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Detecting changes and health status of mangrove forest in Achara estuary, Maharashtra using remote sensing and GIS

Detección de cambios y estado de salud del manglar en el estuario de Achara Maharashtra utilizando sensores remotos y SIG.

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ABSTRACT

Mangrove forests protect the Western coast of Maharashtra from natural disasters striking from seaward and riverside. The quantity and quality of mangroves were influenced by the morphological and hydraulic characteristics of estuaries. The study aims to identify the Spatio-temporal changes that took place in the mangrove forest of Achara estuary in the last four decades since 1989. It also highlights the zonal horizontal distribution of mangrove land from its mouths to the head of the estuary. Most of the mangroves concentrate in the zone that comprises the area of 1-3 km from the mouth. A gain of 39.17% of the mangrove area shows the growth of mangroves in the study area during this period. NDVI value, which ranges from 0.123 to 0.560, acknowledged the dense and healthy status of mangroves in Achara estuary.

Keywords: Mangrove distribution, Non-mangrove area, NDVI, Change Detection, Remote sensing and GIS.

RESUMEN

Los manglaresprotegen la costa occidental de Maharashtra de los desastres naturales que ocurrendesde el mar y la ribera. La cantidad y calidad de los manglaresfueroninfluenciados por las característicasmorfológicas e hidráulicas de los estuarios. El estudiotienecomoobjetivoidentificar los cambiosespacio-temporales que tuvieronlugaren el bosque de manglar del estuario de Achara en las últimascuatrodécadasdesde 1989. Tambiéndestaca la distribución horizontal zonal de la tierra de manglardesdesudesembocadura hasta la cabeza del estuario. La mayoría de los manglares se concentranen la zona que comprende el área de 1-3 km de la boca. Una ganancia del 39.17% del área de manglaresmuestra el crecimiento de los manglaresen el área de estudioduranteesteperíodo. El valor de NDVI, que oscila entre 0.123 y 0.560, reconoció el estadodenso y saludable de los manglaresen el estuario de Achara.

Palabras clave: distribución de manglares, área no manglar, NDVI, detección de cambios, teledetección y SIG.

INTRODUCTION

Mangroves are the salt-tolerant, littoral shrub growing in the intertidal zone. Mangroves enclosed up to 75% of the tropical and subtropical shorelines (Giri et al. .2011, Spalding et al.1997). Mangroves cover 152,000 square kilometers area of 123 countries of tropics and warm temperate regions across the world. Mangroves provide food, shelter, and breeding sites to aquatic animals and birds(Chen et al. 2013). They also protect the coast from tidal waves and wind destructions. Mangroves grant habitat for a variety of flora and fauna(Lu et al. .2004, Murray et al. 2003). Its tangled roots settled sediments that ultimately resist erosion and trapped pollutants to mix in estuarine water, which promotes sedimentation within the estuary (Ibrahim et al. 2013). The sedimentation rate varies with the local condition (Woodroffe et al. 2016). According to Saenger, the rate of deposition trapped by mangroves varies from 1 -8 mm/year, and that causes vertical estuarine material accumulation up to 5 mm/ year in different regions (Saenger,2013). Mangroves are influencing the physical as well as the economic environment of coastal people in the tropical region (Saenger et al.1983). Regrettably, in most of the areas of the world, mangrove forests are declining (Alongi 2002,Concheddaa et al.2008). Therefore preservation of the coastal ecosystem depends on mangroves conservation. The growth and degradation of mangroves forest modify the morphological characteristics of the estuary. The expansion of mangrove forest takes place in high sedimentation and wave protected areas (Adi 2016), whereas coastal development with artificial construction damages mangrove cover (Chen et al. 2013). Intertidal land was considered as public property, which will be utilized for commercial purposes, i.e., shrimp farming at no cost or at least cost, which triggers the rate of mangrove deforestation (Balance 1998). Researchers throughout the world are monitoring the change in mangrove swamps (Giri et al.2011,Chen et al. 2013,Alongi 2002,Giri et al. 2007, Selvam et al. 2003). The management and conservation of mangroves depend on monitoring changes in mangrove habitat (Nurul 2016). It depends on the study of horizontal areal distribution of mangroves and knowledge of the quality of mangrove plants, which determined using the Normalized Difference Vegetation Index (NDVI). Variations in the

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density of mangrove canopy through NDVI reveal the expansion or degradation of the mangroves area (Zaitunah 2018). However, the large forested areas are difficult to access, which are covered by Satellite imageries. Remote sensing and GIS are efficient techniques for quick evaluation through change detection techniques (Lu et al. 2004). Remote sensing data is one of the reliable sources to study the distribution of mangrove. Whereas change detection analysis in GIS is helpful to evaluate Spatio-temporal variations that occurred in mangrove land over the stipulated period (Sremongkontip et al. 2000). The goal of the investigation is to identify the Spatio-temporal changes in the mangrove forest of Achara estuary in the last four decades since 1989. It also highlights the zonal horizontal distribution of mangrove land from its mouths to the head of the estuary.

MATERIAL AND METHODS

Area of study: Achara estuary locates on the southern coast of the Konkan strip in Maharashtra. This area comes under the assured and high rainfall region with average annual rainfall 2300 mm, the average annual temperature between 18 °C to 32 ºC and Relative humidity between 58 to 90%. It covers about 5sq km area consisting of two prominent parts- first is carrying the main channel, which extends up to 9 km, whereas the second part lies along the tributary of Achara River, which meets from the east near the mouth of the estuary (1.6km). Achara estuary has broadened at lower and middle reaches with tapering ends towards its head showing variation in its width.

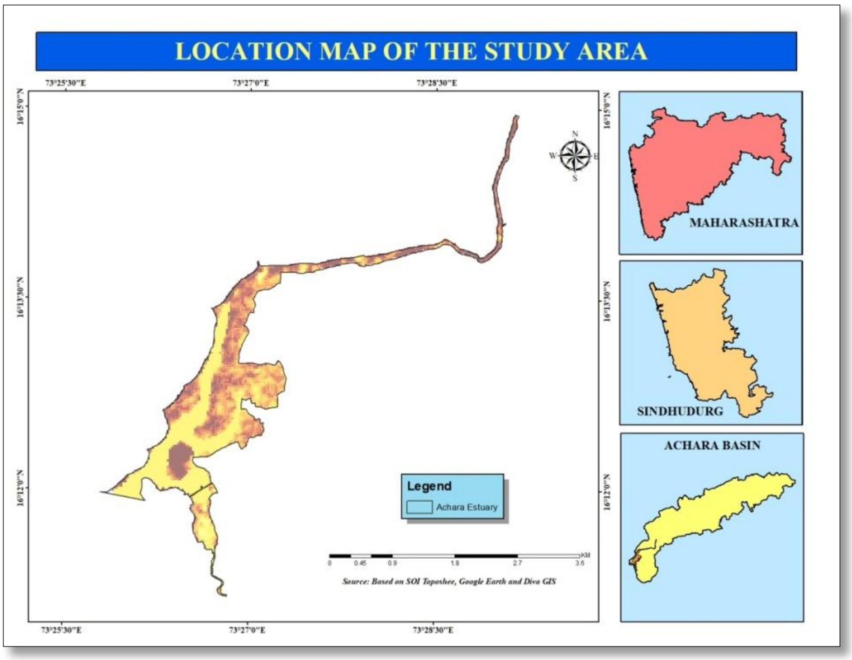

Figure 1. Study area: Achara estuary

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Data collection: For the change detection, base images like Thematic Mapper (TM) images (1989, 1999), Landsat Enhanced TM Plus image (2009), and Operational Land Imager, OLI (2018) of 30 m resolution was acquired from USGS earth explorer. Sentinel-2B (Resolution 10 m) has used for NDVI analysis. Google earth image was taken at the base to study the distribution of mangroves; furthermore, Intensive fieldwork was carried out for hybrid classification to evaluate the current status of mangroves in Achara estuary.

Methods: Change detection was calculated using the mathematical formula: (A present-A past)/A past× 100, where A past and A present are the areas under mangroves and non-mangrove land of Achara estuary in the past and present decades respectively. For studying the horizontal distribution of mangroves, zones of one kilometer have been delineated across the estuary from seaward to the landward side. ArcGIS 9.3, ERDAS IMAGINE 9.1 software was used to process, analyze, and evaluate the images.GCP points of mangroves were collected with GARMIN GPS to support the classification. NDVI analysis was adapted to perceive the health status of mangroves covers in each estuarine zone of Achara estuary.

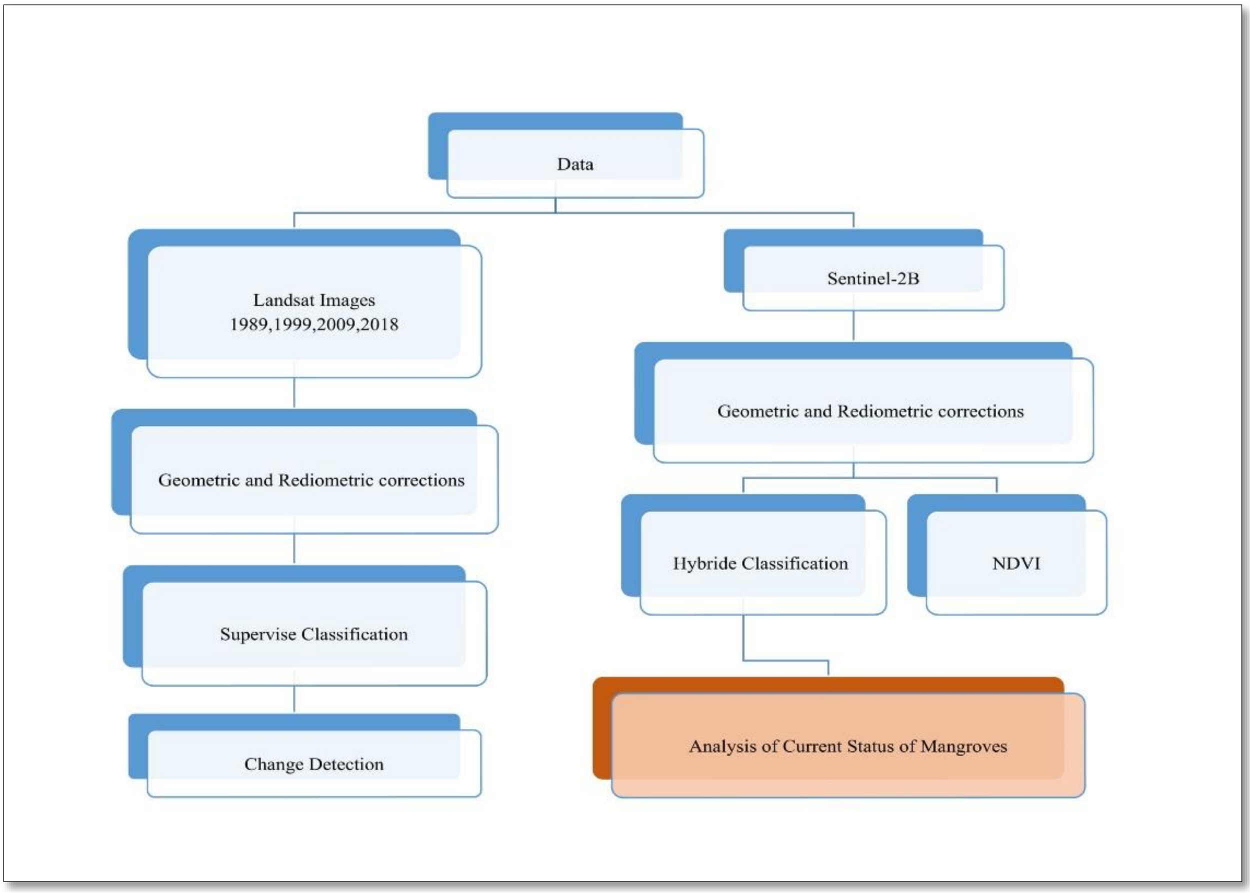

Figure 2. Methodology

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RESULTS AND DISCUSSIONS

Change detection analysis: Geometrically corrected Landsat images of the years 1989, 1999, 2009, and 2018 with 30 m resolution were used to perform change detection analysis in the mangrove area for forty years. By applying supervised classification, the whole estuary divides into two broad categories – Mangrove and non-mangrove area to avoid complexity. Where non-mangrove area includes other features such as mudflats, sand bars, island, water channel as well as artificial construction in the estuary.

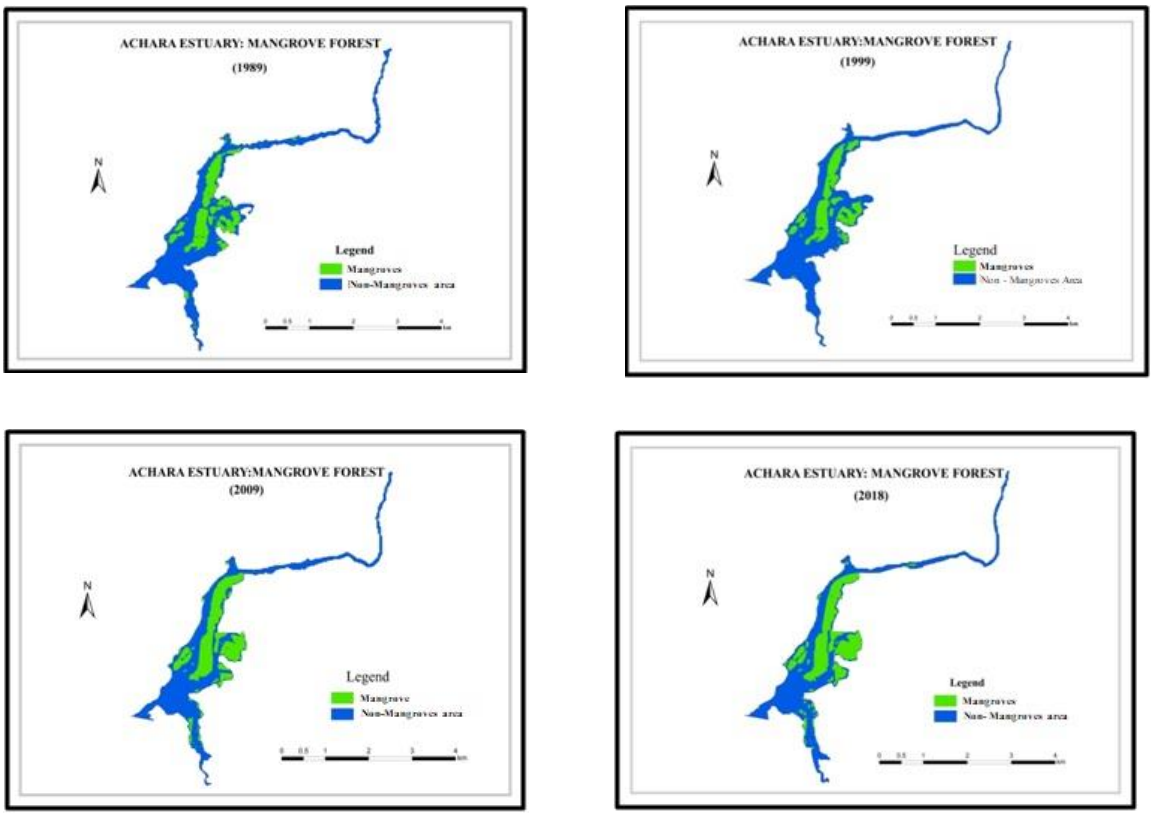

Figure 3. Decadal change in mangrove forest area from 1989-2018

Over forty years, the mangroves abundantly grew in the study region except for the year 1999(Fig 3). Initially, in 1989, mangroves spread over 97 ha area occupying 27.40 % of the entire estuary. From 1989 to 1999, Mangrove cover minimized with a drop of 9.28% (-9 ha) as the result of the overutilization of mangrove forests to fulfill the basic anthropogenic needs of local people. During this period, mangroves were cut down and used as fuelwood; besides this, it used as timber for fencing and construction of houses. The utmost mangrove change occurred from 1999 to 2009, where mangroves were grown rigorously with a rise of 44.32% (39 ha) in the mangrove area so that the mangrove-covered area altered from 24.86

% (88 ha) to 35.88 %(127 ha). It is the impact of the implementation of the CRZ (Coastal Restriction Zone) act. As a result, the ill-legal destruction of mangrove forests was ultimately restricted, which develops awareness about the mangroves among the local people. Achara estuary has an idealistic site for mangrove environments. This estuary is blessed with high sedimentation, protected from direct tidal impact, availability of fresh water sources, etc. hence, the government chose this site for artificial plantation of mangroves for seedlings production, which is another reason for its enormous growth during this period. In the next decade, mangroves show meager growth with an increase of 8 ha area (6.30%).

Table 1: Change Detection in Mangrove Cover of Achara Estuary

Period	Mangrove Area		Non-Mangrove Area	
	ha	%	ha	%
1989	97	27.40	257	72.60
1999	88	24.86	266	75.14
2009	127	35.88	227	64.12
2018	135	38.14	219	61.86

Source: Based on analysis of Landsat Images

Table 2: Decadal Change in Mangrove Cover

Decadal change	Mangrove Area		Non-Mangrove Area	
	ha	%	ha	%
1989-1999	-9	-9.28	9	3.50
1999-2009	39	44.32	-39	-14.66
2009-2018	8	6.30	-8	-3.52
1989-2018	38	39.17	-38	-14.79

Source: Computed from table 1.

Current status of mangrove forest with zonal distribution: Fig no.4 depicts the distribution and share of diverse natural and anthropogenic features within the estuary. In 2018, area of the estuary incorporated with mangroves (135.2 ha) and the non-mangrove area which is primarily constituted by a Sand bar (0.077 ha), Mudflats (2.539 ha.), Beach (2.407 ha), Island (1.362 ha) Marshland (1.379 ha).

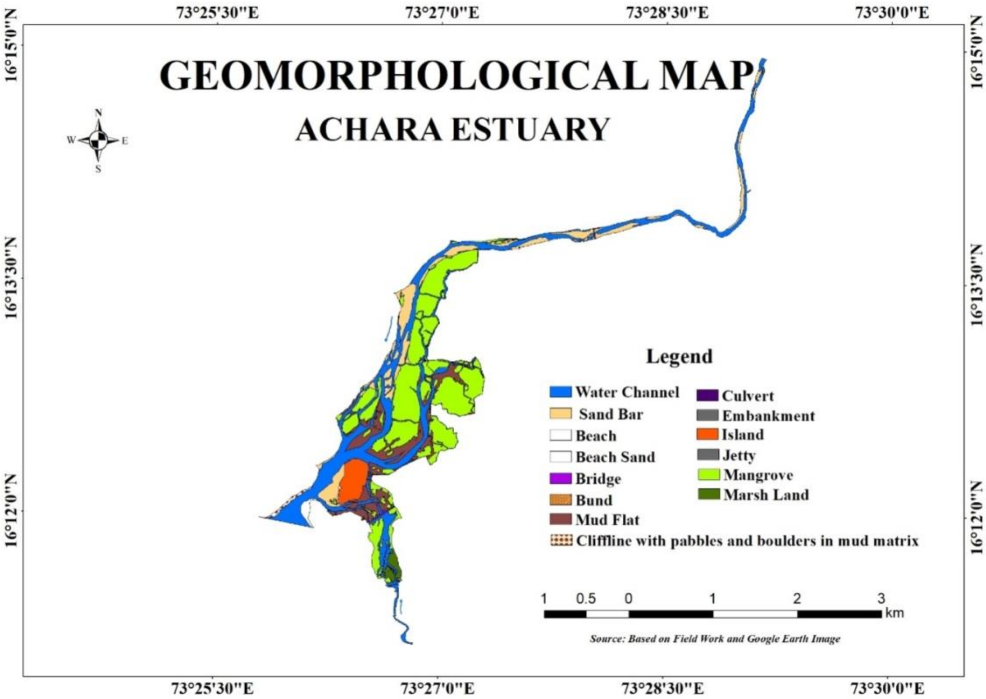

Figure 4. Geomorphological Map.

Figure 5. Dense mangroves with tangled roots in Achara estuary

Figure 6. Artificial plantation of mangroves

In Achara estuary, the strip of mangrove extends up to 6 km from the mouth. Maximum mangroves (60.908 ha) found within the stretch of 2-3 km along the main estuary that followed by 26.843 ha and 20.754 ha mangrove area, which covered up in the zones lies between 1-2 km and 3-4 km respectively. Least density of mangroves noticed along 0-1km (0.276 ha) and 5-6 km (0.494 ha). The zonal pattern indicates that from the middle zone (2-

3km), at both the direction, i.e., towards the mouth and the head of the estuary, the mangrove area decreased significantly due to a decline in freshwater and saline water content respectively. Mangroves concentrate at the confluence zone (1-2 km) at the Hirlewadi branch of estuary, i.e., 9.891 ha. Afterward, the mangrove area declines notably (insert Table 3 here).

NDVI values: NDVI reflects the health condition and density of mangrove forests. Its high value represents the healthy status of mangroves while lower value associated with unhealthy sites of mangroves[Zhang et al. 2005] . The almost estuarine area covers with healthy and densely populated mangroves NDVI value ranges from 0.34 to 0.56. The lower value determines the unhealthy condition and sparse distribution of mangroves along the zones, i.e., 0-1 km near the mouth and 2-3 km at the Hirlewadi branch of the estuary.

Table 3: Zonal horizontal distribution and NDVI value of mangrove forest

Distance from mouth	Area (ha)	NDVI value
0-1 km	0.276	0.275-0.123
1-2 km	26.843	0.529-0.347
2-3 km	60.908	0.560-0.393
3-4 km	20.754	0.542-0.371
4-5 km	13.031	0.517-0.385
5-6 km	0.494	0.522-0.342
1-2 km(Hirlewadi side)	9.891	0.511-0.267
2-3km(Hirlewadi side)	3.014	0.462-0.267
Total	135.211	

Source: Based on Supervised and NDVI classification of Landsat 8-OLI (2018)

As conclusion, currently, a total of 108.505 ha area comprises within the 1-4 km patch of Achara estuary with a dense canopy. NDVI value of most of the mangrove area fluctuates within 3.7 to 5.6, which is the indicator of healthy mangrove biodiversity. Change detection analysis indicates that from the year1989 to 2018, the Mangrove area was increased by 39.17% (38 ha), which occupies 38.14% area of Achara estuary. The non-mangrove area was directly affected by an increase in the total mangrove area. The non-mangrove area was reduced by 38 ha in the last four decades (from 72.60% to 61.86%). It was due to the CRZ implementation and meager use of estuarine resources for commercial purposes. This trend will continue in the coming years. As a result, the rise in the mangrove area triggers the rate of sedimentation which directly influenced the hydraulic characteristics of the estuary.

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