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Spatial and temporal changes in mangrove cover across the protected and unprotected forests of India

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ABSTRACT

Mangroves are vulnerable to natural environmental changes and anthropogenic disturbances; but, the status and change dynamics at a national level are poorly understood. Consequently, this research is aimed to assess the changes in major mangrove forests of India between the period of 1989 and 2013, covering an area of 62678 km^2 from five coastal states. Landsat satellite data, post-classification approach, and ground truth verification were used for the mapping of the mangroves and assessing the changes in protected and unprotected forest regions. Our findings revealed that mangrove extent has increased from 3006 km^2 to 3406 km^2 within the period of study. Of the mangrove extent, 91% in 1989 and 80% in 2013 were located in the protected forest regions. The annual average rate of increase in mangrove area was 0.55%/yr. The mangroves gained and lost were 918 km^2 and 517 km^2 respectively, of which 53% of the growth and 81% of the loss occurred in protected regions. Natural factors were responsible for 97% of gain and 92% of the loss of mangrove area. The anthropogenic drivers were responsible for the 8% of mangrove conversion. The extent of mangroves grown was greater than that of deforestation in India, unlike many other shrimp growing countries. The results of the present study indicate the areas of intense change in mangrove forests and also provide important insight into the supportive efforts of mangrove conservation.

1. Introduction

Mangrove forests, one of the most important and threatened ecosystems with a rich diversity of flora and fauna occupying a global extent of 83495 km^2, continue to reduce at a rate of 0.16–0.39% per year between 2000 and 2012 (Hamilton and Casey, 2016). They are the most carbon-rich forests in the tropics (Donato et al., 2011; Bhomia et al., 2016) and possess a commercial value to the order of 200,000 to 900,000 USD/ha. (Gilman et al., 2006). Mangroves offer ecological services and economic benefits to the local biota and coastal communities, including shoreline stabilization, habitat and biodiversity protection, fisheries and forestry products and coastal protection against natural calamities (Alongi, 2009; Sandilyan and Kathiresan, 2015). The world's mangrove area decreased by 20%, roughly between 1980 and 2005 (FAO, 2007) due to anthropogenic activities and unfavorable climatic and environmental conditions (Duke et al., 2007). Mangrove deforestation will result in disastrous negative consequences to coastal ecosystems and increase the carbon emission if unattended.

Studies on the mangrove forest extent and species diversity have increased over the past decades due to advancement in remote sensing (RS) techniques and the supporting capability of geographical information system (GIS). RS techniques provide a systematic approach for mangrove assessment studies because of synoptic viewing capacity, easy affordability, high level of precision and possibility of time series data for large and remote areas (Jayanthi et al., 2007; Kuenzer et al., 2011). RS captures raster data in different bands and offers a varied range of data products from aerial photographs to high-resolution images. Satellite data from Landsat series, SPOT, Indian Remote Sensing satellite series, IKCONOS, Quickbird are suitable remotely sensed data sources for mangrove mapping (Nayak and Bahuguna, 2001; Van et al., 2015). The choice of satellite images differs based on the requirement of the user, extent of study, data availability, and affordability.

Researchers have used low to high-resolution satellite data for mapping the mangroves (Seto and Fragkias, 2007; Thu and Populus, 2007; Paling et al., 2008; Rahman et al., 2013; Khairuddin et al., 2016). Though high-resolution images can give better accuracy, the high cost and stringent procedures existing to acquire the imagery restrict its routine use in many developing nations. Also, non-availability of high-resolution data for the earlier periods (the 1980s) makes us rely on

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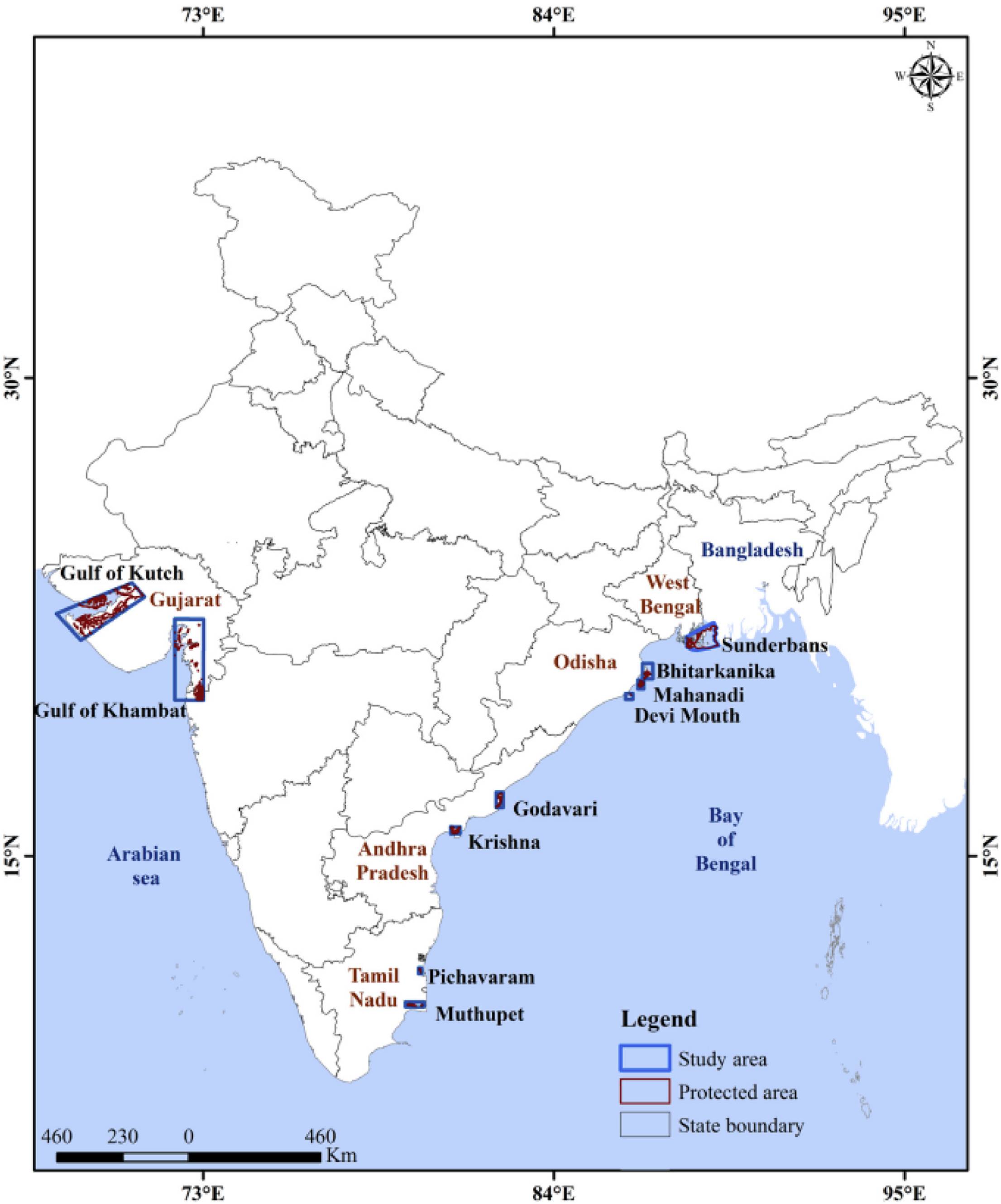

Fig. 1. Location map of ten major mangrove forests of India.

Landsat data available freely from 1988 to till date for the mapping of mangroves (Zhu and Woodcock, 2014).

Change detection methods include, multi-date data classification that combines dataset of two or more dates in a single analysis, and post-classification approach that combines two images from different dates after classified independently (Singh, 1989). The post classified comparison is considered as the preferred method for land use change analysis (Tewkesbury et al., 2015). Changes in mangrove forest extent assessed for the first time at a global scale (Hamilton and Casey, 2016) using the combination of existing products (Olson et al., 2001; Giri et al., 2011; Hansen et al., 2013), did not provide the drivers of change. Mangrove change dynamics was evaluated at a global scale (Thomas et al., 2017) for five segments such as North America, South America, the Middle East and India, Southeast Asia in the period of 1996–2010 and indicated that 12% of the radar mosaic tiles examined had evidence of loss. However, the study did not deliver the extent of change at a national level, which is needed for planning and execution of the conservation. Rates and drivers of mangrove deforestation in Southeast Asia indicated a loss of 0.18% per year, primarily to aquaculture and agriculture (Richards and Friess, 2016). Assessment of the distribution and dynamics of the mangrove forests of South Asia indicated a net loss of 117 km^2 between 2000 and 2012, but the detailed change dynamics were conducted only for three sites, namely the Indus Delta, Goa and the Sundarbans (Giri et al., 2014). Researchers have used RS and GIS to assess the changes in Indian mangrove wetlands as case studies, viz. The Godavari delta of Andhra Pradesh, Pichavaram of Tamil Nadu, the Sundarbans of India and Bangladesh and the Mahanadi delta of Odisha (Satapathy et al., 2007; Giri et al., 2007; Rajitha et al., 2010; Jayanthi, 2011; Pattanaik and Prasad, 2011; Quader et al., 2017; Jayanthi et al., 2018). A close perusal of literature revealed that the studies carried out