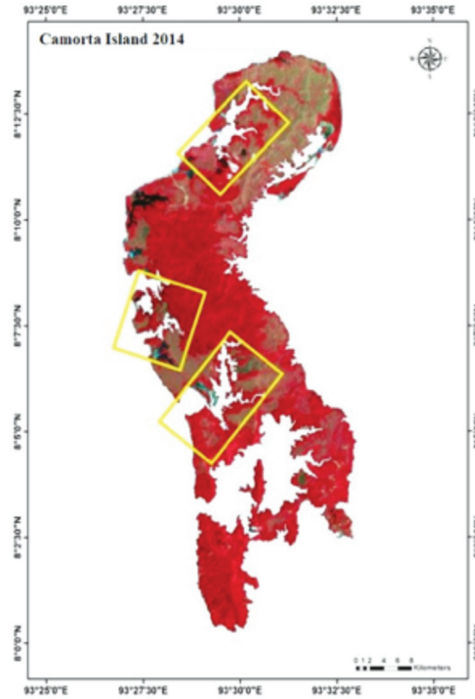

Figure 7: Major Morphological changes in the Camorta Island after the Tsunami 2004 to 2014.

CONCLUSION

The current study reveals the impact of 2004 tsunami and other natural processes on Camorta Island by using the archived satellite images and DSAS. This Island is highly vulnerable to rapid erosion not only due to rapid-onset disaster but also slow-onset disasters. The following results concludes that this Island is witnessing a high rate of erosion than accretion which shows that recovery of this land of this Island difficult and time taking. The recent developments in earth observation technologies and advanced tools like DSAS helps us to understand and continuously monitor the coastal morphological changes. In addition, we can also use the same methodology for analysing shoreline movements and the morphological changes for other coastal regions.

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