

USING REMOTE SENSING AND GIS TECHNIQUES FOR DETECTING LAND COVER CHANGES OF MANGROVE HABITATS IN GOA, INDIA

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ABSTRACT

Ecologically Sensitive Marine Habitats (ESMH), including mangroves ecosystems, is of immense ecological and socioeconomic values. Goa, a tourist destination, has limited cover of such habitats and has been intensively subjected to anthropogenic pressures during the past decade. Time lapse (1997, 2001 and 2006) satellite data (IRS-1C LISS III, IRS-1D LISS III and IRS-P6 LISS III) indicated alterations in land use patterns. The present study showed that mangrove habitats in Goa have increased by 22 % in area between 1997 and 2006. The increase in mangrove cover could be attributed to rehabilitation as well as invasion by mangroves of agricultural farms, inundated due to breach of embankments. Present findings may be of a great help in understanding the changes in ESMH and for formulating effective strategies for their conservation and rehabilitation.

Key words: Remote sensing, Mangrove, land use pattern, change detection, conservation and rehabilitation.

INTRODUCTION

Coastal areas around the world are currently experiencing the impact of human activities dealing with economic, land use, and resource development. India in particular is facing increasing stress as a result of cumulative environmental changes driven by urbanization, industrialization, unsustainable growth, and ever increasing population leading to degradation of coastal zones and ecosystems (Jagtap *et al.*, 2003).

The land cover change is a complex environmental indicator from regional to global level, and an important aspect of resource management and environmental mitigation. Therefore, any unplanned interference can prove detrimental to its inherent value. Trends in vegetation cover dynamics, is an important aspect as it provides information about landscape processes and ecological status. Remote Sensing data having good spectral and spatial resolution are found to be very effective in evaluating and monitoring land use and land cover changes (Lillesand *et al.*, 2004). Beach and estuarine habitats are vulnerable to alteration due to constant human interferences of various natures.

Classifying the marine habitats would be of help in formulating effective management strategies and environmental policies, which is useful in mitigating the impacts of natural hazards.

Preparing and upgrading vegetation inventories for certain regions, in different times, used for detecting the vegetation changes in those regions. This is more easily obtainable using satellite imageries and thematic mapper techniques. However, ground truth data collection, literature reviews, visual map interpretation, and collateral and ancillary data are most significant in confirmation and substantiate the satellite data interpretation and production of final maps.

The mangrove cover in Goa is estimated to be about 0.3 to 0.5% (\approx 2,000 hectares) of the total mangrove cover of India (Untawale *et al.*, 1982; Jagtap & Nagle, 2007). Mangroves in Goa are mostly fringing type and occur densely along all the estuarine banks. Major formations occur along Mandovi-Zuari-Cumbarjua estuarine complex, which is approximately 80% of the total mangrove cover in Goa (Jagtap, 1985). Marine vegetation, particularly mangrove, plays a significant role in stabilizing the shores by preventing soil erosion. They serve as breeding grounds for various types of fauna, and also increase the productivity of the region and near shore waters. During recent years, Goa has been undergoing tremendous changes in its land use patterns (Murali *et al.*, 2006). The present investigations were aimed at understanding the changes in mangrove habitats of Goa during the past decade. The data generated would be of importance in protecting and conserving mangrove habitats, which are limited in the state.

METHODOLOGY

Satellite imageries of January/ February months of the years 1997, 2001 and 2006 were selected for the study, based on less cloud cover, bright sunlight, luxuriant growth of vegetation and favorable sea conditions.

Time lapsed False Color Composites (FCC) imageries of IRS-1C LISS III, IRS-1D LISS III and IRS-P6 LISS III with resolution of 23.5 m, obtained from the National Remote Sensing Agency (NRSA), Hyderabad (Figure 1). Survey of India topographical sheets pertaining to Goa (48E/9, 48E/10, 48E/13, 48E/14, 48E/15, 48E/16, 48I/1, 48I/2, 48I/3, 48I/4 and 48J/1) in the scale of 1:50,000 scale for the years 1962-1979 were used as ancillary data for extracting terrain features and also for registering and geocoding the satellite imageries.

Imageries were resampled using the nearest neighborhood method. The projection applied in this study was geographic with spheroid Everest. The geo-referenced satellite imageries were then subjected to digital image processing techniques for enhancement, which involved brightness/contrast technique. Various land cover classes were identified and delineated recognizing spectral pattern (Chandra & Gosh, 2006). A supervised classification process was followed selecting homogeneous training areas for different features of interest. The training data sets were evaluated for separability to determine the distinctiveness of the class signatures.

Supervised classification performed using maximum likelihood classifier and resultant thematic maps were utilized for accuracy assessment. It is essential to incorporate the other related ground information on the manually interpreted map (Ramachandran *et al.*, 1998); therefore, the relevant ground truth information was collected from different locations using GPS.

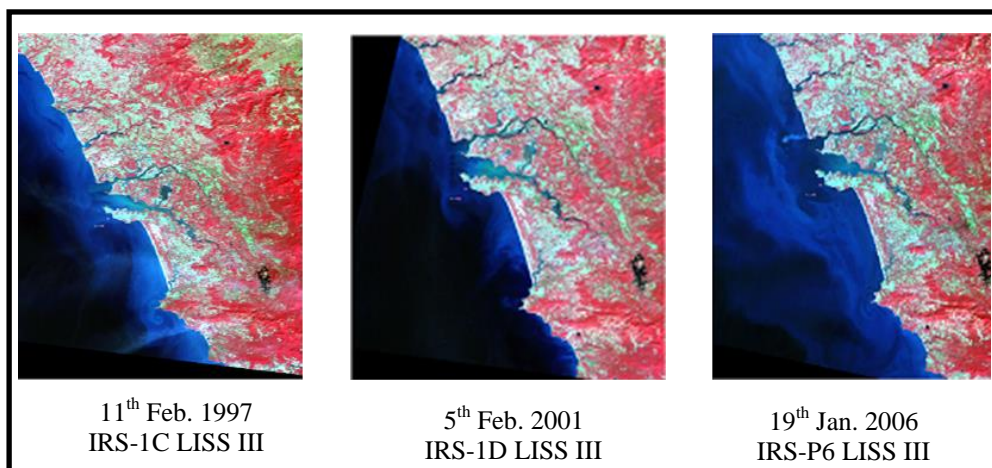


Figure 1: Time lapsed satellite data used in the study.

Different layers of mangrove location maps, and calculation of mangrove areas in each location in the three years were performed using GIS techniques, and results were expressed in hectares (ha).

RESULTS

Mangrove habitats are mainly confined to the intertidal region along banks of the nine major rivers and minor creeks of Goa (Figure 2). The distribution and area changes in major formations have been described in the following text.

Terekhol River

The Terekhol River represents the border between Goa and the State of Maharashtra in the north. It is about 26 km in length, and covers approximately 349 ha of water area. During 1997, mangrove cover was estimated to be 27.2 ha. It increased by 12.82% (30.7 ha) along the river banks and islands from the year 1997 to 2001. However, it slightly decreased (1.96%) to 30.1 ha during 2006. The overall increase of 2.89 ha in the mangrove cover was observed from 1997 to 2006 with an increase of 10.60%.

Chapora River

Chapora River runs about 30 km in length, covering ~ 711 ha of water area. The present investigation revealed reduction in mangrove area from 220.1 ha in the year 1997 to 219.3 ha in 2001, with a slight loss of 0.36% of its area. It was further decreased to an area of 218.5 ha in the year 2006 to add 0.38% of its loss. Thus, the total loss in mangrove area between 1997 and 2006 was estimated to be 0.74%.

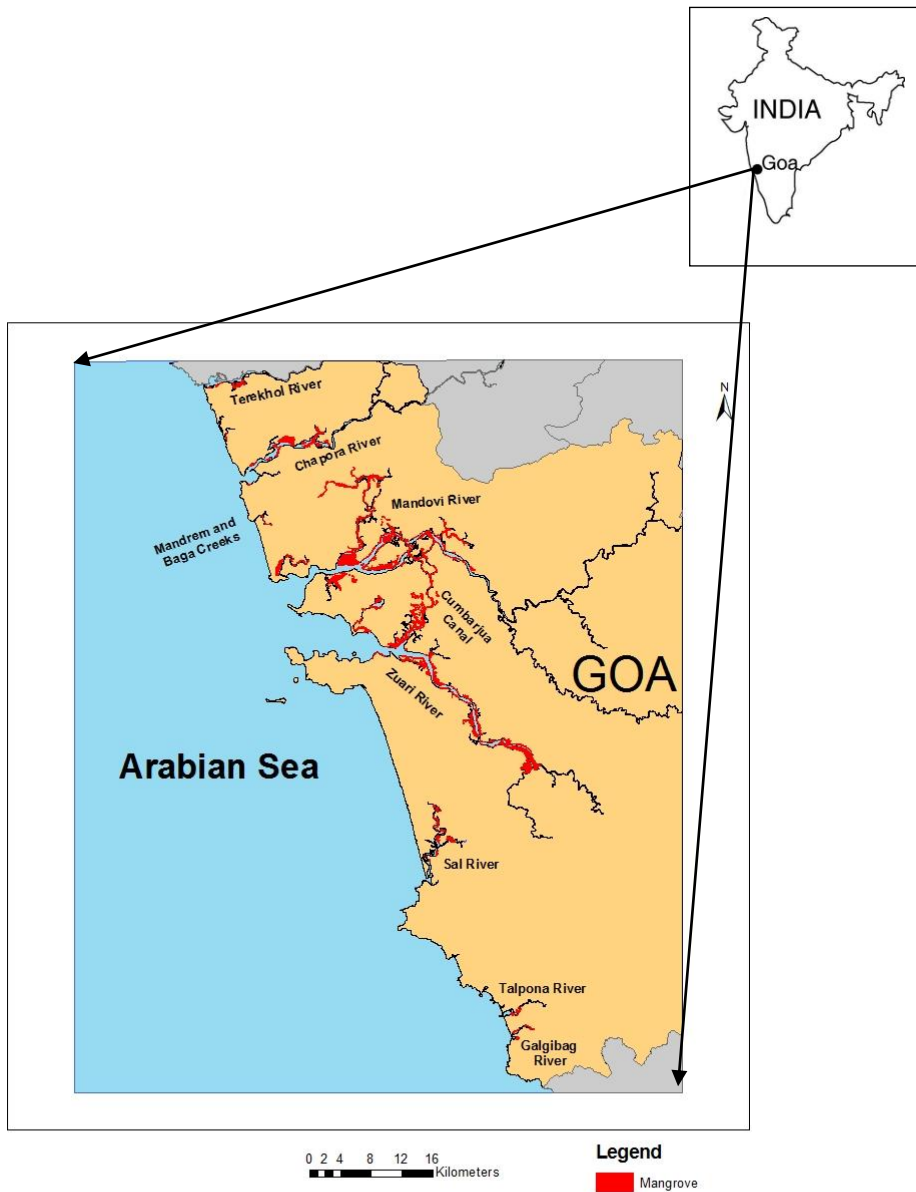


Figure 2: Distribution of mangrove habitats in the state of Goa.

Mandrem and Baga Creeks

Mandrem and Baga represent relatively very small creeks 3.3 km and 5.4 km in length, respectively. Mangroves of Mandrem creek showed a slight increase (0.01 ha) in area cover from in 1997 (1.18 ha) to 2001 (1.19 ha) and further increased up to 1.20 ha in 2006. The overall increase was 0.02 ha.

The satellite imageries showed steep decrease from 6.6 ha in the year 1997 to 5.0 ha in 2001 with a loss of 1.63 ha (24.58%) of its area. However, it was further reduced to 4.48 ha in 2006 with an overall loss of 32.36% during 1997 to 2006.

Mandovi River

Mandovi River forms one of the major rivers in Goa. It covers about 5564 ha of water area along its 58 km length. Satellite data showed mangrove cover of about 811.1 ha in 1997, which increased by 244.57 ha (30.15%) to cover an area of approximately 1055.7 ha during 2001, and continued to increase further between 2001 and 2006 by 51.47 ha (4.88%). The 2006 mangrove was estimated to an area of about 1107.2 ha. Overall increase in mangrove cover from 1997 to 2006 was found to be approximately 296.1 ha (36.50 %) from 1997 to 2006.

Zuari River

Zuari River occupies approximately 5790 ha of water body, along about 145 km stretch of which 64 km is navigable. Mangrove vegetation cover decreased by 2.54% from about 693.9 ha in the year 1997 to around 676.3 ha in 2001. However, it showed increase of 8.71% accounting to 735.2 ha in the year 2006, with overall addition of about 41.3 ha (5.95%) from 1997.

Cumbarjua Canal

Cumbarjua Canal is an interconnection between Mandovi and Zuari Rivers, which form what so called "Mandovi-Zuari-Cumbarjua estuarine complex". Cumbarjua Canal is about 15 km in length and 30 - 40 m in width. It covers about 375 ha of water area. The area of mangrove shows increase by 8.88% from the year 1997 (~ 224.3 ha) to the year 2001 (244.2 ha). The area continued to increase extensively by 40.23% to reach an area cover of 342.4 ha in the year 2006, with overall increase of 52.68% (118.15 ha).

Sal River

Sal River, in southern Goa, has an area of about 302 ha of water body, and it is about 16.13 km in length. The mangrove area decreased from 57.6 ha in the year 1997 to 54.9 ha in the year 2001. The area then increased by 20.78% to 66.3 ha. The results show overall increase by 15.04% (8.67 ha) between the years 1997 and 2006.

Talpona River

Talpona River covers about 40 ha of water body, and It has a length of 9 km. Mangrove cover did not show much difference in the time lapsed imageries. The area in 1997 was 14.6 ha; it changed slightly to about 14.7 ha in the year 2001 and then decreased to about 14.6 ha in 2006.

Galgibag River

Galgibag River covers about 26 ha of water area, with a length of 3.77 km. the mangrove vegetation showed a decrease between the year 1997 and 2006. The satellite imageries show an area of about 26.7 ha in the year 1997 which decreased to 22.9 ha in the year 2001. The area decreased further to 18.8 ha in the year 2006. The overall loss in mangrove vegetation between the years 1997 and 2006 was 29.44% (7.86 ha).

Table 1 summarizes the details of mangrove area change in Goa's rivers. Figure 3 illustrates area change of mangroves in some rivers of Goa.

Table 1: Details of mangrove area change in Goa's rivers.

Year	1997	2001	2006
River	Area (ha)	Area (ha)	Area (ha)
Terekhol	27.22	30.70	30.10
Chapora	220.08	219.28	218.46
Mandrem	1.18	2.20	1.20
Baga	6.63	5.00	4.48
Mandovi	811.12	1055.69	1107.17
Cumbarjoa	224.27	244.18	342.42
Zuari	693.94	676.29	735.22
Sal	57.63	54.89	66.30
Talpona	14.58	11.69	14.60
Galgibag	26.71	22.90	18.85
Total	2083.35	2322.73	2538.79

DISCUSSION

The State of Goa, along the Central West coast of India, lies between 14°55' to 15°45' N, and 74°40' to 74°10' E, with a coastline of 105 Km long. Physiographically, it is divided into the coastal tract consisting of recent broad alluvial plains, estuaries, cliffs, river mouths, beaches and dunes, the tract between the coast and the Ghats (sub-ghats region) and the Western Ghats (Wagle, 1982). The coast trends NNW – SSE more or less in a straight line. The coastal zone of Goa is traversed by seven major dynamic estuarine rivers and four minor river systems where the tidal effect can be felt up to above 50 Km in the hinterland (Shetye *et al.*, 2007).

The climate of Goa is warm and humid and distinguished by three seasons, pre-monsoon (February to May), the southwest monsoon (June to September) and, the post-monsoon (October to January). The region receives an average rainfall of approximately 3000 mm/yr. The coast is micro tidal (tidal height <2m) in nature (Ahmed, 1972) and tidal currents always remain stronger than estuarine flow.

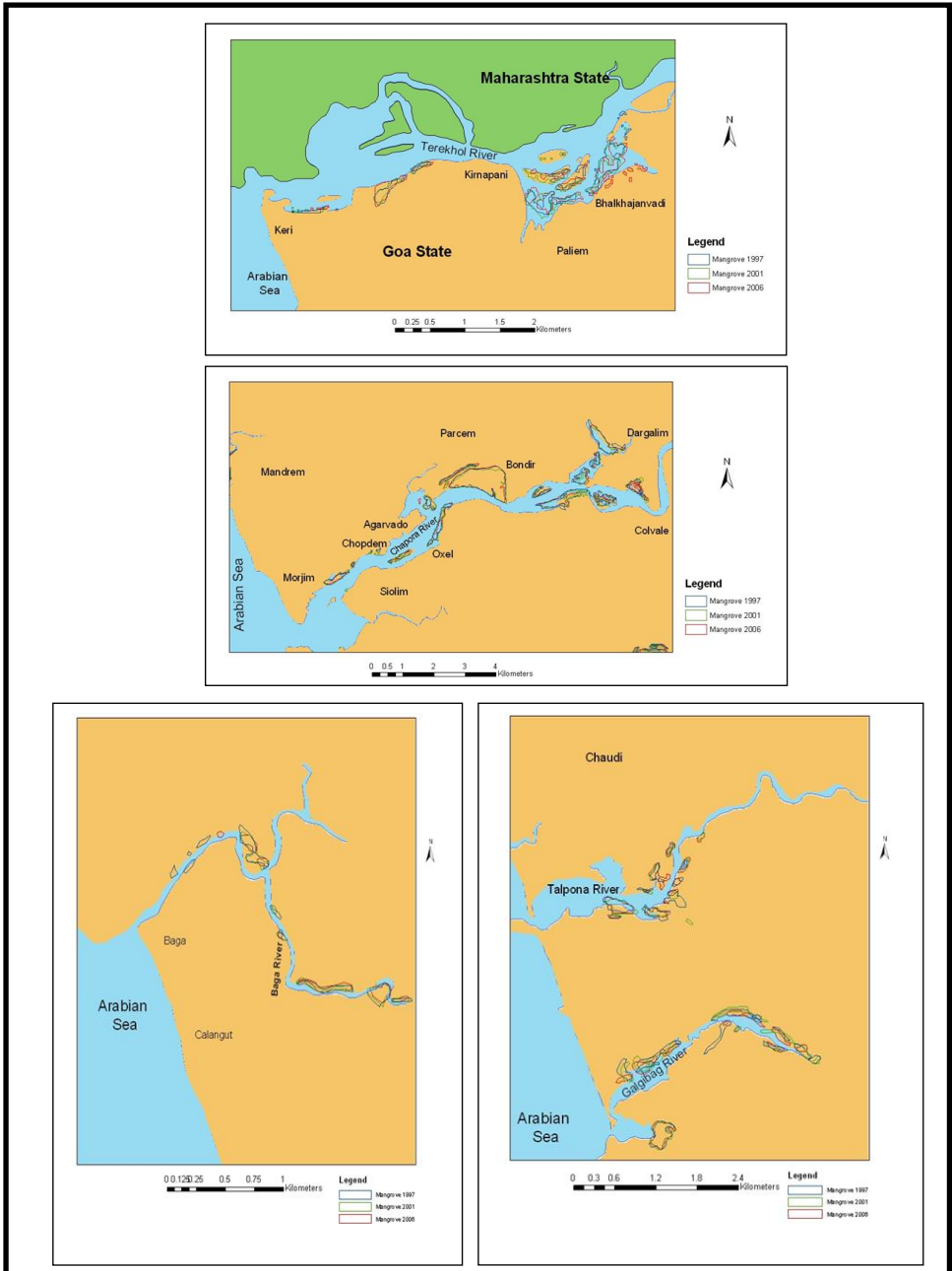


Figure 3: Distribution and area change of mangroves in some rivers of Goa.

Marine wetlands support highly productive and dynamic ecosystems, such as mangroves, coral reefs, seagrasses and sand dunes. Mangroves habitats harbour characteristic flora and fauna of marine as well as terrestrial origin, and also include endangered and endemic species (Clark, 1998). They play a vital ecological role by dissipating energies from waves as well as speedy run from terrestrial water, thus protecting shorelines from various natural coastal hazards (Kathiresan & Qasim, 2005). However, during recent years these important habitats have been subjected to tremendous pressures from increased anthropogenic activities, particularly land conversion, grazing and habitat fragmentation. The mangroves habitats along the west coast of India are generally fringing in nature because of narrow coastal belts resulting from stiff topography (Wagle, 1982). The state of Goa, being a tourist destination, is heavily pressurized from economical activities, leading to deterioration of these habitats.

Different land cover categories give various types of reflections and produce peculiar spectral signatures of individual form. The desired information could be achieved from satellite imageries in an efficient and effective manner by using several basic interpretation keys. Mangrove vegetation gives bright red (if dense) or pale red (if sparse) or orange color tune; they are irregular in shape with a smooth texture on satellite data, and hence can be easily interpreted. Their location are in the intertidal areas associated with estuaries, creeks and low lying flats, which are subjected to weak waves and currents (Anon, 1992).

During recent past, the mangrove cover from Goa was estimated to be approximately 2,000 ha (Untawale *et al.*, 1982; Jagtap, 1985 and Jagtap *et al.*, 2003). The major mangrove formations (~ 80%) exist along the Mandovi-Zuari-Cumbarjua estuarine complex (Jagtap, 1985). Present observations revealed a total increase of approximately 455.4 ha in mangrove areas of Goa from 2083.35 ha in the year 1997 to 2538.79 ha in 2006 (~ 22 %). Mangrove habitats showed increase in some of the rivers, whereas it showed decrease in others (Figure 4). Mangrove cover has been predominantly increased along Chapora, Mandovi, Cumbarjua and Sal Rivers (Table 1), adding over 538 ha since last three decades; comparing with data of 1973 (Jagtap, 1985).

National Mangrove Committee (NATCOM) was established during 1989 by Ministry of Environment and Forest (MoEF). The major role of NATCOM was to promote protection, conservation, rehabilitation and sustainable management of mangroves. Individual coastal states in the country followed action plans in safeguarding these ecologically sensitive habitats since then. The increase in mangrove areas from the study region may be attributed to conservation and reforestation efforts by the state government. Choroa Island in the Mandovi Estuary was declared as a bird sanctuary in 1987 encompassing more than 187 ha. The State Social Forestry Division has proposed to develop approximately 50 ha of mangrove plantation per year, as follow-up of the National Mangrove Plan for the sustainable management of mangrove resources (Jagtap *et al.*, 2003). The mangrove flora is represented by 15 species (Jagtap, 1993), dominated by *Rhizophora mucronata* Lamk., *Avicennia alba* (Blume) Bathkh, *A. officinalis* L. , *Sonneretia alba* J. Sm. and *S. caseolaris* (L.) Engler. This sanctuary has been witnessing a steady increase in mangrove cover during the past decade, until it reached approximately 242 ha during the year 2006, and contributed about 22.9% of the total area cover of mangrove in the Mandovi estuary.

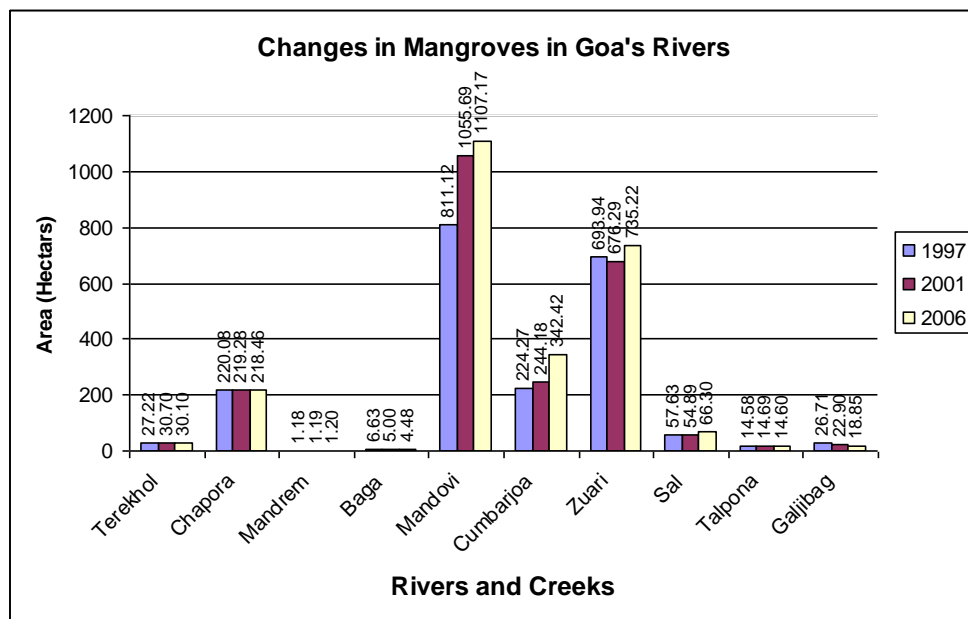


Figure 4: Changes in mangroves areas in the rivers of Goa.

The intertidal expanse of muddy substratum in the some undisturbed areas such as Cumbarjua Canal and river islands, along with feeble wave action and currents, forms suitable features for establishment of mangrove seedlings to grow undisturbed and the habitat to develop further (Figure 5a). The present study showed an increase of approximately 52.7% in the mangrove habitat. The increase in mangrove cover in the Mandovi estuary could also be attributed to the reduction in agricultural area adjacent to mangroves due to abandonment of farming activities. Old bonds have been broken and agriculture areas have been infested by mangroves.

Although ground truth data indicated new formations and rehabilitation by mangrove plantations, loss of mangrove habitats have been also observed in certain localities. Recently, mangrove habitats have been subjected to tremendous pressures from increased anthropogenic activities, particularly land conversion, grazing and habitat fragmentation. The state of Goa, being a tourist destination, is heavily pressurized from economical activities, leading to deterioration of these habitats. The most degraded habitats exist along the Baga creek in North Goa, which is major tourist hub. Baga and Mandrem creeks have been subjected to massive destruction of sensitive habitat due to construction activities relevant to tourism industries, that have been taken place in the area (Nairy *et al.*, 2003), These anthropogenic activities strict mangroves from developing and expanding their areas (Figure 5b). Moreover, tourism-based urbanization, reclamation of mangrove areas for agriculture, mushrooming of saltpans and aquaculture farms in the mangrove areas (Figure 5c), illegal felling for firewood, construction of roads and railway tracks, mining activities, construction of buildings and utilization as dumping sites for garbage and construction waste (Figure 5b), have caused considerable damage to mangrove habitats in particular locations.



Figure 5: (a) Mangrove nursery, as a conservation and management measure; (b) Mangroves area used as dumping grounds and road construction; (c) Salt pans adjacent to mangrove area. (d) Mining activities, showing iron ore transportation in estuarine areas.

Intensive mining practices during last four decades have resulted in deteriorating terrestrial and marine ecosystems. The increase in open mudflats (Figure 5d) from the low lying regions influenced by estuaries and backwaters could also be attributed to the intensive contribution of sediments derived from mining and deforestation. In addition to this, heavy rainfall (~ 3000 mm/yr) and steep topography has also lead to severe erosion of topsoil and mining rejects, resulting in shallowing of low-lying wetlands. However, over the period the stabilized mudflat with pioneer vegetation of various algae, *Halophila beccarii* (Aschers) and *Porteresia coarctata* (Roxb) Tateoka favours the new formations of mangroves, which helps land building at climax stage during succession (Jagtap, 1985; Untawale & Jagtap, 1999). Ground truth observations revealed that new mangrove formations have been established on recent mudflats between the existing mangroves and open mudflats along the waterways.

Mangroves have shown steady increase in their areas during past three decades, indicating improvement and healthy situation. Increase in local and migratory human population and their demands, for urbanization and infrastructure, is constantly pressurizing low laying areas, particularly marine wetlands. Considering ecological and socio-economic significance of mangrove, the limited distribution and issue of global warming and sea level rise, a top priority of the state should be conserving ecological sensitive marine habitats (ESMH). Strict implementation of Coastal Regulatory Zone (CRZ) Act and judicious development within the carrying capacity of the state would greatly help in saving loss of natural habitats.

The present study would be of help to contribute towards effective and sustainable management of ESMH, particularly mangroves. Data generated on the distribution of these mangroves will help in decision-making and ecosystem restoration, which is of prime importance for ecosystem functioning and sustainability.

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إستخدام تقنيات الإستشعار عن بعد ونظم المعلومات الجغرافية في تحديد التغيرات في الغطاء النباتي لبيئات أشجار المانجروف في ولاية جوا - الهند

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الملخص

تعتبر الموائل البيئية الساحلية الحساسة، بما فيها الأنظمة البيئية لأشجار المانجروف، ذات قيمة إيكولوجية وإجتماعية وإقتصادية هائلة. ولاية جوا، كوجهة سياحية، لديها غطاء محدود من هذه الموائل، ولقد تعرضت خلال العقد الماضي لعدة ضغوط بشرية مكثفة. بيانات الأقمار الصناعية لأوقات مختلفة ما بين (١٩٩٧ و ٢٠٠١ و ٢٠٠٦م) للأقمار التالية (IRS-1C LISS III و IRS-1D LISS III و IRS-P6 LISS III) وضحت إلى حد كبير التغيرات في أنماط استخدام الأراضي. وأظهرت هذه الدراسة أن موائل المانجروف في ولاية جوا قد زادت بنسبة ٢٢٪ في الفترة الواقعة ما بين عامي ١٩٩٧ و ٢٠٠٦م. ويمكن أن تعزى هذه الزيادة في غطاء بيئات المانجروف إلى إعادة التأهيل لهذه البيئات بالإضافة إلى غزو أشجار المانجروف للأراضي الزراعية المجاورة، والتي غمرت بسبب إنشاء السدود. قد تساعد النتائج الحالية بشكل كبير في فهم التغيرات الحادثة في الموائل البيئية الساحلية الحساسة، وصياغة استراتيجيات فعالة لصيانتها وإعادة التأهيل.

الكلمات المفتاحية: الاستشعار عن بعد، المانجروف، نمط استخدام الأراضي، تحديد التغيرات، الحفظ وإعادة التأهيل.