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CBD 2010 Target: A Case Study of Kolleru Wetland (Ramsar Site), India Using Remote Sensing and GIS

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Regular monitoring of wetlands is an essential element of management for 'wise use'. Indeed, the Ramsar convention requires routine monitoring in order to detect changes in the ecological character at listed sites. However, there are few examples of monitoring of tropical wetlands on a sustained basis in the world. In the present study, we quantified land use/land cover changes in the lone Ramsar site, the Kolleru Wildlife Sanctuary of Andhra Pradesh, India between 1977 and 2007 using remote sensing and GIS techniques. It was found that there was a significant increase in aquaculture farming (158.5 sq km) from 1977 to 2000, which put the habitat of flora and fauna in adverse conditions. The natural function of lake was being restored after the demolition of fishponds ordered by the Honorable Supreme Court of India in 2006. This study highlights the firsthand information to the user community after demolition, and offers suggestions for the future conservation of the lake. We suggest that remote sensing and GIS tools have a significant role in meeting the reported requirements for the CBD 2010 target.

Keywords: Aquaculture, CBD, Remote sensing, GIS, Kolleru lake, Andhra Pradesh

Introduction

Conservation of biodiversity and nature is now considered to be of fundamental importance for sustaining the global environment. The Convention on Biological Diversity (CBD)[1] launched a new era in the protection and conservation of biodiversity worldwide. At the World Summit on Sustainable Development, Johannesburg, 2002, 190 countries endorsed a commitment to achieve, by 2010, a significant reduction in the current rate of biodiversity loss at the global, regional and national levels. Under the CBD, Indian conservation

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[1] Convention on Biological Diversity, available at http://www.cbd.int/2010-target/framework/indicators.shtml (accessed on May 12, 2008).

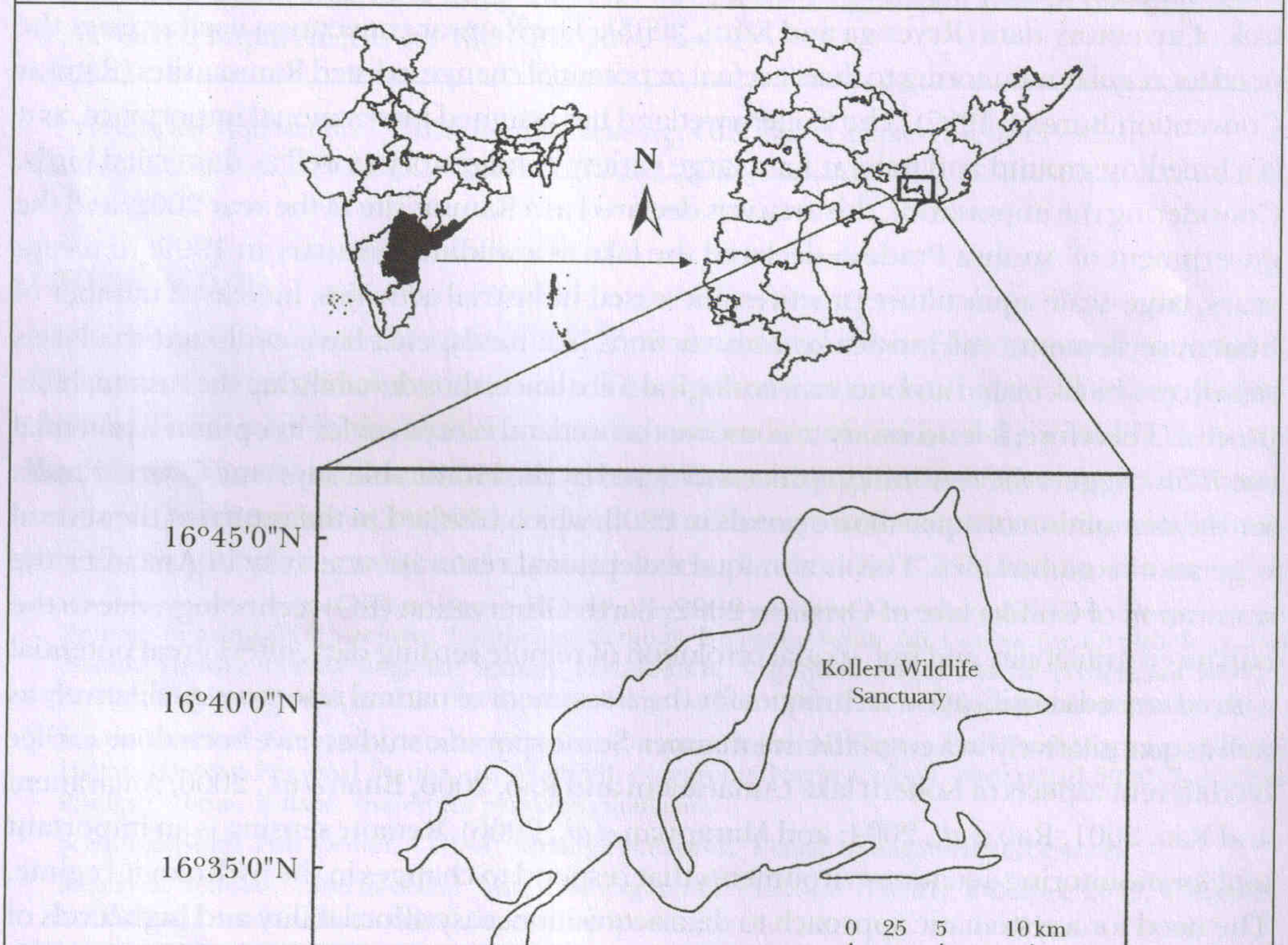
organizations have obligations to ensure the conservation and enhancement of habitats and species in both national and international contexts. To meet the goal 1 of CBD (areas of particular importance to biodiversity protected), it is imperative to study the relevant indicators (trends in the extent of selected biomes, ecosystems and habitats; coverage of protected areas) of that component (CBD Target). A major approach for achieving the target is to implement strict monitoring of biologically rich areas and highlight the urgent need for up-to-the-minute information on biodiversity and habitat conservation status. Since wetlands are the most threatened of all biomes, it is essential that significant conservation attention is given to the same.

Wetlands are important ecosystems that have been evaluated by many researchers in India in the last few decades (Prasad *et al.*, 2002; and Vijayan *et al.*, 2004). In many parts of the world, wetland ecosystems continue to be intensely modified and degraded by human activities. However, alterations in wetlands may also be caused by agricultural changes coupled with aquaculture production, urbanization, pollution, etc. Habitat loss has been accompanied by a decline and loss of freshwater species to a point where the biodiversity of inland water ecosystems is currently in a far worse condition than that of forest, grassland, or coastal ecosystems (World Resources Institute *et al.*, 2000). The status and trends of biodiversity dependent on inland water ecosystems have recently been reviewed for the CBD, which concludes that assessment of the areas and distribution of inland wetlands is difficult due to lack of inventory data (Revenga and Kura, 2003). The Ramsar convention itself stresses the need for regular monitoring to detect actual or potential change in listed Ramsar sites (Ramsar Convention Bureau, 1997). The Kolleru wetland has assumed international importance, as it is a breeding ground and habitat for a large variety of migratory as well as domiciled birds. Considering the importance, this area was declared as a Ramsar site in the year 2002, and the government of Andhra Pradesh declared the lake as a wildlife sanctuary in 1999. In recent years, large-scale aquaculture practices, increased industrial activities, increased number of human settlements, infrastructure constructions like roads, etc., have exploited the lake's resources which created an extensive ecological imbalance, thus destabilizing the sustainability process. Therefore, it is necessary to conserve this wetland ecosystem for its optimum potential use. This triggers the restoration process ordered by the Honorable Supreme Court of India for the demolition of aquaculture ponds in 2006, which resulted in the return of the several vegetation communities. This is a unique exceptional restoration activity in Asia after the restoration of Chilika lake of Orissa in 2002. Earth Observation (EO) technology, due to the enhanced availability and fine spatial resolution of remote sensing data, offers great potential with advanced classification techniques for the assessment of natural resources qualitatively as well as quantitatively in a cost-effective manner. Some sporadic studies have been done earlier on different aspects of Kolleru lake (Amaraneni and Rao, 2000; Bhan *et al.*, 2000; Amaraneni and Rao, 2001; Rao *et al.*, 2004; and Marappan *et al.*, 2006). Remote sensing is an important tool for monitoring aquatic environments that respond to changes in the hydrologic regime. The need for a systematic approach to data acquisition, easy affordability and high levels of precision make satellite sensor data ideally suited to the task of assessing changes in the environment. The present study is a status report after the demolition of aquaculture ponds in 2006. An attempt was made to map Land Use Land Cover (LULC) and to generate baseline information about spatial distribution and variation in the waterspread, aquaculture and aquatic vegetation in the lake for its conservation and management.

Study Area

Kolleru is one of the largest shallow fresh water lakes in Asia, which is located between the alluvial plains of Krishna and Godavari river of West Godavari and Krishna districts of Andhra Pradesh, India. It is situated between 81° 04' 23" and 81° 24' 53" latitude and 16° 32' 03" and 16° 46' 49" longitude (Figure 1). The lake serves as a natural flood-balancing reservoir for the two rivers and sustains a rich native flora and fauna. It is an ideal habitat to nearly 189 local and migratory bird species, including grey pelican (*Pelecanus phillippensis*), spoon-billed sandpiper (*Euryhorhynchus pygmaeus*) and other water birds, passerines and raptors. The lake has four main rivulets, viz., Budameru, Ramileru, Tammileru and Bulusuvagu. Apart from these, nine major drains and seven medium drains empty their water into the lake. There is only one outlet called Upputeru, which runs for a distance of 64 km and connects to the Bay of Bengal. The Kolleru Wildlife Sanctuary (KWS) is populated by 46 bed (inside the lake) and 76 belt villages (on the sanctuary boundary) with an estimated population of 0.3 million.

Figure 1: Location Map of the Kolleru Wildlife Sanctuary



Materials and Methods

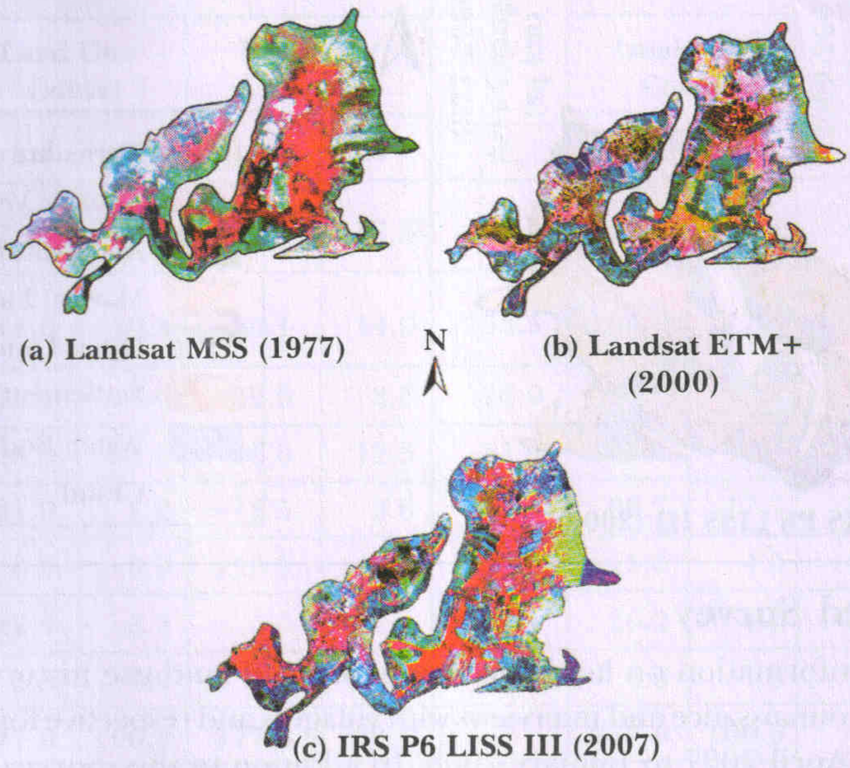
Image Data and Processing

The analysis is based on multi-temporal satellite sensor imagery that included the KWS, the extent of which was analyzed over time. Three different time periods were chosen for the analysis, i.e., Landsat Multi-Spectral Scanner (MSS), Landsat Enhanced Thematic Mapper Plus (ETM+), and Indian Remote Sensing (IRS) P6 (Resourcesat-1) Liner Imaging Self-Scanner III (LISS) (Table 1). To carry out a quantitative comparison of the images in the present study, the original images were resampled to the spatial resolution of the TM raster grids (30 m) (Staus *et al.*, 2002). The raw images were geo-referenced with ortho-rectified Landsat satellite data downloaded from the Global Land Cover Facility (GLCF) using Ground Control Points (GCP). All the datasets were corrected with sub-pixel level accuracy and converted to UTM projection and WGS 84 datum. The Area of Interest (AOI) was delineated from the satellite data for further analysis and false color composite (FCC) images were prepared (Figure 2). Owing to the availability of these datasets along

Table 1: Details of Remote Sensing Data Used

Satellite-Sensor	Path-Row	Date of Acquisition	Spatial Resolution (m)
Landsat MSS	152/48	January 8, 1977	80.0
	152/49	January 1, 1977	80.0
Landsat ETM+	142/48	October 28, 2000	30.0
IRS-P6 LISS III	102/61	April 26, 2007	23.5

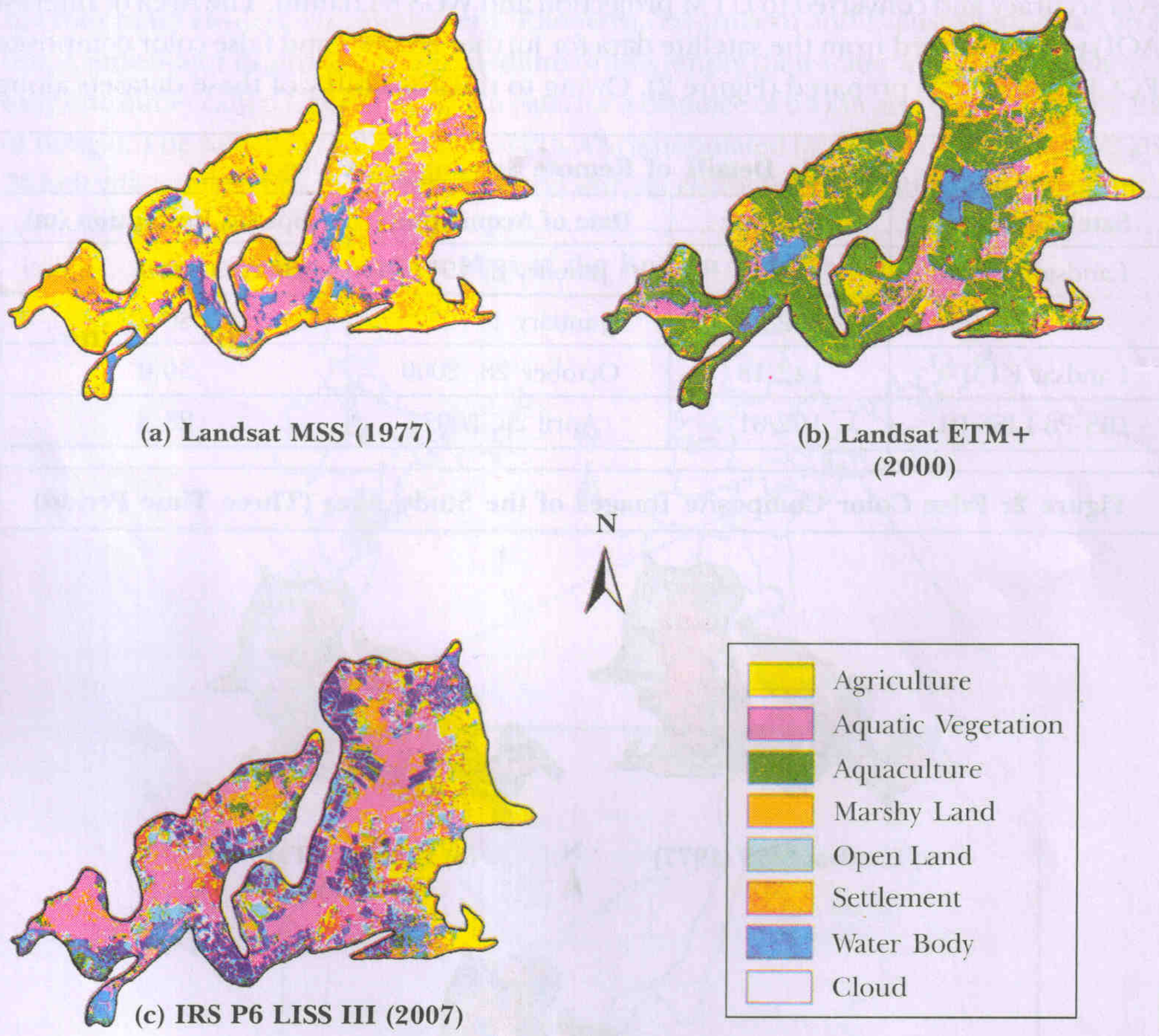
Figure 2: False Color Composite Images of the Study Area (Three Time Period)



(a) Landsat MSS (1977) **(b) Landsat ETM+ (2000)** **(c) IRS P6 LISS III (2007)**

with ground data, a supervised classification was chosen to classify the satellite data. The training sites were selected considering representation of all digital categories of radiance according to the numeric values (spectral signature) and color composites. Some of these training areas were consistently delineated in each scene in order to minimize classification errors when performing change detection (Luque, 2000). The statistical decision criterion of Maximum Likelihood Classifier (MLC) was used in the supervised classification to assist in the classification of overlapping signatures, in which pixels were assigned to the class of highest probability. All the image processing were carried out on a Windows platform using ERDAS IMAGINE 8.7 image processing software. The classified maps of three time periods (1977, 2000 and 2007) were produced (Figure 3).

Figure 3: Land Use Land Cover Classification Maps for Each Time Step



Ground-Based Survey

Ground-based information on land cover category and land use history was collected through field reconnaissance and interviews with villagers and respective forest department officials during April 2007 to January 2008. In addition to this, Survey of India (SOI) toposheets of 1:50,000 scale, forest management maps, and Global Positioning System (GPS) were used for the ground survey. GPS points were collected post-classification for accuracy assessment.

Results and Discussion

The spatial changes in Kolleru wildlife sanctuary were assessed and the details are given in Table 2. Seven land cover categories excluding cloud were identified in the study area and their distribution in 1977, 2000 and 2007 is shown in Figure 3. It is evident from the spatial analysis that the major activities seemed to be crop production and aquaculture from early 1990 to 2006. When there was no aquaculture in 1977, it increased to 158.5 sq km by the year 2000 (Table 2). Aquaculture became a major business in this sanctuary by converting the lake and agricultural land. The aquaculture area reduced to only 15 sq km after the demolition drive by the state government of Andhra Pradesh. There was a significant loss of agricultural land from 1977 (128 sq km) to 2007 (44.1 sq km). A considerable increase in settlement area from 3.3% (1977) to 7% (2007) was observed because most of the wealthy people settled inside the sanctuary area for aquaculture business. After the demolition of several aquaculture ponds below 1.5 m contour level in 2006, the natural lake area was restored. Latest, 2007 satellite images revealed that the total area of water increased to 66.7 sq km (31 sq km in 1977). The area of aquatic vegetation increased to 34.5 sq km from 1977 to 2007. Interestingly, the consequent decrease in aquaculture is much evident and sums to 4%; whilst the area under aquatic vegetation and marshland increased 45.5% in 2007. This clearly illustrates the restored vegetation cover. Weed species like *Phragmites*

Table 2: Results of Land Use/Land Cover Classification for 1977, 2000 and 2007 Images Showing Area of Each Class, Class Percentage and Area Changed

Class Name	1977 Land Use/Cover		2000 Land Use/Cover		1977-2000 Area Changed (sq km)	2007 Land Use/Cover		2000-2007 Area Changed (sq km)	1997-2007 Area Changed (sq km)
	sq km	%	sq km	%		sq km	%		
Aquatic Vegetation	72.4	19.2	65.3	17.3	–7.1	106.9	28.4	41.6	34.5
Marshy Land	114.6	30.4	56.1	14.9	–58.5	64.3	17.1	8.2	–50.3
Open Land	15.1	4.0	32.0	8.5	16.9	46.6	12.4	14.6	31.5
Agriculture	128.0	34.0	46.6	12.3	–81.4	44.1	11.7	–2.5	–83.9
Water Body	31.0	8.2	13.5	3.6	–17.5	66.7	17.7	53.2	35.7
Aquaculture	0.0	0.0	158.5	42.0	158.5	15.0	4.0	–143.5	15.0
Settlement	12.4	3.3	5.3	1.4	–7.1	26.2	7.0	20.9	13.8
Cloud	3.5	0.9	0.0	0.0	–3.5	6.9	1.8	6.9	3.4
Total	**377.0**	**100.0**	**377.0**	**100.0**	–	**377.0**	**100.0**	–	–

karka and *Typha angustata* are found to be spreading vigorously in the lake area. The marshy area lost a 50.2 sq km in 30 years. This is because most of the marshy land was either converted into aquaculture pond or aquatic vegetation spread on that. The overall accuracy has been calculated to 82% for 1977, 86% for 2001 and 90% for 2007 classified images.

The agricultural runoff and aquaculture effluents from the whole catchment area reach the lake, filling it with toxic chemicals, pesticides, excess nutrients and silt at the lakebed. The pesticides deteriorate the water quality, and the excess of nutrients results in weed infestation. During the last three decades, traditional fishing became corporate fish farming (Marrapan *et al.*, 2006). The impacts of the aquaculture invasion on the lake could be clearly understood from the analyses. Now the grey pelicans, with other domicile and migratory birds, are back in the Attapakka region of the lake for mass nesting after the demolition of fishponds. Detection and analysis of LULC changes, thus, serve as a pathway to understand how land use decisions made by various groups have destructive environmental consequences.

Conclusion

In the present study, RS and GIS are shown to have had a major role in obtaining a synoptic view of the present and past status of the KWS as well as support to understand how indicators are important to sustain biodiversity. A comparative study of different time periods brings an overall picture, to convince various stakeholders such as forest officials, managers, decision makers and planners for further conservation and restoration activities. The firsthand information generated for the KWS after the demolition of aquaculture ponds will aid in understanding the spatial distribution of LULC over 30 years and the significant disturbances within a protected area, which ultimately help the Forest Department, Government of Andhra Pradesh in further planning and taking appropriate decisions on time for sustaining the rest of the lake area. ✦

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