"ENVIRONMENTAL IMPACT ASSESSMENT DUE TO AQUACULTURE DEVELOPMENT IN LARGEST FRESHWATER LAKE IN INDIA (ANDHRA PRADESH) USING REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS)"

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Abstract

Kolleru, the largest fresh waterbody in India (Andhra Pradesh), has undergone significant changes due to development of aquaculture in that area. This resulted in the water spread area of the lake's degradation and increase in settlement and these changes directly affected the environment of the lake. The lake slowly started vanishing by losing its potential and ecological importance. Due to this an order was put up by the Honorable Supreme Court of India for the demolition of aquaculture ponds in 2006, which when carried out resulted in the revival of the lake with its original environment. Application of Remote Sensing and GIS techniques help us to assess the environmental Impact on the lake before and after the demolition of the aquaculture ponds. The present study was carried out to assess the environmental impact assessment on the lake. The Satellite Imagery for the year 1977 reveals that there is no aquaculture during that period. IRS 1D LISS III for the year 2000 reveals the development of the aqua farms and IRS P6 LISS III 2007 data clearly shows the revival of lake features. From the year 1977 the area under lake water spread with vegetation and mud were converted as aquaculture farms. After the demolition of the aquaculture farms the following categories were increased (from the year 2000 to 2007) i.e., lake water spread area with vegetation at 34.62 km2, lake-mud as 31.44 km2, agriculture at 5.81 km2 and settlement as 0.52 km2. Aquaculture farms have decreased to 71.93 km2.

Keywords : Kolleru, EIA, RS and GIS.

I. INTRODUCTION

Major environmental issues like conversion of important coastal ecosystems like lakes, mangroves and agricultural lands and salinisation of drinking water resources have been raised over the development of aquaculture. Due to lack of awareness among people and Governments, degradation of coastal wetlands is still continuing. To properly respond to natural and human-induced stresses to wetlands, resource managers must re-consider their functions towards eco maintenance and values for proper planning. Information on existing land use, land cover, its spatial distribution and changes are essential pre-requisite for planning. Rapid expansion of aquaculture activities in India has led to the growing concern about its impact on the environment. In recent years, pollution of the coastal ecosystems has become a national and international problem because of its impact on living organisms, impairment on water quality for use, hindrance to fishery resources and human health (Halstead, 1970). Problems have arisen because of the lack of understanding of the aquatic environment and the use of non-eco means of resources, rather than production technology problems. Remote sensing (RS), GIS and GPS are important tools for the monitoring wetland, responses to changes in the hydrologic regime. Evaluation of aquaculture impacts will be useful to predict the likely environmental impact and finds ways to reduce the adverse impacts if any, to shape the project to suit the local environment (UNEP, 1985).

II. STUDY AREA

Kolleru, the largest fresh water body in India (Andhra Pradesh), is located between the latitudes of 160 32' 03" and160 46' 49" N and longitudes 81004' 23"and 81027' 23" E with an area of 180.38 sqkm. Its catchment spreads to 4,763 sq.km of which

3,403 sq. km. covers the upland region and 1,360 sq km in the delta spread to +10 m contour. Considering its ecological importance, it has been designated as a Ramsar Site (No.1209 on 19.08.02) which provides the framework for national action and international cooperation for the conservation and sustainable use of wetlands and their resources. It functions as a flood balancing reservoirs between two deltas and supports vulnerable species of birds like Spoonbill Sandpiper (Euryhorhynchus Pygmaeus), Grey pelican (Pelecanus philippensis) as well as greater and lesser flamingos. Although the lake is about 35 Km inland from the present coast, it was a coastal lagoon in the geological past, believed to have been formed around 6000 years BP, when the shoreline was far inland along the southern (seaward) margin of the lake, as evident from the presence of a series of relict sandy beach-dune ridges right up to the southern margin of the lake near Kaikalur and Akividu towns (Sadakata and Nageswara Rao, 1997). Figure-1 represents the location map of the lake area.

A. Data Used

Survey of India toposheet for the year 1972 bears the no of 65H/2, 65H/6 and 65H/5 on 1:50000 scale used for the preparation of base map. A False Colour Composite (FCC) of Landsat Thematic mapper for the year 1977 (Row-48&49 and Path142), IRS 1D LISS III (Row-103 and path-61) for the year 2000 and IRS P6 LISS III (Row-103 and path-61) for the year 2007 data has been used for the preparation of land use pattern of the lake.

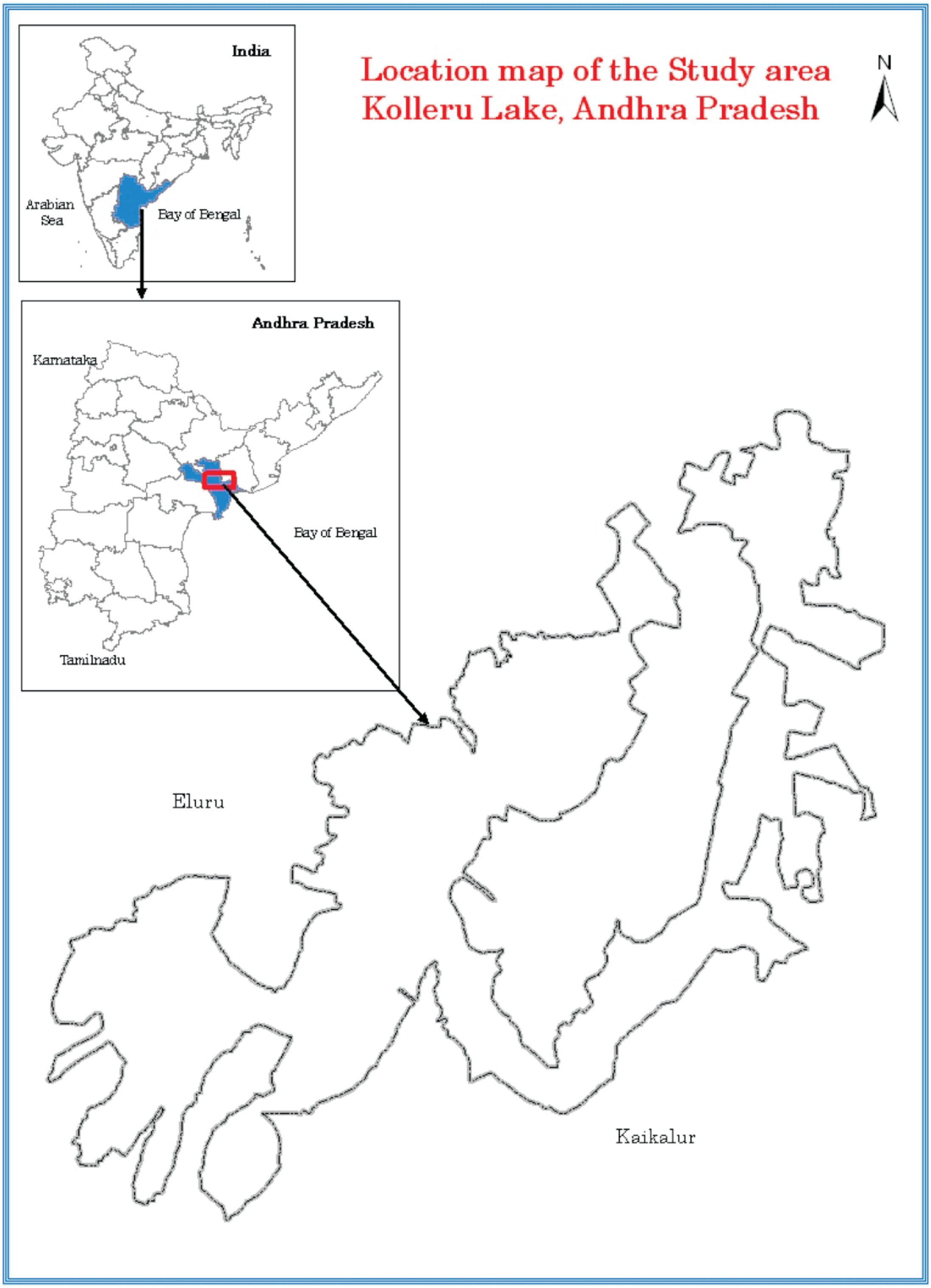

Fig. 1. Location map of the study area

B. Software Used

Erdas Image 9.3 used for the Raster analysis, Arc GIS 9.3 used for the GIS analysis, Arc Pad 7.0 used for Importing the GPS data to the map and Microsoft office 2007 used for data preparation.

Digital Image Processing

The SOI (Survey of India) toposheets were rectified and mosaiced and outer boundary was derived from the mosaiced map in 1:50,000 scale. The Imageries were geo-referenced using the auto synchronies method of Erdas Image 9.3 with the help of the rectified toposheet and sub setted using the boundary layer. It was projected as geographic lat/long wgs84 datum wgs84. In Erdas Image software spatial, spectral, radiometric and enhancement techniques were followed to produce a crispy image and to reduce the noise, atmospheric attenuation and salt pepper effect. Figure 2 represents the lake boundary over laid on rectified image. It was visually interpreted using the visual interpretation keys (Table-1).

GIS Analysis

Using Arc Info 9.3 vector layer was created for base map and landuse/landcover map for the year 1977, 2000 and 2007 and it was further analyzed like clean, built and projected as utm zone 440 north wgs84 and datum wgs84 for area calculation. Figure-2 explains the methodology adopted for the study. Ground truth verification was carried out using GS5+ Global Positioning System (GPS). The latitude and longitude of the different classes were verified in the field and it was directly imported into Arc map 9.3 for the updated map. Figure-2 represents the methodology adopted for the study.

Table 1. Image interpretation keys for coastal mapping using remote sensing data

Category	Tone	Shape	Texture	Remarks
Lake water Spread area	Blue/ Dark blue	Various shapes	Smooth	Semi enclosed body. Part of the lower river course that is affected by mixing of salt water with fresh water
Mud	Bluish green	Irregular	Smooth	Made up of fine grained soft mud. Act as a suitable habitat for the growth of mangroves marsh vegetation and variety of flora and fauna.
Aquaculture	Dark blue, light blue	Rectangular, Square	Smooth	
Agriculture	Bright red	Rectangular, Square	Medium to Smooth	Continuous to Non continuous pattern
Vegetation	Yellow to Greenish blue	Irregular	Medium to Smooth	Dispersed
Settlement	White to grayish white	Irregular	Medium to Smooth	Dispersed

(Source: NRSA)

C. Accuracy Assessment

The latitude and longitude of the different classes were verified with its extent and doubtful areas were mapped through GPS readings in Arc Pad 7 and imported to Arc Gis 9.3. Accuracy assessments determine the quality of the information derived from remotely sensed data. Totally 25 points were taken and it was verified in the field; out of this 25 points 2 points were of different classes; all the verified points were imported using Arc Pad 7 and updated on the landuse map for the year 2007. User and producers accuracy is about 92% of the map for the year 2006.

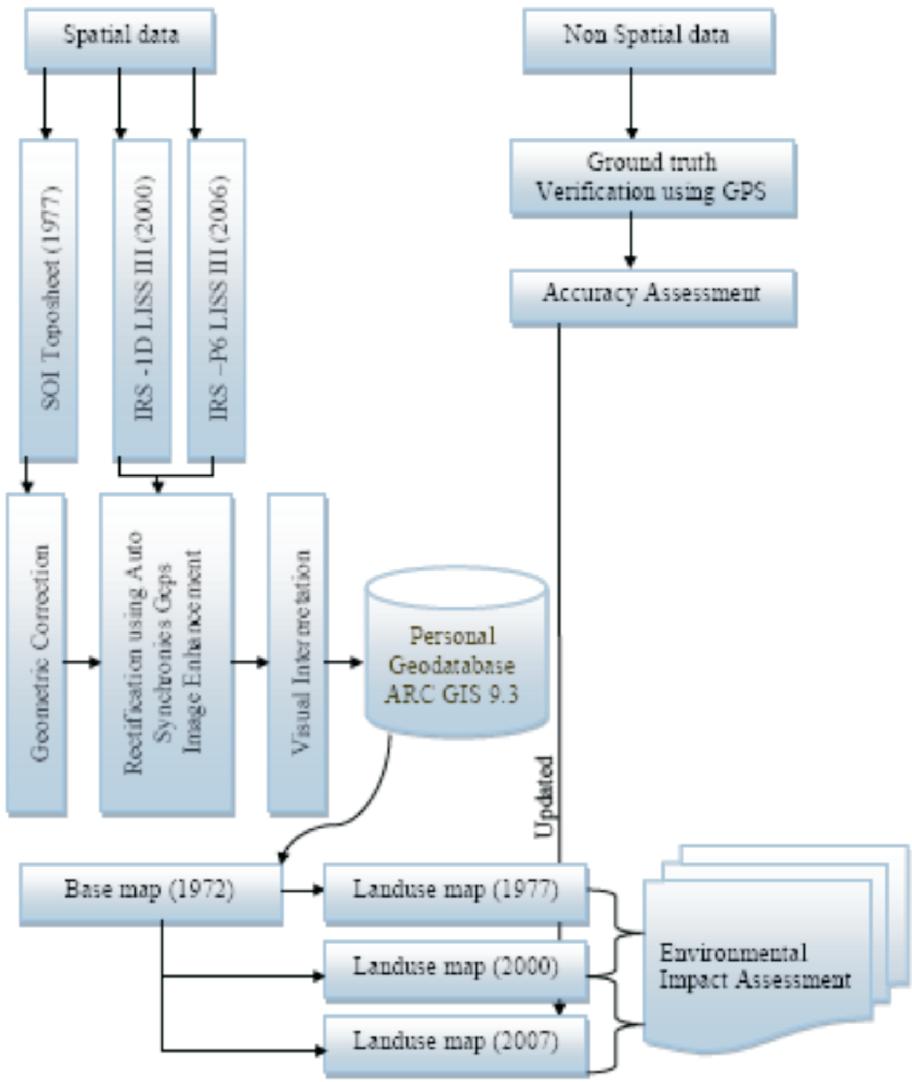

Fig. 2. Methodology for the study

III. LANDUSE PATTERN OF KOLLERU LAKE FOR THE YEAR 1977

GIS analysis using Landsat thematic mapper estimated that the total area of Kolleru lake was 180.38 km2 (Figure.3), in which the area covered by water with vegetation was 67.09 (37.19%) km2, the area comes under mud was 102.10 km2 (56.60%), agriculture covers an area of 10.80 km2 (5.99%), and settlement covers an area of 0.39 km2 (0.22%). The aquaculture was not developed in the years of 1972 and 1977. The traditional fishing in Kolleru Lake was the main source of income for the local fishermen. (Table-2 represents the landuse pattern of Kolleru).

Table 2. Landuse pattern of Kolleru lake 1977, 2000 and 2007

No	Categories	Area (sq.km)					Area (percentage)				
		1977	2000	2007	77-00	00-07	1977	2000	2007	77-00	00-07
1	Lake – water spread with vegetation	67.09	32.08	68.92	35.01	-36.84	37.19	17.78	38.21	19.41	-20.4
2	Lake - Mud	102.10	50.40	81.84	51.70	-31.44	56.60	27.94	45.37	28.66	-17.4
3	Agriculture	10.80	14.56	20.37	-3.76	-5.81	5.99	8.07	11.29	-2.08	-3.22
4	Settlement	0.39	1.33	1.39	-0.94	-0.06	0.22	0.74	0.77	-0.52	-0.03
5	Aquaculture farms	-	82.01	7.86	-82.01	74.15	*	45.47	4.36	-45.47	41.11
	Total	180.38	180.38	180.38	0.00	0.00	100.00	100.00	100.00	0.00	0.00

IV. DEVELOPMENT OF AQUACULTURE ON THE LAKE ENVIRONMENT

Aquaculture in India has grown from subsistence activity in early forties to an enterprise incorporating scientific and technical inputs by the late eighties. The successful development of hatchery technology in the late 1980's and the opening up of the economy at the beginning of the 1990's saw an aggressive expansion of shrimp aquaculture in the country. 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, salinisation of groundwater and agricultural lands, and subsequent loss of goods and services generated by natural resource systems. Aquaculture became a major business in this sanctuary by converting lake and agricultural land. The scenario has changed and aquaculture was developed in Kolleru Lake slowly. During the 1990,s, 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 to 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. Obstructions on the lake's periphery have led to flooded agricultural land near the lake, even during normal rainfall. Infrastructure facilities, such as roads, were developed in the pre-aquaculture era in the lake liable to be flooded region and aquaculture alone cannot held be responsible for this lake eco-degradation.

A. Landuse pattern of Kolleru Lakefor the year 2000

IRS 1Dimage of Kolleru Lake (Figure.2)indicates the different land use classes such as lake water spread area with vegetation, mud, aqua-culture ponds, agriculture and settlement. The land use pattern map for the year 2000 revealed that the area (Table -2) under aqua-culture as 82.01 km^2(45.47%),lakewater spread area with vegetation has greatly reduced to32.08km^2(17.78%),lake area with mud reduced to 50.40 km^2(27.94%)The principal vegetative plants were identified as elephant grass (Pennisetumpurpurium) and water hyacinth (Eichhornia crassipes). Agriculture area increased to 14.56 km^2(8.07%).The area covered by settlements increased to 1.33km^2(0.74%).The average depth of the lake, which varies from 0.5 to 2m,is gradually being reduced due to siltation. The lake has existed for thousands of years in spite of sediment imports through inland streams and reductions in the flushing capacity of Upputeru due to the over extension of its course by progressive advancement of the coastline far away into the sea (Rao et al.2004).There is speculation that its topographical location over a deep-seated tectonic depression, which is geophysically known as Gudivadasub-basin, between the Bapatla and Tanuku subsurface ridges (Rajuet., al2003), is responsible for the persistence of the lake, although other lagoons much younger to Kolleru, in the area towards the coast seem to have been dried out subsequently (Rao and Pillai 2001).

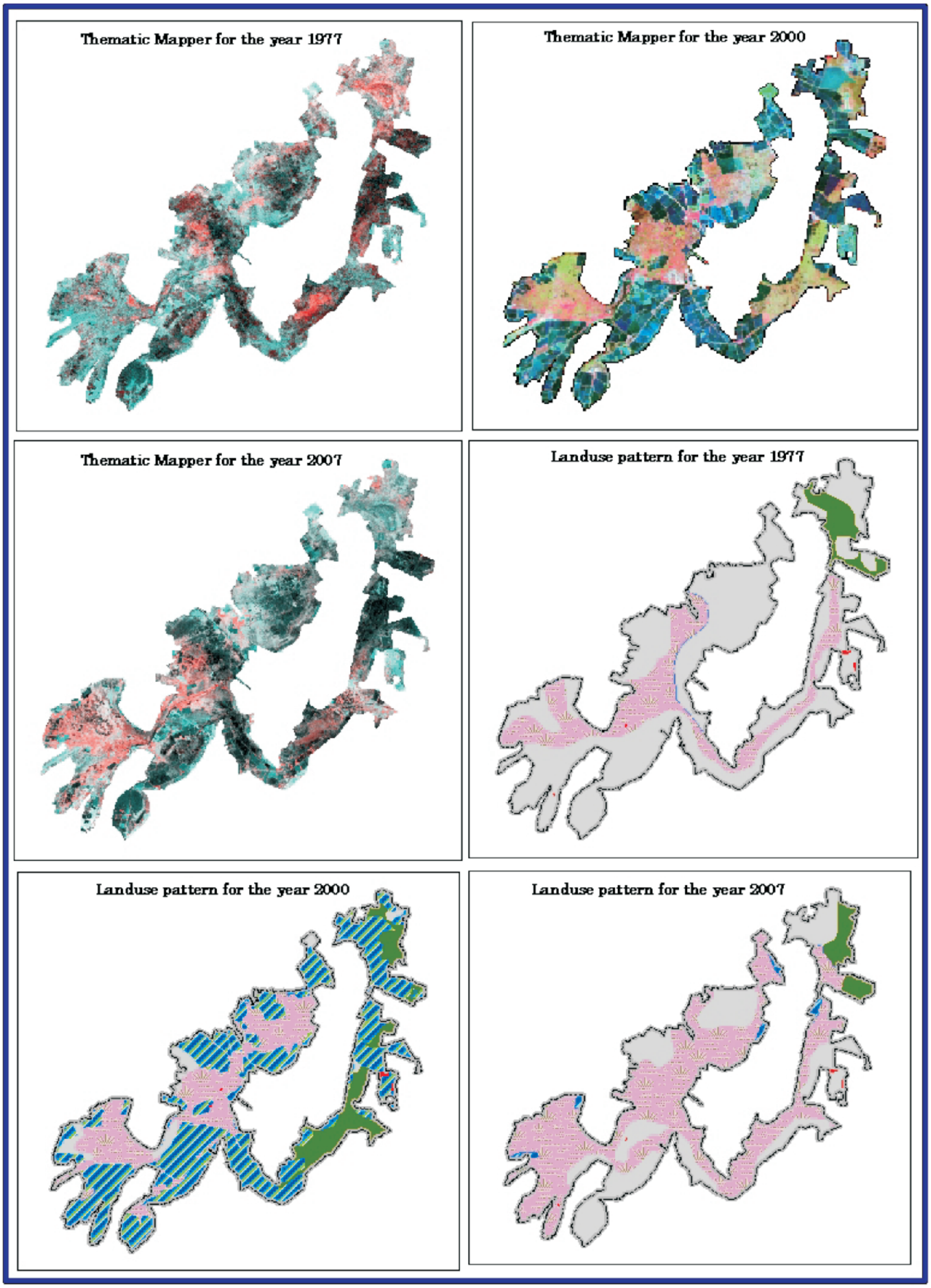

Fig. 3. Kolleru lake view1977, 2000 & 2007

B. Landuse pattern of Kolleru lake for the year 2007 (Post Demonization Scenario)

After demolition of several aquaculture ponds (Figure-4) below 1.5 m contour level in 2006, the natural lake area was restored (Nadhi Nagabhatla et.,al -2008). Satellite images for the year 2007 (Figure-3) revealed that the following categories have increased, lake water spread area with vegetation to 68.92 km2 (38.21%), lake mud to 81.84 km2 (45.37%), area under agriculture to 20.37 km2 (11.29%) and settlement as 1.39 km2 (0.77%). Aquaculture area drastically decreased to 7.86 km2 (4.36%). Table-2 clearly explained the restored lake and its 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 km2 in 30 years. This is because of most of the marshy land were either converted to aquaculture pond or aquatic vegetation spread on that (Chiranjibi Pattanaik et., al. 2008). On the social front the post demolition survey (below +5 contour area) by the management authorities that centered on the socio-economic activities associated with the lake identified about 14,000 families in about 44 villages that were affected by the demolition of fish tanks (gathered from the discussion by Forest department officials). Following the above discourses; the demolition of 380 fish tanks covering an extent of 21,796 acres (8820.5 hectare) was initiated to ease free flow of water in June, 2006 (as per the Forest Department records- refer to figure 1d). It was seen

Fig. 4. Demolition of aquaculture ponds

that of official demolition records that of the 76 tanks in the encroached region in West Godavari region, 50 were breached that amounts to 191.5 hectare whilst in Krishna a total of 94.4 hectare of encroached area under aquaculture was demolished (Nadhi Nagabhatla et.,al -2008).

V. ENVIRONMENTAL IMPACT ASSESSMENT OF THE LAKE DUE TO AQUACULTURE 1977-2000

The bed of Kolleru Lake has been used for ages to cultivate Yerra vari, a native paddy variety. In 1954, the government initiated cooperative farming and organized 93 farming societies on 2.1 million acres of the lake bed. By 1969, huge embankments were constructed in the lake area (liable to be flooded in rainy season) for agricultural purpose and the native paddy was replaced with shorter, high-yielding varieties requiring more fertilizers and pesticides. But floods threatened the cultivated areas every year. There were no aquaculture ponds shown in the 1972 topographic maps, although considerable areas of rice fields and settlements were present. By the time flood control measures were completed in1980, most of the people had become disillusioned with agriculture and had abandoned it. By1984, 5000 acres of government lake-bed land had been converted to fish tanks under the management of cooperative societies for the local fishermen (Narender 1993).

Environmental Impact analysis using RS and GIS for the year 1977 to 2000 the following categories were decreased. The area under lake water spread area with vegetation is decreased to 35.01 km2 (19.41%), lake mud area to 51.70 km2 (28.66%) and agriculture to 3.76 km2 (2.08%). Aquaculture and settlement increased to 82.01 km2 (45.47%) and 0.94 km2 (0.52%).

The conversion of Kolleru Lake for agriculture and aquaculture resulted in ecological imbalance and affected the free flow of flood waters. With encroachers constructing bunds across the lake area, the flow of water into the sea was being obstructed leading to inundation of 50 to 60 villages during the rainy season. The rampant use of seawater for aquaculture in the tanks resulted in increased salinity levels in the area leading to acute drinking water shortage in summer. Sewage inflow from the towns of Eluru, Gudivada and even Vijayawada and industrial effluents, pesticides and fertilizers from the Krishna-Godavari delta region contaminate the lake. Major industries release about 7.2 million litres of effluents into the lake every day. An Andhra Pradesh Pollution Control Board report states that more than 17,000 tonnes of fertiliser wash enters the lake annually. Studies have shown the presence of organic pollutants in lake sediment and in the fast-growing weeds. The sewage and discharge from factories have also affected the growth of water-borne organisms that the fish consume (Down to earth, 1993).

The average depth of the lake, which varies from 0.5 m to 2 m, is gradually being reduced due to siltation. Moreover, the urban sewage, industrial effluents, and fertilizer and pesticide residues that reach the lake through a number of streams and drains are polluting the lake waters. The roads and bridges that had come up with agricultural development in the area, along with an increased demand for fish, created a new and vast market for fish. Andhra Pradesh High court, had directed the Government to adhere to the standards laid down by the Ministry of Environment regarding the lakes and effluents is acting as per the directions given by the There was a government order No.120 which was intended to protect the lake from encroachments.

VI. ENVIRONMENTAL IMPACT ASSESSMENT OF THE LAKE DUE TO AQUACULTURE 2000-2007

Excessive nutrient loads have caused eutrophication in some parts of the Kolleru Lake. In general, pesticides were present at all the locations of Kolleru Lake water (Rao & Pillala 2001). The fish of Kolleru Lake are contaminated with metals and not suitable for human consumption (Sekhar et. al., 2004). If this type of human-induced degradation continues, the lake will become an effluent drainage system losing its ecological importance and freshwater condition. Considering the importance of the Kolleru Lake, the Government of Andhra Pradesh, State High Court, directed the Government to adhere to the standards laid down by the Ministry of Environment regarding the lakes and effluents. It gave a categorical ruling that no aquaculture be permitted within Kolleru Lake other than traditional activities like fishing. The court also directed the removal of encroachment for free flow of water. While the Kolleru conservation debate continues, there is a need for immediate action plan and execution with real dedication. Kolleru is the best example of human degradation of lakes and should be the last one in this manner.

Environmental Impact analysis using RS and GIS for the year 2000 to 2007 the following categories were increased. The area under lake water spread area with vegetation is decreased to 36.84km2 (20.04%), lake mud area to 31.44km2 (17.04%), agriculture to 5.81km2 (3.22%) and settlement 0.06km2 (0.03%). Aquaculture drastically decreased to 74.15 km2 (41.11%).

The conversion of lakes is mainly because of unawareness of the consequences and inadequate monitoring from the Government sector. The extent of degradation of Kolleru insisted upon the need for continuous monitoring of freshwater resources throughout the world. Although the fresh water resources cannot be created, but it can be protected considering the ever growing population. It is expected that densely populated regions of the world such as the Mediterranean, the Middle East, India and China will face severe water shortage in the coming decades (Huang & Chen 1999; Chashm 2000; Narain 2000; Zahra 2001; Yang et. al., 2003).We cannot afford to lose freshwater resources for any type of development as the available 0.1% of freshwater resources are being depleted day by day. Although the global water crisis has been well recognized by both international and national agencies, little progress is being made in the management of this most precious global resource (Ragab & Prudhomme 2002;Thomas 2004). There is a need for a long-term preventive approach to prevent the causes of lake degradation throughout the world and resolve the conflicts among competing users of lake resources taking into consideration the needs of future generations and of nature.

The post-demolition soil analysis both in bed and belt villages indicated that the black clay soils with a pH from 6.5-7.5 and appropriate phosphorous and potash content supports paddy as a Rabi crop (report by Forest Department); however the annual and seasonal variation in the rainfall pattern and the flood water dynamics in the wet season makes it slightly uncertain. Palpably, the drainages of the Kolleru wetland had been severely impacted (blocked) the by construction of large number of fish tank in the past; at times also inundating the Kharif crop, such incidences were recorded in 1986, 1996 and 2005 (Rao 2002; The Hindu-2005). In addition, Kolleru occasionally receives the back water flows from the sea through the Upputeru that tends to spread into the paddy field below +5 contour, therewith impacting the crop productivity and the soil salinity,while, the seepage from the fish tanks into the surrounding cultivated areas adds to the salinity. As of now, the backwash of the aquaculture necessitates the rehabilitation of the cultivated area to handle the salinity issues, before the farmers get back to this livelihood practice. Also the proposed set of post-demolition activities to restore the ecological and the socio-economic attributes of the lake; include the raising the of traditional fishing; and more than 60 species of fish can be cultured. The low density stocking mostly by natural feeding is also among the permitted set of activities. The government order [G.O.Ms.No.120] for demolition also posited that the Kolleru Lake restoration cannot be treated in isolation of people living in that area and hence the plan of action should integrate respective departments and should put people in the Kolleru bed villages primal to the planning (Nidhi Nagabhatla et.al., 2008). 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. (Chiranjibi Pattanaik et. al, 2008)

VII. CONCLUSION

The study highlights the significance of RS and GIS analysis of the in accurately assessing the land use pattern and environmental impact analysis of the Kolleru lake. The ecological and social impacts of shrimp aquaculture include large-scale degradation of coastal wetland due to the lack of guidance available on environment impact assessment for shrimp farming. Even though the Kolleru lake was in the stage of vanishing it was reverted back by the Government with its original environment. Regular monitoring of the lake will be helpful to protect the environment of the lake.

REFERENCES

[1] Deb A.K., 1999, Fake blue revolution: environmental and socio-economic impacts of shrimp culture in the coastal areas of Bangladesh. Ocean and Coastal Management 41,63-88.

[2] Halstead B.W., 1970, 'Toxicity of marine organisms caused by pollutants', FAO, Technical conference Marine pollution and its effects of living resources and fishing, Rome, Italy, pp.1-21.

[3] Huang Y.J. & Chen M., 1999, Water saving situation, problems and policies in China. Water Conservation 1, 42-43.

[3] Chashm K.K., 2000, Water-conscious development and the prevention of water misuse and wastage in the Eastern Mediterranean Region. Eastern Mediterranean Health Journal 6,734-745.

[4] Chiranjibi Pattanaik, Nidhi Nagabhatla, S Seneratna Sellamuttu, S. N. Prasad and C. M. Finlayson, 2008, Remote Sensing Application To Study The Aquaculture Dynamics In Kolleru Lake, India.

[5] Jayanthi, M., Rekha, P.N., Kavitha, N. and Ravichandran, P., 2006, Assessment of impact of aquaculture on Kolleru Lake (India) using remote sensing and geographical information system. Aquaculture Research, 37: 1617-1626.

[6] Kolleru is going, - Down to earth. www.rainwaterharvesting.org/Crisis/kolleru_etc.html

[7] MPEDA, 2004, Marine Product Development Authority Government of India database available at www.MPEDA. com.

[8] MPEDA, 2007, Marine Product Development Authority, India Government of India database available at www.MPEDA.com

[9] Narain V., 2000, India's water crisis: the challenges of governance. Water Policy 2, 433-444.

[10] Narender K., 1993 The broken mirror. Down to Earth 2,3-4

[11] Nidhi Nagabhatla and Sonali. S Sellamuttu, 2008, Political Ecology of Wetland Management: the post aquaculture demolition case of Lake Kolleru in India Nagabhatla, N.; Sellamttu, S.S./ Rev. Geogr. Acadêmica v.2 n.1 (vi.2008) 10-19.

[12] Perez F.A., Luna A.R.,Turner J., Robles C.A.B. & Jacob G.M., 2003, Land cover changes and impact of shrimp aquaculture on the landscape in the Ceuta coastal lagoon system, Sinaloa, Mexico. Ocean and Coastal Management 46,583-600.

[13] Primavera J.H., 1994, Environmental and socio economic e!ects of shrimp farming; the Philippines experience. Info¢sh International1,44-94.

[14] Ragab R. & Prudhomme C., 2002 Soil and water: climate change and water resources management in arid and semi-arid regions: prospective and challenges for the 21st Century. Biosystems Engineering 81,3-34.

[15] Raju D.C.V., Rajesh R.S. &Mishra D.C., 2003, Bouguer anomaly of the Godavari basin, India and magnetic characteristics of rocks along its coastal margin and continental shelf. Journal of Asian Earth Science 21,535-541.

[16] Ramsar, 1971, The Ramsar Convention on Wetlands www.ramsar.org;

[17] Rao A.S. & Pillala R.R., 2001, The concentration of pesticides in sediments fromKolleru Lake in India. PestManagement Science 57,620-624.

[18] Rao K.N., 2002, Evolution of land forms in the area between the Krishna and Godawari delta. Indian Geographical Journal 60,30-34.

[19] Rao K.N., Krishna G.M. & Malini B.H., 2004, Kolleru lake is varnishing - a revelation through digital processing of Aquaculture Research, 2006, 1-10

[20] Sadakata, N. and Nageswara Rao, K., 1997, “Radiocarbon ages of the subsurfacesediments in the Krishna delta and their geomorphological implications”. Quart. J. Geog., 49, 163–170.

[21] Sekhar K.C., Chary N.S., Kamala C.T., Raj D.S.S. & Rao A.S., 2004, Fractionation studies and bioaccumulation of sediment- bound heavy metals in Kolleru lake. Environment International 29, 1001-1008.

[22] The Hindu., 2005, Restoration of Kolleru runs into trouble–Wednesday, Dec 07, 2005 http://www.thehindu.com/2005/12/07/stories/2005120721700100.html

[23] Thomas R.L., 2004, Management of freshwater systems: the interactive roles of science, politics and management, and the public. Lakes and Reservoirs: Research and Management 9,65-74.

[24] UNEP, 1985, 'Environmental problems of the Marine and coastal area of India', National report , UNEP regional seas report and studies No.59, p.28.

[25] Yang H., Zhang X. & Zehnder A.J.B., 2003, Water scarcity, pricing mechanism and institutional reform in northern China irrigated agriculture. Agricultural Water management 61,143-161.

[26] Zahra B.A., 2001, Water crisis in Palestine. Desalination136, 93-99.