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Assessment of Three Decade Vegetation Dynamics in Mangroves of Godavari Delta, India Using Multi-Temporal Satellite Data and GIS

C. Sudhakar Reddy and Arijit Roy
Forestry and Ecology Division, National Remote Sensing Agency,
Balanagar, Hyderabad-500 037, India

Abstract: The present study assess spatial change in the mangrove cover over the last three decades in the Godavari delta, using Landsat MSS, TM, ETM + and IRS P6 LISS III images. From 1977 to 1988, the mangrove vegetation cover had a drastic change and lost about 24.6 km^2, which was mostly recovered during the next period (1988-2000). Over the entire three decade period the net change was negative, which was quantified as 8.8 km^2. It is also observed that plantation cover shows increase of additional 7.6 km^2 during 1977 to 2005. In Coringa Wildlife Sanctuary the net change was positive with an increase in mangrove area of 107.2 to 114.2 km^2. The study concluded that mangrove loss is mainly due to encroachment by aquaculture, agriculture and coastal erosion. The gain in the forest cover is attributed to the accretion, restoration and protection.

Key words: Mangrove, vegetation, change assessment, remote sensing, accretion, erosion, Godavari, India

INTRODUCTION

Mangroves are a group of highly adapted halophytes occupying the intertidal zone in estuaries, lagoons and coastal mud flats in tropical and subtropical regions of the world. Mangroves are socioeconomically important ecosystems, especially for the inhabitants of coastal regions, who depend on them as their primary source of income, fuel, food, medicine and other basic necessities and also safeguard the coastal environments.

Mangrove forests are undergoing constant changes-short term and/or successional/long term-due to it's dynamic nature itself and to a greater extent through various natural and biotic influences. Growing industrial areas along the coastlines and discharge of domestic and industrial sewage are polluting these areas. The expansion of agriculture and aquaculture farms in the coastal areas has led to conversion of mangroves in the recent past (Barbier and Cox, 2004). The extent of mangroves has also changed due to the accretion near river mouths, leading to the formation of new mangrove areas.

An accurate and up-to-date information on the status of mangrove vegetation, continually over time, is pre-requisite for a sustainable management of mangrove forest. Traditional field survey inside the mangrove swamps is extremely difficult. Remote Sensing (RS) and Geographic Information System (GIS) provides valuable aids for the purpose because RS and GIS is a fast, efficient and accurate mean of information retrieval to detect such changes continually over time (Ricketts, 1992; Hashiba *et al*., 2000). The information gained can be utilized for effective planning and management of mangrove forest.

The mangrove forests comprise 15.8 million hectares, roughly less than half the original mangrove forest cover and are fast declining further at an assumed rate of 2 to 8% per year in the world

Corresponding Author: Dr. C. Sudhakar Reddy, Forestry and Ecology Division, National Remote Sensing Agency Government of India Balanagar, Hyderabad-500037, Andhra Pradesh, India Tel: +91-040-23884219

(Spalding *et al*., 1997). India has a total area of 4461 km^2 under mangroves which is 0.14% of the countries total geographic area. It account for about 5% of the world's mangrove vegetation (Anonymous, 2003). Nearly 57% mangroves are found along the east coast (Kathiresan, 2003). There is a decline of 59.18 km^2 of mangrove between 1972-1975 and 1980-1982 (Anonymous, 1983). According to the Government of India Report (1987), India lost 40% of its mangrove area during the last century (Kumar, 2000).

Mangroves of Godavari Delta

The mangrove forests in Andhra Pradesh are located in the estuaries of the Godavari and the Krishna rivers. The Godavari mangroves are lies between the latitudes 16°30' and 17°00' N and the longitudes 82°11' and 82°21' E in East Godavari District, East Coast of India. The mean annual rainfall in this region is 110 cm and the annual mean temperature is 28°C. The Godavari River is connected to Kakinada Bay by two major canals, namely the Coringa and the Gaderu. There are numerous other small canals branching from these canals, supplying tidal water to the mangroves. The Godavari River flows into the sea through two mouths, one near Bhairavapalem in the north and the other near Kottapalem in the south.

The presence of numerous canals, river tributaries along with mangroves makes Godavari delta as a unique habitat (Tripathy *et al*., 2005). Anthropogenic activities are such as discharge of industrial and municipal sewage, aquaculture, tourism, maritime transport, offshore oil exploration and production, dumping at sea degrading the marine environment of Godavari.

Vadlapudi (1999) carried out change analysis on mangroves of Godavari using IRS 1B LISS II data and observed that during a span of one year period (1994-1995), the spread of aquaculture has caused destruction of mangrove up to 22.69 ha. Ramasubramanian *et al*. (2006) analysed the remote sensing images of 1986 and 2001 and reported that the changes in the vegetation due to forest restoration and natural regeneration are significant.

Realizing the importance of Godavari delta and mangroves, the present study was undertaken to assess the three decade spatial changes in vegetation dynamics using multi-temporal satellite data and Geographical Information System (GIS).

Coringa Wildlife Sanctuary

Coringa Wildlife Sanctuary, a part of the Godavari mangroves was declared as a sanctuary in July 1978 to conserve the mangrove vegetation of the estuary, extending in an area of about 236 km^2 Coringa Wildlife Sanctuary has three Reserve Forests, namely Coringa R.F., Coringa Extn. R.F. and Bhairavapalem R.F. Most of the mangroves in the Sanctuary are not directly connected with the Bay of Bengal. The Gaderu and Coringa rivers are the distributaries of the River Godavari. The mangroves of Coringa Wildlife Sanctuary receives tidal flushing through Matlapalem canal, Coringa river and Gaderu river. The other six Reserve Forests namely Rathikalava RF, Masanitippa RF, Matlatippa RF, Balusutippa RF, Kothapalem RF and Kandikuppa RF are situated on the southern side of Nilarevu River and fall under non-sanctuary area. The Sanctuary has an unique distinction of having a 18 km long sand spit in the north eastern side (Hope island), where the species of olive Ridley sea turtle (endangered species) nests during January-March of every year. The sand spit of Hope Island has changed with time and has grown nearly 2.6 km between 1937 and 2001 (Ramasubramanian *et al*., 2006).

MATERIALS AND METHODS

Field Survey

Field survey was carried out in the study area during April 2006 to study the vegetation and other land cover. False colour composite satellite images and Survey of India topographical maps (65 H and 65 L) were used to collect ground information. Ground truth data was collected using GPS, at various locations before the image classification.

Remote Sensing Techniques

Data Used

The study was carried out using temporal satellite images of Landsat MSS (Landsat Multi Spectral Scanner-path/row: 152/48; date 8th January, 1977), Landsat TM (Landsat Thematic Mapper-path/row: 141/48, 141/49; date: 12th October, 1988), Landsat ETM + (Landsat Enhanced Thematic Mapper+-path/row: 141/48, 141/49; date: 8th December, 2000) and IRS P6 LISS III (Indian Remote Sensing P6 Linear Imaging Self Scanner-path/row: 103/61; date: 13th December, 2005). The orthorectified Landsat data was downloaded from GLCF website (http://glcf.umiacs.umd.edu/). The images were processed using the ERDAS Imagine 9.0 software.

The Landsat TM, ETM+ and IRS P6 LISS III images was geometrically corrected in relation to the MSS image to obtain the same spatial resolution (since Landsat Multi Spectral Scanner (MSS) image downloaded at 57 m resolution from http://www.glcf.umiacs.umd.edu.) i.e., from 30 to 57 m (in case of IRS LISS III from 23.5 to 57 m).

Study Area Image Extraction

Mosaicing of satellite data, corresponding to the study area was done. To understand spatial patterns with in mangroves and also surroundings towards landward side, a buffer of 5 km was generated from mangrove boundary using January 1977 data as a base. By using 5 km buffer as mask, study area has been extracted from Landsat MSS, TM, ETM+ and IRS P6 LISS-III scenes (Fig. 1).

Classification

Supervised digital classification method is used for mapping of vegetation and land cover of the study area. This has been the most frequent method for remotely sensed data classification. In supervised classification the samples of known identity were used to classify pixels of unknown identity. Training sites in the images are generated to represent the typical spectral information of the land cover classes (dense mangroves, open mangroves, plantations, agricultural lands, built up area, aquaculture, sand, mudflats and water bodies). After the selection of training sites, the classification was run on the images using Maximum likelihood classifier in ERDAS Imagine 9.0 software. Prior to the classification, signature separability analysis was carried out on the training signatures for better classification.

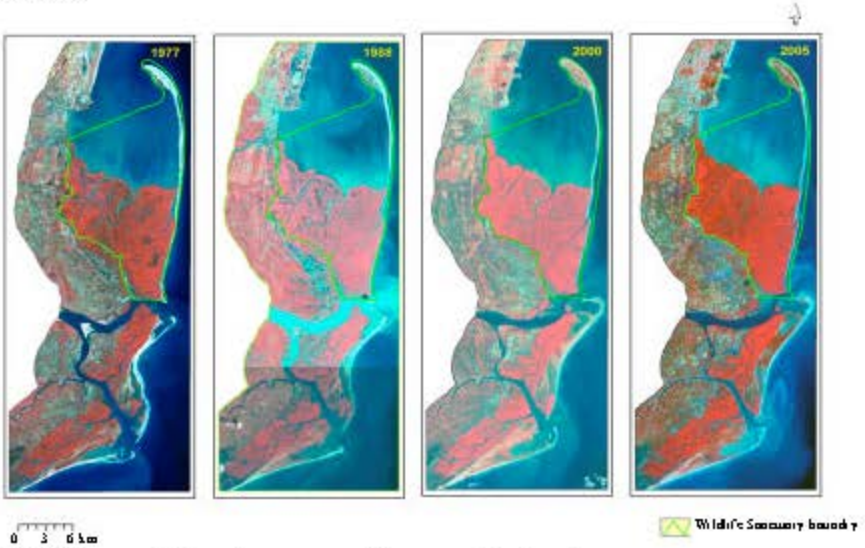

Fig. 1: Multi-temporal false colour composite images of Godavari mangroves

To determine the accuracy of the thematic maps obtained using the supervised classification, an accuracy assessment was carried out using the GCPs recorded during the field survey. Overall accuracy was calculated, based on error matrix method (Congalton and Green, 1999) that included mangrove, non mangrove and water classes, as the percentage of agreement between GCP reference points and the classification results.

Change Detection

After the images of the four time periods (T_1, T_2, T_3 and T_4) were classified independently, the post classification change detection method was applied to determine the changes and to see the nature of changes. The change in the spatial extent of mangroves and other land cover types detected in the three decades were analysed. From the change map the change area matrix table was generated for the result and discussion.

RESULTS AND DISCUSSION

Delta of Godavari River with rich alluvial soil, abundant water supply and highly favorable geomorphic terrain, predominantly support agricultural lands. Nine major land cover types were delineated using satellite data viz: Dense Mangroves, Open Mangroves, Plantations, Agriculture, Built up area, Aquaculture, Water bodies, Mudflat and Sand (Table 1).

From land cover map of the year 2005, it may be seen that water bodies (sea/rivers/streams/canals/reservoir/tank) in the study area constitutes 44.1% of the area. Another major feature is most of the inland area is under intense agriculture (20.2%). In 1977, the forest cover (Dense Mangroves and Open Mangroves) accounted for about 194.8 km^2 (Table 1, Fig. 2).

The changes in the mangrove cover have been assessed and the details were given in Table 1-4. There were inter-period variations (1977-1988, 1988-2000, 2000-2005), both positive and negative,

Table 1: Areal extent of vegetation and other land cover in Godavari mangroves: study area (area in km^2)

	1977		1988		2000		2005	
Land cover class	Area	Area (%)	Area	Area (%)	Area	Area (%)	Area	Area(%)
Dense Mangrove	20.6	2.1	7.9	0.8	8.4	0.9	10.3	1.1
Open Mangrove	174.2	17.9	162.3	16.7	176.8	18.2	175.7	18.1
Sub total	194.8	20.0	170.2	17.5	185.2	19.1	186.1	19.1
Plantations	10.6	1.1	11.4	1.2	17.4	1.8	18.2	1.9
Agriculture	208.8	21.5	200.8	20.7	181.9	18.7	196.2	20.2
Built up area	14.2	1.5	19.5	2.0	20.7	2.1	22.4	2.3
Aquaculture	0.0	0.0	17.6	1.8	54.7	5.6	46.5	4.8
Water bodies	438.2	45.1	456.0	46.9	434.0	44.7	428.8	44.1
Mudflat	85.5	8.8	77.1	7.9	56.5	5.8	60.1	6.2
Sand	19.8	2.0	19.2	2.0	21.3	2.2	13.6	1.4
Grand total	972.0	100.0	972.0	100.0	972.0	100.0	972.0	100.0

Table 2: Change area matrix of vegetation and other land cover in Godavari mangroves: study area during January 1977 to December 2005 (area in km^2)

1977/2005	Dense Mangrove	Open Mangrove	Plantations	Agric-ulture	Built up area	Aquaculture	Water	Mudflat	Sand	Total
Dense Mangrove	4.3	14.9	0.0	0.0	0.0	0.0	1.0	0.30	0.0	20.60
Open Mangrove	5.8	124.7	0.7	5.0	0.0	8.2	14.2	14.50	1.2	174.20
Plantations	0.0	0.4	7.1	0.0	0.0	0.2	0.3	1.20	1.4	10.60
Agriculture	0.0	0.8	0.1	164.2	8.3	18.8	6.6	9.40	0.6	208.80
Built up area	0.0	0.0	0.0	0.7	13.5	0.0	0.0	0.00	0.0	14.20
Aquaculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.00
Water	0.1	12.5	5.1	8.3	0.1	1.9	388.1	15.10	7.2	438.20
Mudflat	0.2	21.1	1.4	17.4	0.5	17.4	12.3	14.50	0.7	85.50
Sand	0.0	1.2	3.9	0.7	0.0	0.1	6.3	5.00	2.5	19.80
Grand total	10.3	175.7	18.2	196.2	22.4	46.5	428.8	60.10	13.6	9720.00

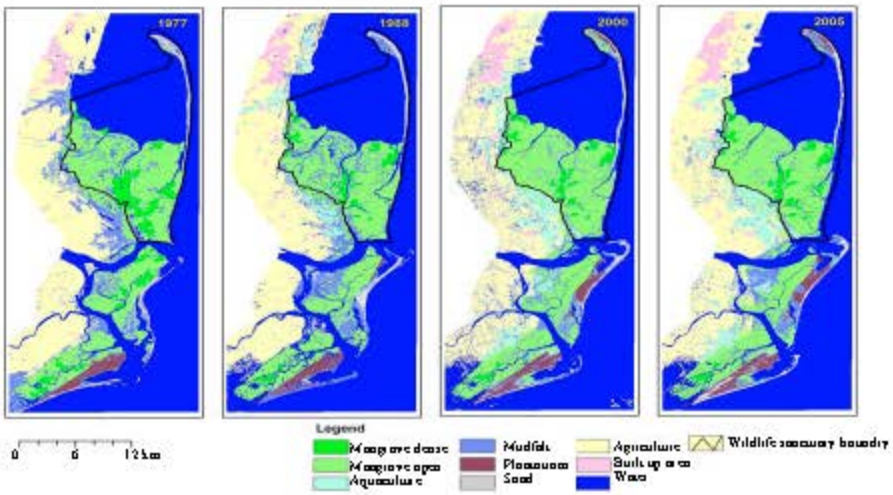

Fig. 2: Classified vegetation and land cover maps of Godavari mangroves

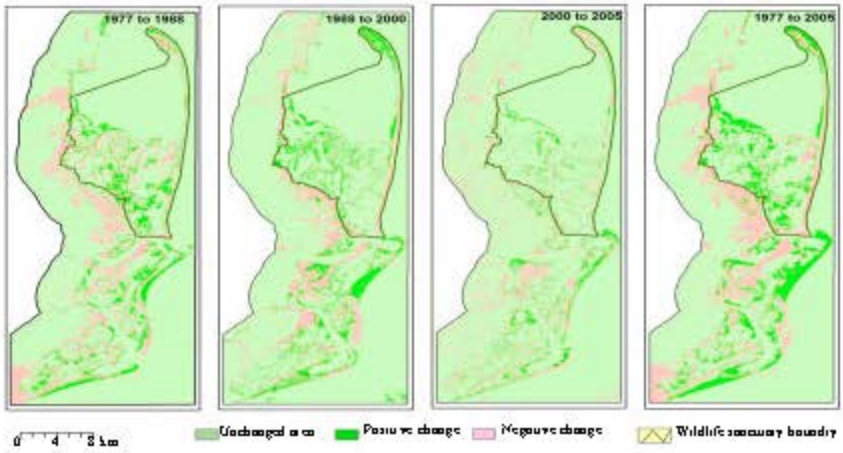

Fig. 3: Vegetation and land cover Change maps of Godavari mangroves

those are related mainly to the dynamics of the natural mangrove vegetation structure, accretion, erosion and anthropogenic influence (Fig. 3). In addition to it, variations in the extension of mangrove as a result of between-date tidal differences, especially in the area of the bay mouth bars were observed. But these changes are not large enough to consider as the main source of error in the classification.

From 1977 to 1988, the mangrove vegetation cover had a negative change and lost about 24.6 km^2, which was mostly recovered during the next period (1988-2000), giving a total balance of 185.2 km^2 from 1988 to 2000. In the last period (2000-2005) there was gain with an area of 0.9 km^2, but over the entire three decade period the net change was negative, which was quantified as 8.8 km^2. During January 1977 to December 2005, the important positive instances to be mention are an increase of Plantations cover (7.6 km^2) and formation of new mangroves as a result of accretion and restoration. In anycase, it was not possible to analyze the change in species composition and our results take into account only the mangrove/non mangrove covers.

Table 3: Areal extent of Vegetation and other land cover in Coringa Wildlife Sanctuary (area in km^2)

	1977		1988		2000		2005	
Land cover class	Area	Area (%)	Area	Area (%)	Area	Area (%)	Area	Area (%)
Dense Mangrove	13.5	5.7	6.9	2.9	7.3	3.1	9.2	3.9
Open Mangrove	93.6	39.7	92.2	39.0	105.5	44.6	105.1	44.5
Sub total	107.2	45.4	99.1	41.9	112.9	47.7	114.2	48.4
Plantations	0.0	0.0	0.2	0.1	1.5	0.7	1.8	0.8
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Built up area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aquaculture	0.0	0.0	0.2	0.1	2.9	1.2	1.1	0.5
Water bodies	103.2	43.9	107.6	45.5	102.4	43.3	102.3	43.4
Mudflat	17.0	7.2	24.1	10.2	11.3	4.8	11.4	4.8
Sand	8.3	3.4	5.2	2.2	5.3	2.2	4.8	2.0
Grand total	236.0	100.0	236.0	100.0	236.0	100.0	236.0	100.0

Table 4: Change area matrix of vegetation and other land cover in Coringa Wildlife Sanctuary during January 1977 to December 2005 (area in km^2)

1977/2005	Dense mangrove	Open mangrove	Plantations	Agriculture	Built up area	Aquaculture	Water	Mudflat	Sand	Grand total
Dense Mangrove	3.8	9.5	0.0	0.0	0.0	0.0	0.1	0.2	0.0	13.5
Open Mangrove	5.2	77.0	0.0	0.0	0.0	0.5	5.7	4.6	0.6	93.6
Plantations	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Built up area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aquaculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water	0.1	5.5	0.6	0.0	0.0	0.2	92.3	2.4	2.2	103.2
Mudflat	0.2	12.8	0.1	0.0	0.0	0.4	1.2	2.1	0.2	17.0
Sand	0.0	0.2	1.1	0.0	0.0	0.0	3.1	2.1	1.7	8.3
Grand total	9.2	105.1	1.8	0.0	0.0	1.1	102.3	11.4	4.8	236.0

The change analysis map shows that the major changes have been taking place in the proximity of agricultural lands as a result of high anthropogenic pressure (Fig. 2). It is noticeable that 13.2 km^2 of mangrove have been encroached upon by commercial aquaculture (8.2 km^2) and agriculture (5 km^2) during the 1977-2005. Due to intense anthropogenic pressure 34.8 km^2 of mudflats have been converted to human land use (aquaculture and agriculture). Due to erosion and tidal activities, around 15.2 km^2 of mangrove cover has undergone inundation in three decades (Table 2).

As part of plantation efforts by Andhra Pradesh State Forest Department, there has been a significant increase in the area (7.6 km^2) under forest plantations, which is mostly constituted by *Casuarina equisetifolia*.

The changes in the vegetation due to forest restoration, natural regeneration and accretion are appreciable during 1988 to 2005. In this period, the gain of 15.8 km^2 area of mangrove cover was noticed. Most of the recent studies in other parts of country reported a loss of mangrove cover due to anthropogenic pressure and natural factors (Samant, 2002; Barnali, 2006; Reddy *et al*., 2007). Until now, it seems that this is one of the few studies of the India that reports an increase in the mangrove cover since 1988 (Singh *et al*., 2004). The sand spit of Hope Island has grown drastically and now bears plantations and new mangrove formations in the northern part (Ramasubramanian *et al*., 2006).

Accuracy assessment was carried out with total 90 ground control points to assess the accuracy of the supervised classification of different periods. The overall accuracy assessment stands at 95.5% for latest data of 2005 (Table 5).

Coringa Wildlife Sanctuary

Analysis of vegetation and land cover inside Coringa Wildlife Sanctuary reveals that during 2005, mangrove cover occupies 114.4 km^2 (48.4%) area of the sanctuary. The second highest land cover class is water bodies, which represents 43.4% of area. An increase in mangrove area of 7.1 km^2 was observed

Table 5: Accuracy assessment of vegetation and other land cover classification for Godavari mangroves: study area

	1977		1988		2000		2005	
Classified data	UA*	PA**	UA	PA	UA	PA	UA	PA
Dense Mangrove	59.00	90.0	60.00	90.0	60.0	90.0	80.00	90.0
Open Mangrove	90.00	90.0	96.00	100.0	94.7	100.0	94.90	100.0
Plantations	91.00	94.0	100.00	96.2	100.0	100.0	100.00	100.0
Agriculture	85.00	83.6	95.00	94.1	97.0	92.3	97.00	94.1
Built up area	50.00	66.7	53.00	70.0	54.0	72.4	58.00	66.7
Aquaculture	---	---	71.40	83.0	80.0	91.0	71.40	83.0
Water bodies	90.00	92.0	100.00	100.0	96.8	100.0	100.00	100.0
Mudflat	74.30	79.0	85.70	75.0	87.0	75.0	85.70	75.0
Sand	91.00	93.0	100.00	100.0	100.0	100.0	100.00	100.0
Overall accuracy (%)	85.00		91.10		92.3		95.50	
Kappa statistics	0.82		0.89		0.9		0.93	

*: UA: User's Accuracy (%); **: PA: Producer's Accuracy (%)

compared to 1977 (Table 3). In addition, plantation activity by State Forest Department has resulted 1.8 km^2 area under plantation cover by planting of *Casuarina equisetifolia*. Mudflats are mainly contributes to the area for regeneration and restoration of the mangroves in the sanctuary.

It is observed that an area of 2.9 km^2 was converted to aquaculture ponds by 2000, was under recovery and reduced due to conservation approaches to an area of 1.2 km^2 by 2005 (Table 4).

It is clear that the mangrove vegetation cover can display great variability depending on its dynamics, environmental events and developmental activities in the area.

CONCLUSIONS

An estimate of spatial extent of mangrove and other land cover classes have been worked out. Three decadal time series data reveals that the period of 1988 was critical with reference to mangrove cover. By 1988, there is a drastic reduction in mangrove forest, which was quantified as 24.6 km^2. In spite of various causes of depletion of mangrove cover, it has been found that there is an overall increase in mangroves as compared with 1988 by 2000 and 2005. But over the entire three decade period the net change was negative, which was quantified as 8.8 km^2.

During the past three decades accretion and restoration have played a major role in the formation of mangrove areas as well as improvement of mangrove cover. Overexploitation, conversion of mangrove into other land uses and coastal erosion were found to be the three major threats.

It is observed that there is a significant positive change in the mangrove cover of Coringa wildlife sanctuary in terms of area. Due to natural growth in terms of restoration and regeneration and protection efforts by the forest department the area under mangrove has increased in Coringa Wildlife Sanctuary. But being a dynamic system there has been lot of changes in the mangrove cover as evident by the change matrix table.

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REFERENCES

Anonymous, 1983. Mapping of forest cover in India from satellite imagery (1972-75 and 1980-82). Summary Report, Nat. Remote Sen. Agency, Hyderabad, pp: 5-6.

Anonymous, 2003. State of Forest Report Forest Survey of India. Ministry of Environmnt Forest Government of India, New Delhi, pp: 21-22.

Barbier, E.B. and M. Cox, 2004. An economic analysis of shrimp farm expansion and mangrove conversion in Thailand. Land Econ., 80: 389-407.

Barnali, C., 2006. Satellite based monitoring of the changes in mangroves in South Eastern Coast and South Andaman Islands of India-A Tsunami related study. M.Sc. Thesis, Indian Institute of Remote Sensing, Dehradun.

Congalton, R.G. and K. Green, 1999. Assessing the Accuracy of Remotely Sensed Data: Principles and Practices. Lewis, New York, USA.

Hashiba, H., K. Kameda, S. Uesugi and S. Tanaka, 2000. Land use change analysis of Tama River Basin with different spatial resolution sensor data by Landsat MSS and TM. Adv. Space Res., 26: 1069-1073.

Kathiresan, K., 2003. Conservation strategies for mangroves in India. The Botanica, 53: 61-75.

Kumar, R., 2000. Distribution of mangroves in Goa. Indian J. For., 23: 360-365.

Ramasubramanian, R., L. Gnanappazham, T. Ravishankar and M. Navamuniyammal, 2006. Mangroves of Godavari-Analysis through Remote Sensing approach. Wetlands Ecol. Manage., 14: 29-37.

Reddy, C.S., C. Pattanaik and M.S.R. Murthy, 2007. Assessment and monitoring of Mangroves of Bhitarkanika Wildlife Sanctuary, Orissa, India using remote sensing and GIS. Curr. Sci., 92: 1409-1415.

Ricketts, P.J., 1992. Current approaches in geographic, information systems for Coastal management. Mar. Poll. Bull., 25: 82-87.

Samant, H.P., 2002. Quantifying mangrove cover change in and around Mumbai using satellite data. Proceeding National Seminar on Creeks, estuaries and mangroves. Poll. Conserv., pp: 334-337.

Singh, I.J., S.K. Singh, S.P.S. Kushwaha, S. Ashutosh and R.K. Singh, 2004. Assessment and monitoring of estuarine mangrove forests of Goa using satellite remote sensing. J. Indian Soc. Remote Sen., 32: 167-174.

Spalding, M.D., F. Blasco and C.D. Field, 1997. World Mangrove Atlas, Okinawa. Int. Soc. Mangrove Ecosyst., pp: 178-180.

Tripathy, S.C., A.K. Ray, S. Patra and V.V. Sarma, 2005. Water quality assessment of Gautami Godavari mangrove estuarine ecosystem of Andhra Pradesh. India during September 2001. J. Earth Syst. Sci. 114: 185-190.

Vadlapudi, S., 1999. Identification and quantification of changes in mangrove forest using Remote Sensing: A case study near Kakinada Bay Andhra Pradesh. India, GIS Development.