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ASSESSMENT AND MONITORING OF ESTUARINE MANGROVE FORESTS OF GOA USING SATELLITE REMOTE SENSING

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ABSTRACT

The present study highlights the application of satellite remote sensing in the assessment and monitoring of the mangrove forests along the coastline in Goa state of India. Based on on-screen visual interpretation techniques various land use and land cover classes have been mapped and classified. An attempt has been made to analyse changes in the mangrove forest cover from 1994 to 2001 using IRS-1B LISS-II and IRS-1D LISS-III data. An increase in the mangrove vegetation in the important estuaries has been found during 1994 and 2001. During this period, the mangrove forest increased by 44.90 per cent as a result of increased protection and consequent regeneration. Plantation of mangrove species has been raised in 876 ha (1985 to 1997) by the State Forest Department. .

Introduction

Mangroves occur along 7500 km long coastline of India including west coast, east coast and Andaman and Nicobar Islands. The increasing human population in coastal areas has resulted in increased pressure on mangrove ecosystems (Saenger *et al.*, 1983). According to Government of India report (1987), there was a loss of 40 per cent of mangrove forests during the last century (Kumar, 2000a). The National Remote Sensing Agency (NRSA) recorded a decline of 5918 ha of mangrove between 1972-1975 and 1980-1982 (Anonymous, 1983). Growing awareness about the protective,

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productive and social role of mangrove ecosystems, has highlighted the need to conserve and manage them sustainably (FAO, 1994). Numerous workers have carried out study on various aspects of mangroves in India (Jagtap, 1985; Banerjee and Gosh, 1998; Singh, 1998; Dagar and Singh, 1999; Naskar and Mandal, 1999; Singh, 2002). Kumar (2000b) has worked extensively on the status of natural regeneration in mangroves of Goa through sample surveys in all the estuaries and also compared the observation with Untawale *et al.* (1982).

Recognizing the importance of mangroves, the Government of India set up the National Mangrove Committee in the Ministry of Environment and Forests in 1976 to advise the Government on mangrove conservation and development. The need to conduct survey on the extent of existing mangrove areas, identification of selected mangrove areas for conservation, preparation of management plan, promotion of research, adaptation of multidisciplinary approaches involving State Government, Universities, researchers, institutions and local organizations have been recommended (Anonymous, 1987).

The detailed information on the extent and distribution of mangroves is vital for the management and conservation. Remote sensing technology can be used to assess spatial extent of forest cover and land use types (Roy, 1989; Kushwaha, 1997; Porwal *et al.*, 1992). Untawale *et al.* (1982) have estimated the mangrove cover in Goa using aerial photographs (20 km^2). As per latest report of Forest Survey of India, the state has got five km^2 area under mangroves, which appears to be an under-estimate (Anonymous, 1999a). Goa State Forest Department initiated afforestation works to restore degraded mangrove areas in 1985 in all the estuaries and by 1997 an area of 876 ha was planted (Anonymous, 1999b).

This study was taken up to assess the extent and distribution of Goan mangroves at two points of time *i.e.*, 1994 and 2001. It is hoped that the results of the study would be useful in effective development and management of mangroves.

Study Area

Goa is one of the smallest states of India (3702 km^2) located on the central western coast of the country (14° 53' 54" to 15° 48' 00" N and 73° 40' 33" to 74° 20' 13" E). The altitude ranges from the sea level to 1072 m. Climate is tropical-warm and humid with maximum temperature of 33°C and minimum of 21°C, humidity varies between 76 and 86 per cent and average annual precipitation ranges from 2844 mm to 3548 mm. As per 2001 census record, the population of the state is 1.3 million with population density of 363 per km^2 (as against 324 per km^2 for India) (Anonymous 2001). Many estuaries: Terekhol, Chapora, Mandovi, Zuari, Sal, Talpona, Galgibag and long coast line (120 km) support mangroves. Cumbarjua canal also has dense mangroves. All the estuaries originate from the Sahyadri hill ranges of Western Ghats and flow westward before joining the Arabian Sea.

Data and Methods

The satellite imagery in digital as well as False Colour Composite (FCC) hard copy print form were used in the study (Fig. 1). Remotely sensed data of November-December were found suitable for discrimination of the mangrove forests. Both data sets were co-registered using WGS-84 datum and UTM projection. The digital IRS-1B LISS-II (1994) and IRS-1D LISS-III (2001) data were on-screen visually interpreted using ERDAS IMAGINE software. Ancillary data like Survey of India toposheets and forest management maps were also used as reference data.

Results and Discussion

The spatial changes in the mangrove cover have been assessed estuary-wise (Figs. 2 and 3; Tables 1-3) and the details are given below:

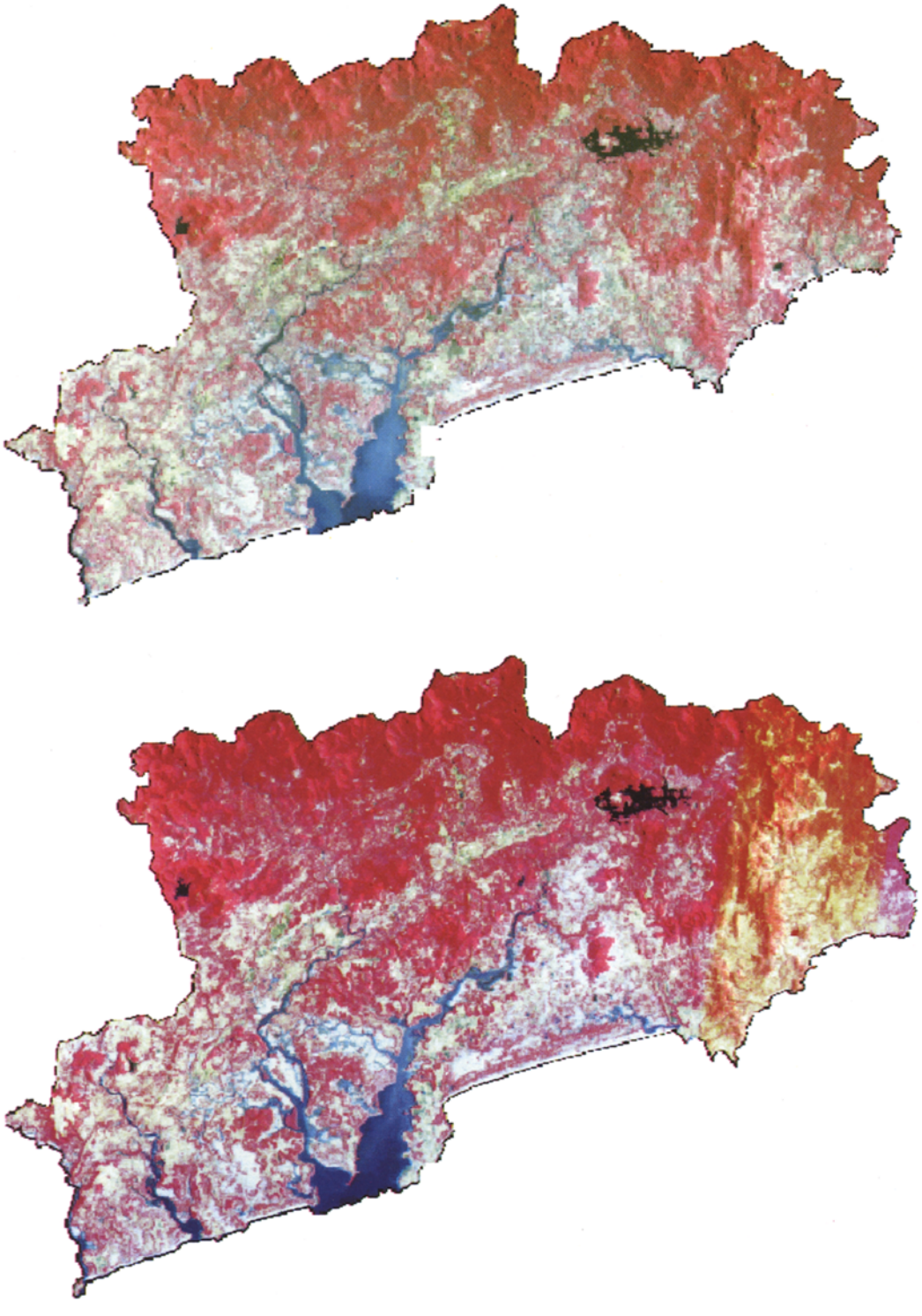

Fig. 1. Temporal imagery of Goa

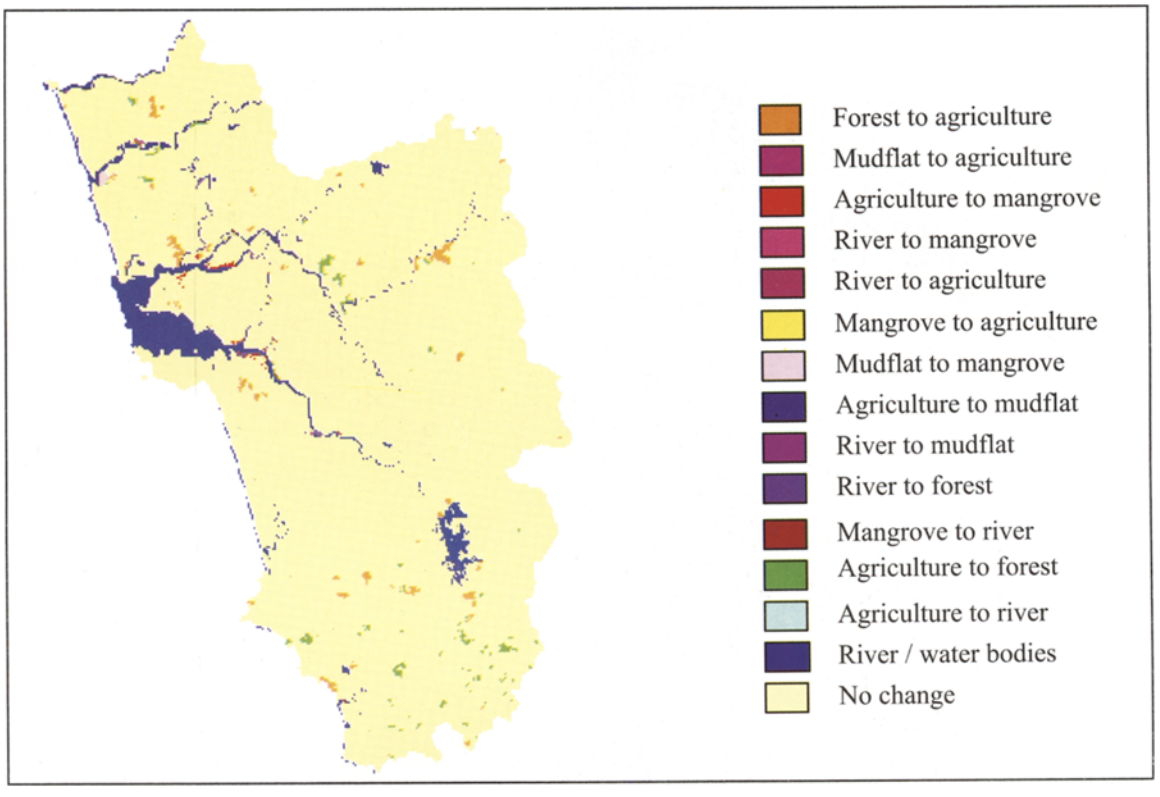

Fig.2. Forest and other landuse/land cover change in Goa from 1994 to 2001.

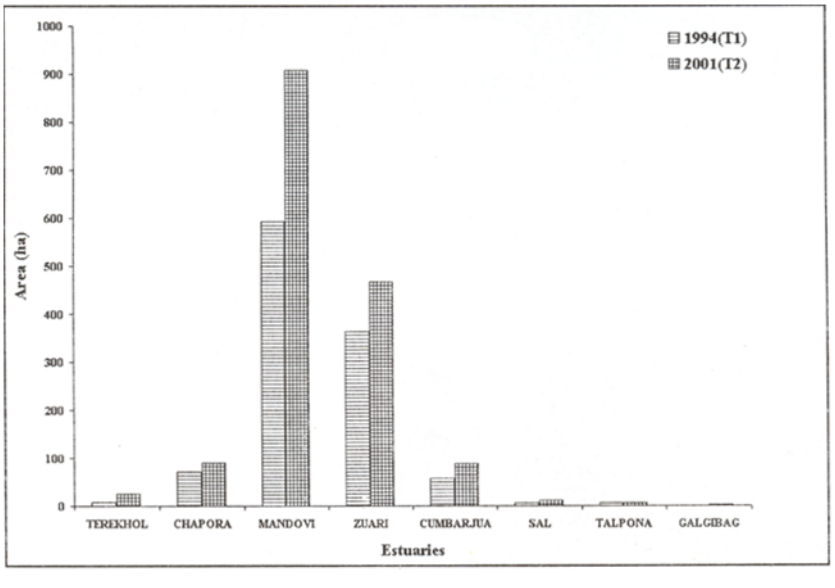

Fig.3. Estuary-wise changes (ha) in mangrove forest in Goa

Table 1: Distribution of areas in forest cover types and other land use categories (km^2) in Goa

Category	1994 (Time 1)	2001 (Time 2)
Forest	1675.22	1644.80
Forest mixed with cashew	27.09	36.20
Forest mixed with coconut	26.09	13.05
Mangrove	9.02	14.61
Mangrove with coconut	2.00	1.36
Cashew plantation	0.24	13.05
Coconut plantation	72.24	98.34
Forest blank	43.49	31.11
Mudflat	16.05	18.43
Agriculture	1647.51	1647.42
River /waterbodies	183.05	183.63

Table 2: Changes in forest cover types and other land use categories (km^2) in Goa

Category	Area
Agriculture to forest	23.00
Agriculture to mangrove	4.00
Agriculture to mudflat	4.00
Agriculture to river/waterbodies	0.18
Forest to agriculture	29.00
Mangrove to agriculture	0.68
Mudflat to agriculture	1.34
Mudflat to mangrove	0.97
River/waterbodies to agriculture	0.08
River/waterbodies to mangrove	1.18
River/waterbodies to mudflat	2.25
No change	3635.32

Table 3: Estuary-wise area (ha) under mangrove forests

Name of Estuary	1994 (Time 1)	2001 (Time 2)	Change (Time2 - Time1)
Terekhol	7.3	24.6	17.3
Chapora	70.8	90.0	19.2
Mandovi	593.0	908.0	315.0
Zuari	363.0	467.0	104.0
Cumbarjua	57.7	87.8	30.1
Sal	5.0	11.0	6.0
Talpona	5.0	6.1	1.1
Galgibag	0.0	2.0	2.0

1. Terekhol Estuary

The Terekhol estuary is about 26 km long and it separates Goa state from Maharashtra. The

commonly found species are; *Ceriops tagal*, *Acrostichum aureum*, *Acanthus ilicifolius*, *Avicennia officinalis*, *Avicennia marina*, *Derris heptaphylla*, *Rhizophora mucronata*, *Sonneratia alba*, *Sonneratia caseolaris*, *Excoecaria agallocha*, *Kandelia candel*. There is large concentration of *Ceriops tagal*, which is not found elsewhere in the state. It was found that mangrove cover increased from 7.3 ha to 24.6 ha in Terekhol estuary between 1994 and 2001, thereby showing 236.98 per cent increase.

2. Chapora Estuary

The Chapora estuary is 30 km long. The main mangrove species in this estuary are; *Sonneratia alba*, *Avicennia officinalis*, *Avicennia marina*, *Acrostichum aureum*, *Acanthus ilicifolius*, *Excoecaria agallocha*, *Kandelia candel*, *Thespesia populnea* (a mangrove associate), *Rhizophora mucronata*, *Acacia intsia*. Tall grasses also grow along the estuary. Coconut and *Thespesia populnea* are commonly found along the banks. Mangrove species are found in small, scattered patches and in degraded condition. Mangroves species have come up in the abandoned paddy fields. It was found that mangrove cover increased from 70.8 ha to 90.0 ha in Chapora estuary between 1994 and 2001, thereby showing 27.11 per cent increase.

3. Mandovi Estuary

The Mandovi estuary is about 68 km long. A number of its tributaries are spread over a total length of about 109 km. This estuary is popular due to the occurrence of a variety of the mangrove species and as an excellent habitat for birds. About 178 ha area has been declared as Dr. Salim Ali Bird Sanctuary. Main mangrove species are; *Rhizophora mucronata*, *Rhizophora apiculata*, *Sonneratia alba*, *Avicennia officinalis*, *Kandelia candel*, *Acanthus ilicifolius*, *Excoecaria agallocha* and *Acrostichum aureum*. It was found that mangrove cover increased from 593.0 ha to 908.0 ha in Mandovi estuary between 1994 and 2001, showing 53.11 per cent increase. Mapusa is an important tributary of the estuary exhibiting good growth of mangroves. Old trees of *Avicennia* are found at Betim, Britona and Aldona villages. From Betim to Pomburpa plantation of mangroves along the estuary have been raised successfully. It was found that mangrove cover as 80.0 ha in Mapusa estuary.

4. Zuari Estuary

The Zuari estuary is 63 km long. Important mangrove species found in this estuary are; *Avicennia marina*, *Avicennia officinalis*, *Aegiceros corniculatum*, *Sonneratia alba*, *Sonneratia caseolaris*, *Bruguiera gymnorrhiza*, *Bruguiera cylinderica*, *Rhizophora mucronata*, *Excoecaria agallocha*. *Rhizophora mucronata*. *Avicennia officinalis* in abundance. But, *Rhizophora apiculata* and *Avicennia alba* are not found, whereas, *Bruguiera cylinderica* and *Aegiceros corniculatum* are rare. It was found that mangrove cover increased from 363.0 ha to 467.0 ha in Zuari estuary between 1994 and 2001, thereby showing 28.65 per cent increase.

5. Cumbarjua Canal

The Cumbarjua canal joins Mandovi and Zuari estuaries and is 15 km long. The mangrove species found are : *Rhizophora mucronata, Avicennia officinalis, Acanthus ilicifolius, Derris heptaphylla*. Mangrove vegetation is quite dense along the canal. It was found that mangrove cover increased from 57.7 ha to 87.8 ha in Cumbarjua Canal between 1994 and 2001, thereby showing 52.16 per cent increase.

6. Sal Estuary

The Sal estuary is 10 km long. Mangroves are present all along the estuary in scattered patches.

Good patches of mangroves are found near Colvaddo village along the estuary. The mangrove species found are; *Avicennia officinalis*, *Sonneratia alba*, *Thespesia populnea* (a mangrove associate). Along the estuary, *Rhizophora* sp. has been planted. It was found that mangrove cover increased from 5.0 ha to 11.0 ha in Sal estuary between 1994 and 2001, thereby showing 120 per cent increase.

7. Talpona Estuary

The Talpona is 9 km long. *Rhizophora mucronata* having 20 m height and *Bruguiera gymnorrhiza* with 12 m height are growing. Other mangrove species found are : *Avicennia officinalis, Derris heptaphylla, Excoecaria agallocha, Sonneratia alba, Acanthus ilicifolius, Thespesia populnea* (a mangrove associate). Mangrove species are also growing in the private adjoining lands, where tidal water enters during high tide period. It was found that mangrove cover increased from 5.0 ha to 6.1 ha in Talpona estuary between 1994 and 2001, thereby showing 22 per cent increase.

8. Galgibag Estuary

The Galgibag estuary is 16 km long near Galgibag village, which is close to the estuary mouth. Mangrove vegetation is dense. The main species found are : R*hizophora apiculata*, *Rhizophora mucronata*, *Avicennia officinalis*, *Sonneratia alba*, *Avicennia marina*, *Derris heptaphylla*. It was found that mangrove cover increased from nil to 2.0 ha in Galgibag estuary between 1994 and 2001, thereby showing 200 per cent increase.

Most of the challenges to mangrove forests in all these estuaries are natural hazards such as cyclones, floods as well as destructive human activities. The root causes are poverty, lack of education, improper planning, short supply of fuel wood, absence of systematic surveys, difficulty in protection and shortage of supervisory staff also contribute to mangrove depletion. There are certain threatened mangrove species in the state *viz.*, *Ceriops tagal*, *Bruguiera cylindrica* and *Avicennia alba*. Other mangroves species which also need protection are *Rhizophora apiculata*, *Avicennia marina*, *Bruguiera gymnorrhiza* and *Aegiceros corniculatum* (Kumar, 2000a).

Conclusion

Inspite of the various causes of depletion of mangrove forest cover, it has been found out that there is an overall increase in mangroves from 9.02 km^2 (1994) to 14.61 km^2 (2001) (Table 1). An estimate of spatial extent of various land use/ land cover classes have been worked out. In case of agriculture land use, there is change, *viz.* forest (23 km^2), mangrove (4 km^2), mudflats (4 km^2) and river/ waterbody (0.18 km^2). Also, forest-land use has changed to agriculture (29 km^2). Mangrove bearing areas have also changed to agriculture (0.68 km^2). Mudflats have changed to agriculture (1.34 km^2) and mangroves (0.97 km^2). River/waterbody have changed to agriculture (0.08 km^2), mangroves (1.18 km^2) and mudflats (2.26 km^2) (Table 2). The net gain in mangroves could be attributed to new plantations by the State Forest Department; agriculture to mangroves; mudflat to mangroves and river/ waterbody to mangroves (Tables 1 and 2). Positive change in mangroves in all the estuaries indicates effective protection and development by Goa State Forest Department. It is expected that the results of this study will provide much needed input for different development schemes. It may also be significantly useful in preparing the eco-friendly tourism development schemes in Goa. Principles of sustainable development, concept of joint forest management and plantation of rare and endangered species of mangroves can be helpful in conservation of mangrove ecosystems.

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