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ABSTRACT

Aquaculture has developed rapidly over the last two decades and has become an important economic activity worldwide, which resulted in growing concerns about its impact on important ecosystems. Kolleru lake, India's largest fresh water lake, and lone Ramsar site in Andhra Pradesh state have undergone tremendous changes due to development of aquaculture. Large-scale aquaculture practices, increased industrial activity, increased number of human settlements, etc. have exploited the lake's resources which created an extensive ecological imbalance, hence instabilising the sustainability process. This trigger to the restoration process ordered by honorable Supreme Court of India for the demolition of aquaculture ponds in 2006, which has resulted in come back of the seral vegetation communities. Improved Earth Observation technology like remote sensing combined with Geographical Information System could contribute to this in a cost effective manner, for instance trough rapid assessment and mapping of aquaculture scenario before and after demolition. The present study highlights the assessment of aquaculture in Kolleru lake using multi-temporal satellite datasets. The digital image processing of 1977 Landsat MSS data revealed that there is no aquaculture in that period, which increased to 158.5 sq km in 2000 (Landsat ETM+). We processed the IRS P6 LISS III 2007 satellite data and found the aquaculture area reduced to only 15 sq km after the demolition of fishponds. The maximum conversion to aquaculture occurred from agriculture and marshy lands in the period of 1977 to 2000. This is an unique exceptional restoration activity in Asia after restoration of Chilika Lake of Orissa in 2002. So, there is an urgent need for regular monitoring of important lake and wetland resources in India as well as in world to protect the biodiversity of the earth.

Keywords: Aquaculture, GIS, Kolleru Lake, Remote sensing

INTRODUCTION

Aquaculture, mainly referring to the farming of fish and shellfish, forms a major enterprise in the primary production sector in the inland, freshwater, brackish water areas of India. Use of indigenous and foreign technologies has been in vogue in enhancing aquaculture production. Aquaculture the farming of aquatic organisms, particularly fish, shell fish and shrimp, represents some 25% of food fishery supply, and is expected to contribute an increasing share to meet the world's future food needs. In India, brackish water aquaculture is widespread in the east coast, in West Bengal, Orissa, Andhra Pradesh and Tamil Nadu. Along the west coast, Kerala had dominant traditional system of paddy-cum-shrimp culture, followed by traditional systems in Karnataka and Goa.

Aquaculture has developed rapidly over the last two decades and has become an important economic activity worldwide. According to Food and Agriculture Organization, total aquaculture production of aquatic animals (excluding aquatic plants) increased from 6.7 million tones in 1984 to 42.3 million tones in 2003, and India's contribution to world aquaculture production was 6.2%. Aquaculture has been transformed from a traditional activity to commercial farming of high profit sector in the early nineties, and the area increased from 60,235 ha in 1989-1990 to 221,250 ha in 2003-2004 (MPEDA, 2004). Export of marine products from India set an ever time record of 612,641 tonnes of value reached 1852.93 million US dollar during 2006-07 (MPEDA, 2007). This rapid expansion of aquaculture in India has led to a growing concern about its impact on the environment. Major environmental issues such as the conversion of important coastal ecosystems likes, lakes, mangroves and agricultural lands to aquaculture farms and pollution of drinking water resources adjacent to aquaculture farms have been raised over the development of aquaculture (Primavera, 1994; Deb, 1999; Perez et al., 2003). In addition, serious socio-economic consequences have occurred which includes large-scale removal of valuable coastal wetlands, salinization of groundwater and agricultural lands, and subsequent loss of goods and services generated by natural resource systems.

Inventorying and regular monitoring the wetlands are essential for decision making on aquaculture development, including regulatory laws, environmental protection. In the aquaculture development policy of the government, attention has to be focused on identification and monitoring of the expansion of shrimp farms, often located in remote areas. However, reliable and timely information on the nature, extent, spatial distribution pattern and temporal behaviour of degraded lands, including those subject to aquaculture, which is a prerequisite for their reclamation and management, is not available. Remote sensing (RS) coupled with geographic information system (GIS) can be use as important tools for rapid monitoring aquatic environments that respond to changes in the hydrologic regime with a cost effective manner. Remotely sensed data can fill the gap by providing essentially uniform coverage over large areas at reasonably high positional accuracy, spatial and temporal resolution (Ehlers et al., 1991). A number of studies have been published on the application of GIS and remote sensing in aquaculture (Kapetsky et al., 1988; Salam et al., 2003, Diwedi and Kandrika, 2005; Jayanthi et al., 2006). The present aquaculture dynamics study is first of its kind after demolition of illegal fish ponds in Kolleru Lake using remote sensing and GIS.

STUDY AREA

Kolleru is one of the biggest shallow fresh water lake 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 situated between 81º 04' 23" to 81º 24' 53" latitude and 16º 32' 03" to 16º 46' 49" longitude. The lake serves as a natural flood-balancing reservoir for the two rivers and sustained the rich native flora and fauna. It is used to be an ideal habitat to nearly 189 local and migratory bird species including Grey pelican (*Pelecanus phillippensis*), spoonbill 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, 9 major drains and 7 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.

MATERIALS AND METHODS

The analysis is based on a multi-temporal satellite imagery study that included the KWS, the extent which was analyzed over time. Three different time period data were chosen for analysis. i.e. Landsat Multi-spectral Scanner (MSS) of 1977, Landsat Enhanced Thematic Mapper Plus (ETM+) of 2000, and Indian Remote Sensing (IRS) P6 (Resourcesat-1) of Liner Imaging Self Scanner III (LISS). The raw images were geo-referenced with ortho-rectified Landsat satellite data downloaded from Global Land Cover Facility (GLCF) using proper ground control points (GCP). All the datasets were corrected with sub pixel level accuracy and brought into UTM projection and WGS 84 datum. The area of interest (AOI) was delineated from the satellite data for further analysis and False Colour Composite (FCC) images were prepared (Fig. 1).

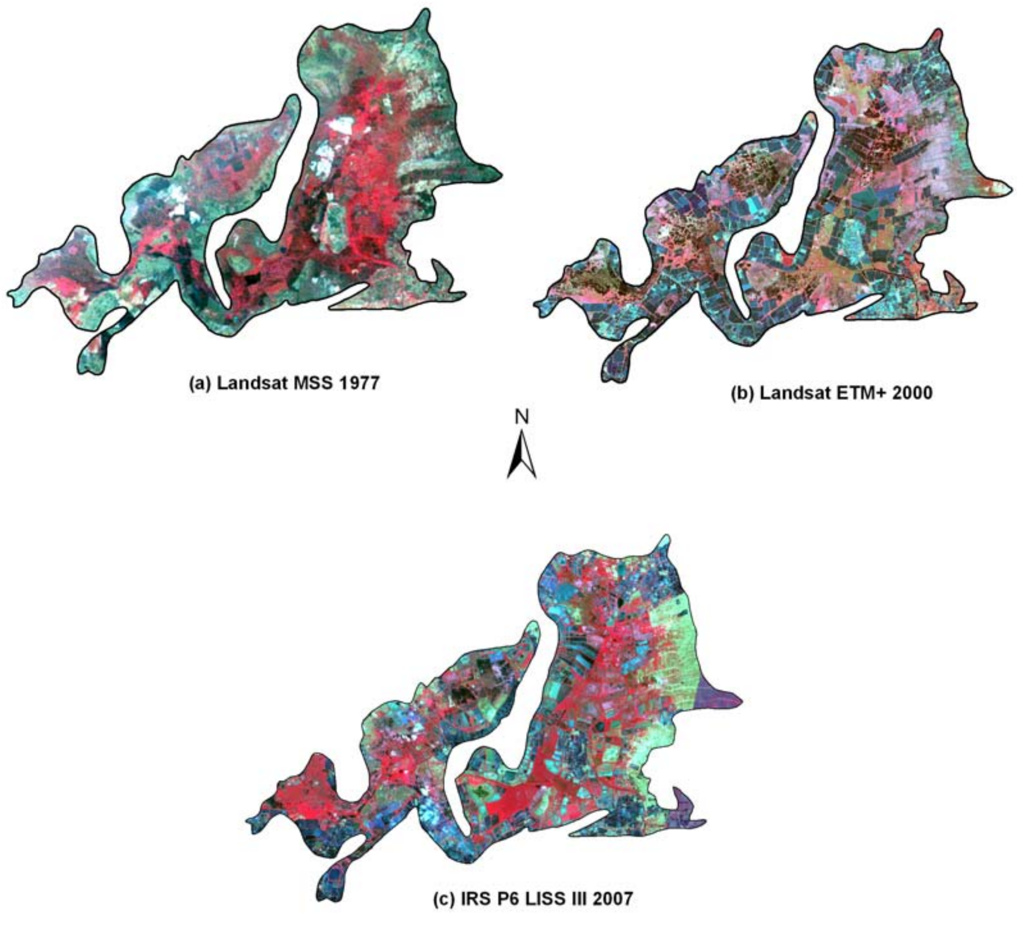

Figure 1. FCC image of Kolleru Wildlife Sacnctuary; (a) Landsat MSS 1977 (b) Landsat ETM+ 2000 (c) IRS P6 LISS III 2007

Owing to the availability of these data sets along with ground truth, a supervised classification was chosen to classify the satellite data. The selection of training sites was done 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. The statistical decision criterion of Maximum Likelihood 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 these image processing was 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) are produced (Fig. 2).

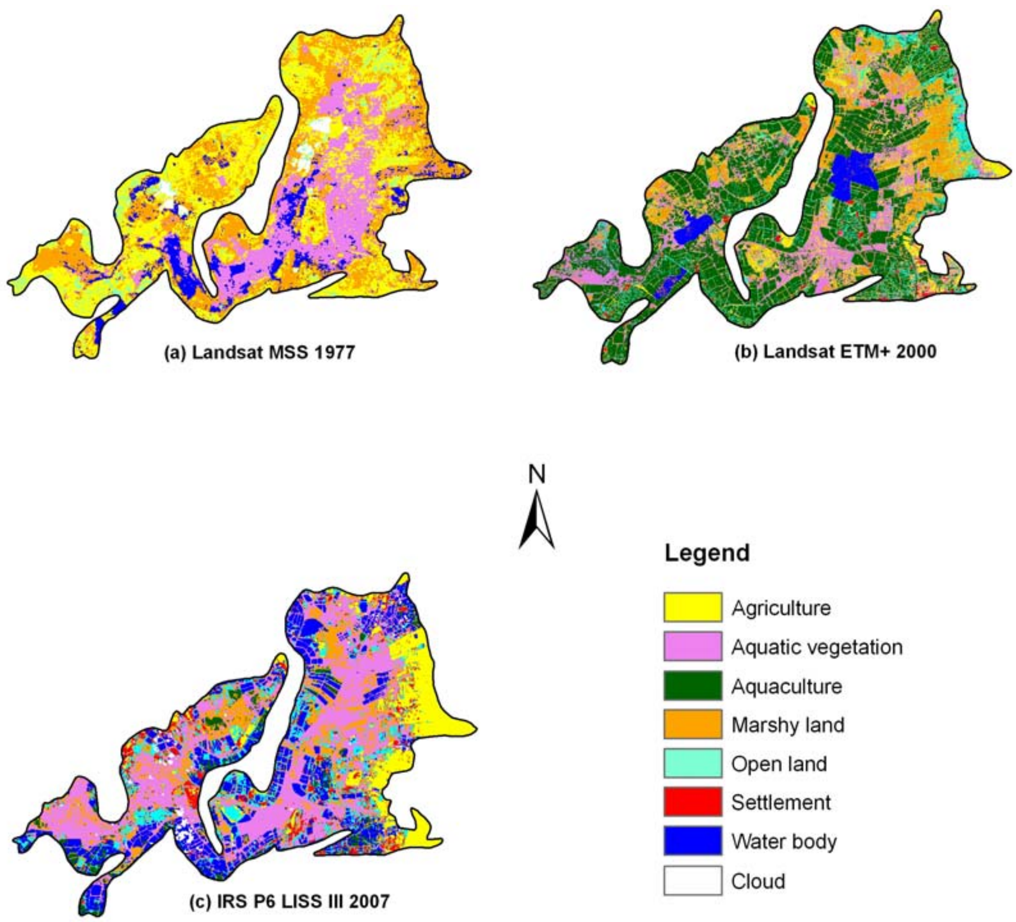

Figure 2. Classified map of Kolleru sanctuary (a) Landsat MSS 1977 (b) Landsat ETM+ 2000 (c) IRS P6 LISS III 2007

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, Global Positioning System (GPS) were used for the ground survey. GPS points were collected after post classification for accuracy assessment.

RESULTS AND DISCUSSION

The spatial changes in Kolleru wildlife sanctuary were assessed and the details are given in Table 1. Seven land cover categories were identified in the study area and their distribution in 1977, 2000 and 2007 is shown in Figure 2.

It is evident from the spatial analysis that the major activities seemed to be crop production and aquaculture from early 1990's to 2006. When there was no aquaculture in 1977, it increased to 158.5 sq km by the year 2000 (Table 1). Aquaculture became a major business in this sanctuary by converting lake and agricultural land. The aquaculture area reduced to only 15 sq km after the demolition drive by 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 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 total water spread area was increased to 66.7 sq km (31 sq km in 1977). The area of aquatic vegetation has increased to 34.4 sq km since 1977 to 2007. Interestingly, the consequent decrease in aquaculture in much evident and sums to 4%; whilst the area under aquatic vegetation and marshland increased 45.5% in 2007. This clearly illustrated the restored vegetation cover. Weed species like *Phragmites 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 of most of the marshy land either converted to aquaculture pond or aquatic vegetation spread on that. The overall accuracy has been calculated 82% for 1977, 86% for 2001 and 90% for 2007 classified images.

	1977	**2000**		**2007**			
	Land use/cover	Land use/cover	1977-2000	Land use/cover		2000-2007	1977-2007
Class name	(sq km)	(sq km)	Area changed (sq km)	(sq km)	(%)	Area changed (sq km)	Area changed (sq km)
Aquatic vegetation	72.4	65.3	-7.1	106.9	28.4	41.5	34.4
Marshy land	114.6	56.1	-58.4	64.3	17.1	8.2	-50.2
Open land	15.1	32.0	16.9	46.6	12.4	14.6	31.5
Agriculture	128.0	46.6	-81.4	44.1	11.7	-2.4	-83.9
Water body	31.0	13.5	-17.5	66.7	17.7	53.2	35.7
Aquaculture	0.0	158.5	158.5	15.0	4.0	-143.6	15.0
Settlement	12.4	5.3	-7.1	26.2	7.0	20.9	13.8
Cloud	3.5	0.0	-3.5	6.9	1.8	6.9	3.5
Total	**377**	**377**		**377**	**100**		

Table 1. Distribution of land use land cover in Kolleru sanctuary from 1977 to 2007

The aquaculture area which was not there in 1977, increased upto 158.5 sq km in 2000 and after demolition of fish ponds it came down to only 15 sq km area. During the 1990s, aquaculture grew at a very fast rate due to high profit, economic viability, suitable soil and environmental conditions and encouraging market scenario, which made the farmers convert their agriculture field to fish farms. In addition to the conversion of agricultural fields to aquaculture farms, new farms were constructed in the lake liable to be flooded region by big entrepreneurs. Now, aquaculture has become the major activity and replaced agriculture. There were 1050 fish ponds within the lake in addition to 38 dried up ponds in 2001 (Rao et al., 2004). The flow of water into the sea is obstructed due to the construction of bunds across the lake area, which has led to the inundation of nearby villages during the rainy season. After demolition of the aquaculture ponds the pristine glory of the lake back again. Now, a number of domesticated as well as migrated birds started coming to the lake for breeding. The government also allowed the traditional fishing inside the lake which is one of the alternative livelihood options for those farmers.

The kolleru lake also receiving agricultural waste, domestic and industrial effluents from surrounding catchment area and contaminate the lake environment. Excessive nutrient loads have caused eutrophication in some parts of the lake. All these activities should immediately checked at point of origin to save the environment of the lake. In the present study, RS and GIS are shown to be having 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 period brings an over all picture, to convince various stakeholders such as forest officials, managers, decision makers and planners for further conservation and restoration activities. The first hand information generated for the KWS after demolition of aquaculture ponds will aid in understanding the spatial distribution of LULC over 30 years and significant disturbances within a protected area which ultimately help the forest department, Government of Andhra Pradesh in further planning and taking in time appropriate decision for sustaining rest of the lake area.

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