Evaluation of Land and Water Management Systems of Kolleru Lake and its Adverse Affects on Fragile Coastal Geo-Environment using Geospatial Technologies

P.Raghuram, T.Rambabu, P.Sankara Pitchaiah, P.A.R.K.Raju

Abstract: ***Lake Kolleru is the largest fresh water lake in India is located in between twin deltas of Krishna and Godavari in West Godavari and Krishna districts of Andhra Pradesh and lies between the two mighty rivers, the Godavari and Krishna. It is an extremely shallow depression formed in between the two deltas due to fluvial and marine activities. The kolleru lake and its surroundings have been subjected to human induced degradation due to mismanagement of land and water resources particularly with the introduction of intensive agricultural and aquaculture activities. The striking manifestation of this phenomenon is seen in various kinds of hazards such as flooding of foreshore areas of the lake, back water intrusion, ground water pollution, coastal morphological changes, etc. The present study is mainly focused on the present status of various parameters related to land and water resources of the lake Kolleru and the adjoining fragile coastal geo-environment using spatial information techniques. The study includes the generation of updated spatial information on land and water resources that cover rainfall, lithology and structure, geomorphology, drainage and surface water bodies, Land use / land cover and also transport network and settlements. The integrated analysis of these parameters has helped in thoroughly addressing the perennial issues like flooding of foreshore areas of the lake, intrusion of back water in Upputeru and its tributaries, adverse effects near Upputeru river mouth etc and the need for suitable land and water management measures.***

Keywords: Lake, Geology, Geomorphology, Land Use / Land cover

I. INTRODUCTION

Lake ecosystems are vital resources for aquatic wildlife and human needs, and any alteration of their environmental quality and water renewal rates have wide-ranging ecological and societal implications. They serve the important needs of life and played a crucial role in the growth of human civilization. The most significant values of lake / wetland, as a result of its hydrological functions and storage include water quality, water supply, flood control, erosion control, wildlife support, recreation, culture, and commercial benefits and thus play a vital role in the ecological sustainability in the region. Further, they provide support to innumerous activities that include habitat breeding ground, sites of biodiversity conservation, ground water recharge and discharge, salinity control, climate stabilization, natural fisheries etc. They are the richest and perhaps one of the most neglected of the entire terrestrial ecosystems [1].

The studies on wetlands indicate that nearly one hectare of wetland is degraded per every minute. In the absence of human intervention, the earth would have approximately 29.83 million km^2 of wetland ecosystems [2]. About 50% of world's wetland ecosystems had been lost in the last century and primarily damaged through agriculture and water system regulation. The areal extent of wetland loss has been highest in Asia and also the Europe has experienced the most severe losses. Further, the lake / wetland ecosystems throughout the world are considered by many to be of little or no value, or even at times to be of negative value and often termed to be as wastelands. This lack of awareness of the value of conserved ecosystems and their subsequent low priority in the decision making process has resulted in the destruction or substantial alteration and sometimes even extinction of lake / wetlands causing and unrecognized social cost. Despite the increasing recognition of the need to conserve wetlands, losses / degradation have continued.

Rapid pace of development surrounding many of the lake catchments has had significant effects on the quality of the water body [3]. Limnological studies of the freshwater lakes in Malaysia were reported to have begun in the early 1970s . Most of studies that have been carried out concentrated on fisheries and aquaculture, water quality analysis and flora and fauna [4] . Deterioration of water quality and quantity was reported for Lake Bera [5], Lake Chini [6] and Loagan Bunut Lake [7].

Limnological study has been carried out for Kenyir Reservoir in 1990s. Loagan Bunut is another lake, which has been selected to promote the conservation and sustainable use of the highly significant and fragile ecosystem of tropical peat swamp forests in Malaysia [3]. Various Limnological studies were carried out on bacterial accumulation in freshwater ecosystems [8]; and on biodiversity.

Mostafa and Soussa carried out an extensive research on Lake Nasser for assessing the environmental impacts including morphological aspects and sedimentation issues using geospatial technologies.
Speight (1963) observed

Revised Manuscript Received on June 01, 2019.

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geomorphology of the Lake Pukaki of New Zealand[9].

The main cause of degradation includes surface run off containing nutrient-rich water from nearby plantations, sewage from communities living around the lake. The higher amounts of nutrients are degrading the lake Bera [5]. Several scientific studies have also reported eutrophication as a growing preoccupation for the scientific community around the world [10].

Various methods developed in the interpretation of satellite images have been used globally for generating information on various natural resource aspects. The central and state institutions have been involved in effectively utilizing the remote sensing data in their programs for mapping and monitoring of resources and its evaluation.

Wetlands are the most productive of the ecosystems[11]. These wetlands are natural harvesters of rainwater, acting as sinks into which surface water and/or groundwater flows from the surrounding catchment [12]. Kolleru, one of Asia's largest fresh water lakes located in Andhra Pradesh is a famous habitat for a number of resident and migratory birds, including the vulnerable Grey Pelican (Pelecanus Philippensis). It is an invaluable wetland ecosystem [13] situated between the Godavari and the Krishna river deltas. It has a catchment area of about 9000 sq.km with Budameru, Tammileru, Ramileru, Gunderu rivers and major and minor drains empty into the lake. This lake has only one outlet i.e., Upputeru river [11]. It is acting as a natural flood balancing reservoir and is fed directly by water from the seasonal rivers Budameru, Ramileru and Tammileru. It is also connected to the Krishna and Godavari irrigation systems that consists of over 68 inflowing drains and channels [14]. Aparna et al., 2015 used Geographic Information Systems for Quantitative Analysis of Geomorphology and Flow Pattern Analysis of Muvattupuzha River Basin. Asadi et al., 2015 also used Remote Sensing & GIS for the detection of coastal geomorphological changes for effective coastal management in Pulicat lagoon [15].

The geomorphology of the East coast lagoons such as Kolleru Lake, Chilka and Pulicat lakes were studied by Nageswara Rao (1985); Nageswara Rao and Sadakata (1996); Sadakata et al. (1998). Khlystov et al. (2016) studied geological and geomorphological characteristics of the Baikal Lake[16], [17], [18]. The Hydrodynamic and geomorphic conditions of the Vembanad Lake were studied [19].

The accelerated and intensified human activities are pushing the fragile coastal ecosystems of Kolleru Lake and the Upputeru estuary in the inter-deltaic plain of rivers Godavari and Krishna closer to instability. The highly delicate ecological / environmental equilibrium is being restrained by man-made interventions that have bearing conflicting demands of the people in the area. The lake and estuary environment is undergoing to drastic changes mainly in the form of alteration of hydrological systems and rampant land use changes. Already the overexploitation and mismanagement of land and water resources with intensive / aggressive land use practices of both fresh and brackish water aquaculture and development of special economic zones etc[20]. have created adverse impacts on these lake and estuarine ecosystems, agriculture, water resources and irrigation systems, sedimentation of lake, soil chemistry, biodiversity, flooding risks and drainage congestion, salt / back water intrusion, coastal dynamics, human health etc. particularly in the last four decades. Further, there is a drastic decrease in water resource potential in the area because of increase in harvesting of water and irrigation expansion in the catchment area. It is evident that the closing of Krishna basin and the resulting drastic depletion of irrigation water to delta and land use dynamics is posing serious impacts on the lake and estuarine systems and associated environment on a decadal scale. The rampant mainstream developmental activities have outpaced the environmental carrying capacity of this highly vulnerable coastal region associated with these ecosystems. The mitigation strategies implemented in the form of hydrological modifications by the line departments have turned out to be counterproductive and further complicated the land and water management systems pertinent to these ecosystems. It is certainly a perilous situation prevailing in this region and threatening the highly sensitive, dynamic, complex and yet highly productive ecosystems and thus need to be addressed. The outcome of the recent studies clearly manifest that still there is potential left in the lake for restoration and thus propelled to conduct this research work.

II. OBJECTIVES

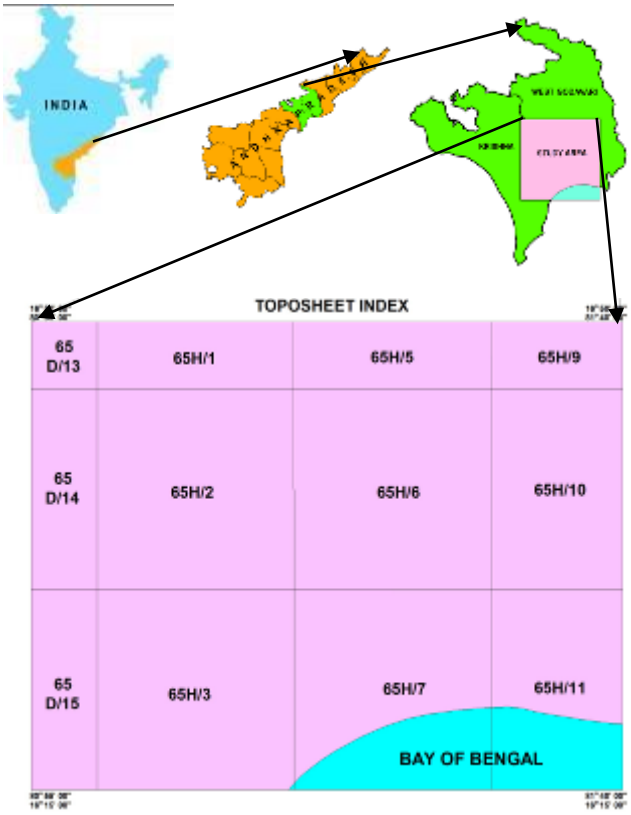
The prime objective of the study is to critically evaluate the prevailing main drivers of change that include land and water management systems, which are posing serious threat to the lake and estuary environment and suggest appropriate solutions for restoration of lake and protect the estuary environment.

The specific aims of the present research include:To generate an updated spatial / non-spatial database and evaluate all the characteristics that relate to land i.e. Tectonic frame work, geological and geomorphological set-up, neotectonic activity, physiography, land utilization / land use dynamics, soil erosion / deposition, coastal erosion / accretion etc. To analyze the hydrological system of lake proper, drainage congestion / flooding phenomena, salt water intrusion etc. To integration of all the above land and water resources parameters and suggest appropriate scientific management strategies / restoration measures to precious Kolleru Lake and Upputeru Estuary ecosystems and sustain a green inter-deltaic environment in the coastal region.

A. Study Area:

The study area is situated in the coastal tracts of West Godavari and Krishna districts of Andhra Pradesh. The area lies between north latitudes 16º15' and 16º50' and east longitudes 80º55'and 81º40'. The location map of the area is shown in figure1. The area is mostly covered by Godavari western and Krishna eastern deltas. The total study area is about 4768.08 sq.km. and covered by 44 mandals of West Godavari and Krishna districts. It is covered by Survey of India toposheets of 65D/13, D/14, D/15, 65 H/1, H/2, H/3, H/5, H/6, H/7, H/9, H/10 and H/11 on 1:50,000 scale. Agriculture and aquaculture

are the main land use practices of the people in the area.



III. METHODOLOGY

The required input data for the generation of spatial database in the present study included i. Satellite data, ii. Collateral / ancillary data and iii. Field data. All the input datasets collected from various organizations were used for the preparation of resource maps using visual interpretation techniques. The raster maps were geometrically rectified using Ground Control Points (GCP) with ERDAS Imagine software and converted into vector format by on-screen digitization method using Arc GIS software. The details of input data and the generation of spatial information on various land and water resource parameters is presented in the following sub-chapters.

A. Satellite Data

A satellite image carries detailed information of all the features over the surface of the earth on that date and time of acquisition. Scrutinizing of the images and the intricacies that occur during the interpretation of the satellite imagery is methodically done. The study of spatial images includes various image characteristics displayed on an image viz., tone, pattern, texture, shape, size, and association etc. and helps in the interpretation of different features on satellite imagery during the classification of features. Image interpretation key is used for the extraction and transferring of the thematic features from the satellite imagery.

IRS-P6 Resourcesat LISS IV FCC geocoded photographic products on 1:50,000 scale of Rabi season and digital data covering the study area have been used for mapping of geology, geomorphology, land use / land cover, drainage and surface water bodies, settlements and transport network. Also, IRS-P6 LISS IV MX geocoded photographic products on 1:25,000 scale and digital data pertaining to the lake portion have been used in the preparation of land use / land cover. The above data has been procured from National Remote Sensing Centre, Hyderabad.

B. Collateral Data

The collection of collateral data is initiated by procuring the toposheets of 1:50,000 and 1:250,000 scale covering the study area and its environs from Survey of India, Hyderabad. The geology and minerals map of West Godavari and Krishna districts on 1:250,000 scale published by Geological Survey of India (GSI) has been acquired from GSI, Hyderabad. Besides, the published reports and literature on climate, rainfall, tectonics, lithology, hydrology, geomorphology, land use, surface and ground water resources, stream discharges, river cross-sections, socio-economic profile, district / mandal boundaries etc. from various line departments have been utiised in the mapping and analysis of various resource parameters. Climatological data (Humidity, Wind, Temperature), precipitation and ground water conditions data were collected from respective departments like Agriculture department, Department of Economics and Statistics, Ground water department etc.

C. Field Data

The ground truth / verification of doubtful areas and ground data collection and generation of field photographs is an important component of satellite based remote sensing studies. The doubtful areas while carrying out preliminary interpretation of satellite image were physically verified on the ground. The field observations about the terrain conditions, cropping pattern, land use/land cover changes, water resources utilization etc., have been made and accordingly the resource maps have been finalized. The field data also included the periodical collection of water samples from Upputeru River and different drains joining the same for measurement of salinity and extent of the sea water/ back water intrusion.

The integrated analysis has been done by overlaying the multiple resource data sets / categories, all of which are generated in GIS domain and transform the data into information suitable for a given application. This step includes the intersection of thematic / resource maps like base, drainage, soil, soil erosion, geology, geomorphology, land use / land cover, rainfall etc. one over the other by choosing appropriate resolution criteria. The overlay analysis has been done by assigning appropriate weightage to the themes. The overlay / association analysis helped in better understanding of the cause and effect in respect of not only problems / limitations but also the potential that exists in the study area. The spatial analysis has ruled out the possibility of missing out any special aspects / peculiarity.

IV. RESULTS AND DISCUSSION

Spatial information is generated on geology, geomorphology, Drainage and Surface water Bodies settlements and transport network of the study area and theirs discussion is as follows

A. Geology

The study area is characterized by a diversity of geological formations covers

oldest Archaeans to the recent Alluvium. The oldest rock types of Easternghat Super group is represented by Khondalite and the East coast Gondwanas by Gollapalli and Tirupathi formations in the area. The Rajahmundry sandstones formed due to marine transgression during Mio-Pliocene occur in the norther area. Laterite occurs as capping on Rajahmundry sandstone as isolated patches. The Quaternary sediments of fluvial and marine origin cover major portion in the southern part of the study area. The lithology and structure map derived from satellite image interpretation is shown in figure 2. The areal extent of various geological formations are shown in table 1

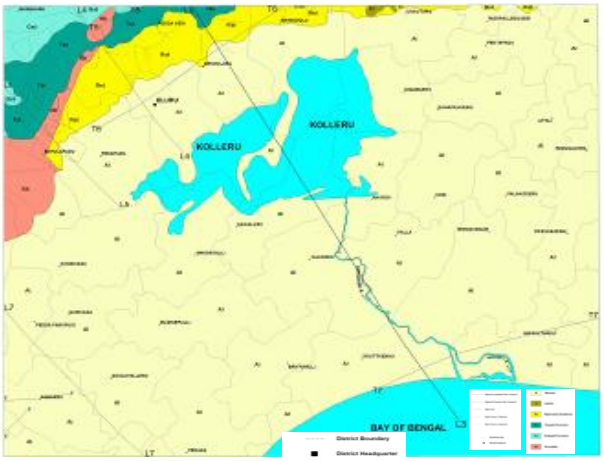


Figure 2 lithology and structure map

B. Structure

The study area is dissected by numerous major and minor fractures / lineaments and faults. The lineaments in the study area have been devided into two types such as major fractures / lineaments and minor fractures / lineaments. The lineaments having more than 3km. length have been considered as major lineaments. Most of these lineaments are associated with topographic lows and control the drainage in the area.

Table 1 Areal extent of various geological formations

Lithology Unit	Area in sq.km
Alluvium	4207.54
Gollapalli Formation	73.70
Khondalite	115.88
Laterite	3.99
Rajahmundry Sandstone	224.66
Tirupathi Formation	142.31
Total	4768.08

The directions of these lineaments are NW-SE and NE-SW and follow the trends of regional faults. These fractures / lineaments are conspicuous and delineated in the northwestern part covered by sandstones and Khondalites. The structures in the area manage the occurrence and movement of ground water. The depth of weathering is relatively more in the areas associated with fractures. The fracture zones are associated with good weathering, shallow water table conditions and good recharge contributed by the drainage system.

C. Geomorphology

The study area of Kolleru and the inter-deltaic plain lying between the deltas of Krishna and Godavari rivers is a land of alluvial tract developed due to the coalescence of these deltas. It is an area of fluvial plain along the right bank of Vasishta branch of Godavari and the left bank of Krishna and the Inter-deltaic fluvio-marine deposit. However, it has become customary to include these parts in delta and calling this area as Godavari western and Krishna eastern deltas. This inaccuracy is not so important and so convenient that the word delta has been used in its extended application and distinguished them as Godavari western delta and Krishna eastern delta. Geomorphologically, this area has been categorized into 19 geomorphic units / landforms. The upper part of the area is predominantly occupied by flood plain interspersed with paleo-channels of Godavari and Krishna Rivers. The Kolleru formation and Kolleru Lake occupying the northern central part are almost encircled by flood plain. The flood plain is bordered in the north and northwest by pediplains of sandstones and Khondalites and by paleo-beach ridge swale complex in the southern lower part. The upper part is devoid of any beach ridges and only paleo-channels of Godavari and Errakalava in the east and paleo-channels of Krishna in the west are identified. Geomorphology map is shown in figure.3. Areal extent of different geomorphic units is shown in table 2.

The landforms of marine origin that occur in the lower part include paleo-tidal flat, paleo and active beach ridge swale complexes, Dumpagadapa formation, mudflat, tidal flat, lagoon, beach etc. The lower part of the area exhibits four distinct series of beach ridges. The most landward set of paleo-beach ridges in the area corresponds to the one that immediately borders the southern side of Kolleru Lake.

Figure.3 Geomorphology map

This almost parallels the present coastline and reported be formed 6500 yrs. BP.

Table 2 Areal extent of various geomorphic units

Geomorphic Unit	Area sq.km
Active Beach Ridge	3.68
Active beach ridge Swale Complex	10.48
Beach	3.58
Channel Island	0.27
Deltaic Plain	153.69
Dumpagadapa Formation	12.92
Flood Plain	1502.85
Inselberg	0.01
Lagoon	1.50
Lake Formation	554.65
Linear Ridge	0.86
Morphostructure	26.60
Mud Flat	9.43
Paleo Tidal Flat	1083.40
Paleo Beach Ridge	125.17
Paleo-Beach Ridge & Swale Complex	394.71
Paleo Channel	215.95
Paleo-Natural Levee	4.24
Pediment Inselberg Complex	0.16
Pediplain Deeply Weathered	349.62
Pediplain Moderately Weathered	128.94
Pediplain Sahallow weathered	75.57
Spit	1.10
Structural dome	1.01
Swale	9.20
Tidal flat	94.52
Undissected Plateau	3.97

This set of beach ridges passing through Mandavalli, Kaikaluru, Akividu and Undi possesses more width in the western part and narrows down beyond Upputeru River towards east. The second set, which is the most elongated beach ridge swale complex in the area and almost parallel to first passes through Kalidindi, Elurupadu, Bhimavaram, Veeravasaram and Palakollu and positioned below the first towards south. This set shows discontinuous pattern towards east of Upputeru.

The third set is located relatively far below the second towards south passes through Bantumilli, Mogalturru and Narsapuram. This set is very conspicuous in the eastern and western parts and highly disturbed in the middle part around Upputeru. The alignment of this set in the western side near Munjuluru morphostructure is highly varying from NNE-SSW to NE-SW and ENE-WSW. Also, several small, discontinuous beach ridges in the lower part manifest the changes in coastal configuration during that period. The fourth set which is the most seaward beach ridge swale complex near the coast is very close to third set. The set three and four were cut across by the ENE-WSW trending Narsapuram-Yanam fault and eliminated these sets of beach ridges in the NNW side of the fault. The deviations in the alignment of beach ridges with respect to the present coastline, the evolution of morphostructures, discontinuity of beach ridges near Gogileru Lagoon and the elimination of beach ridges due to Narsapuram-Yanam fault are to be viewed that the this part of the area is neo-tectonically active particularly in the late Holocene period.

A conspicuous depression of paleo-tidal flat of large extent exists in between the beach ridges of sets 2 and 3 on either side of Upputeru. This is a late Holocene tidal flat of elevation varying from 1.6 to 2.2 m above m.s.l. formed due to marine regression. Gogileru Lagoon is another prominent geomorphic unit in the southern-most part of the area. The abrupt termination of fourth set of beach ridge swale complex in the western and eastern sides of this lagoon and the varying trends of isolated small ridges in this area manifests that the formation of this lagoon may be attributed to the play of Narsapuram-Yanam fault. The Kolleru lake and the depression between sets of beach ridges two and three and Gogileru depressions have been formed exactly one below the other in southern direction at the concave portion of strandlines and the present coastline and positioned at the centre of the Godavari and Krishna deltas. These depressions are separated by elevated beach ridge swale complexes. The elongation and sinuous nature of Upputeru in the lower southern part is attributed to the dominance of marine forces over the continental processes during the development of this inter-deltaic plain.

The Upputeru river runs for a length of about 64 km joins the Kolleru Lake and the Bay of Bengal. The estuary has been developed along with the progradation of inter-deltaic plain since mid-holocene. Except during monsoon season, the tidal / back water in Upputeru flows to its entire length towards inland and enters even Kolleru Lake even during summer period.

D. Land use / land Cover

The land use/ land cover classes delineated in the area include i. Built-up land, ii. Agricultural land, iii. Forest, iv. Wasteland, v. Water bodies and vi. Others like Aquaculture, Quarrying / Mining, Tank bed cultivation and Salt pans. The different land use / land cover classes occurring in the area are discussed as follows. Land use/ Land Cover map is shown in figure 4. Various land use / land cover area estimates are shown in table 3.

E. *Land Use / Land Cover Analysis*

Kolleru Lake Area

Besides fishing, the people of Kolleru region used to have their livelihood on agriculture. The agriculture was being practiced using traditional methods. The cropping schedule was planned to the non-monsoon rabi season. The land use practices in the Kolleru region have been drastically changed in the last three decades. In the beginning, the aquaculture was permitted to the fisherman societies in the lake region during 1976. However, intensive aquaculture has been introduced initially in the foreshore areas and then in the lake proper within 1.52 m (5') contour. The lake in its original / natural state occupies only 101.729 sq.km and the lake with demolished aquaculture covers 212.799 sq.km within 1.52 m (5') contour. The peripheral areas which are lying beyond 1.52 m (5') and below 3.04 m (10') are also occupied by aquaculture to an extent of 146.693 sq.km. The agriculture area within 1.52 m (5') contour extends up to 53.235 sq.km and the settlements occupy 3.083 sq.km. The water management in the area is mainly focused on development of agriculture and mitigation of floods and

not on the protection of the lake and sea water intrusion

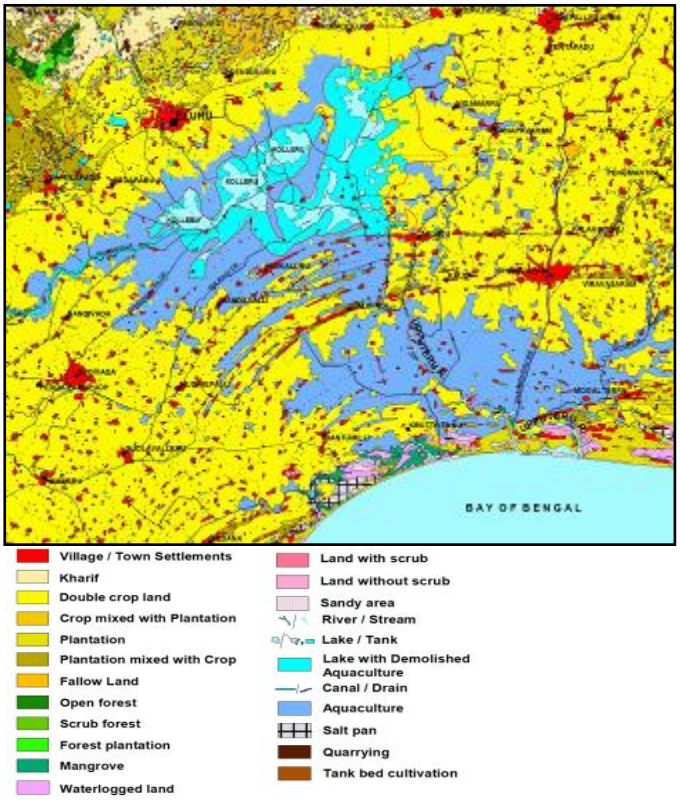


Figure 4. Land use/ Land Cover map

Inter-Deltaic Plain

Prior to the construction of barrages on Godavari and Krishna, the deltaic region was desolated by frequent famines during summer and floods during monsoon. People used to walk for long distances to meet their thirst for drinking water. There was no programme for proper development and management of land and water resources. The admirable irrigation systems constructed one and half centuries back have brightened and revived this area and totally eradicated the famines in this region. Slowly, the entire area has been brought under paddy irrigation with double crop and thus people of this region have prospered. Thus, it has been a long painful journey for the people of this region and now called the rice bowl of Andhra Pradesh.

However, in the recent past i.e. since mid-eighties, the frequent and regular cyclones during northeast monsoon were causing floods in the low lying areas and severely affecting and disrupting the harvest of kharif crop particularly in the low lying areas and drainage choked regions.

Table 3 Areal distribution of land use/land over

Land Use /Land cover	Area Sq.km
Aquaculture	1082.58
Builtupland	265.52
Cropland Mixed with planation	44.64
Double Crop	2613.23
Dry Portion	18.23
Embankment	11.70
Fallow land	9.51
Forest Area	10.24
Forest Plantation	4.22
Kharif	126.56
Lake Fomation	102.40
Land with Scrub	1.04
Land wihout Scrub	6.45
Mangrove	18.62
Open Forest	1.80
Plantation	222.21
Plantation mixed with Crop	108.53
Qurrying	0.93
Salt pans	19.20
Sandy Area	17.01
Scrub Forest	3.81
Tank Encroachment	0.25
Tanks	47.13
Water Logged Land	32.27

This has resulted in the people of this region to think for an alternative to agriculture. Keeping in view of the availability of copious supply of water in canals and drains for at least ten to eleven months in a year, to avoid impact of floods, higher rate revenue, less labor intensive etc. the people started shifting to aquaculture particularly in the low lying areas and along the major drains. The information on land use / land cover clearly shows that in the study area of Kolleru and the coastal environs is predominantly occupied by water intensive agriculture and aquaculture activities. The elevated sand beach ridges are occupied by plantation and plantation mixed with cropland and the moderately elevated Inter-deltaic plain covered by irrigated double cropland. The low lying Kolleru region and the low lying inter-deltaic plain in the southern part are used for aquaculture. The huge requirement of water for these two activities is met by irrigation systems of Godavari and Krishna and also the inflows of rivers into Kolleru from Upland area. Though the water holding capacity of the barrages of Godavari and Krishna is very less, the perennial / unchecked inflows into these systems help in providing water irrigation and drinking water in the delta region.

F. *Dynamics in Kolleru and its Environs Land Use*

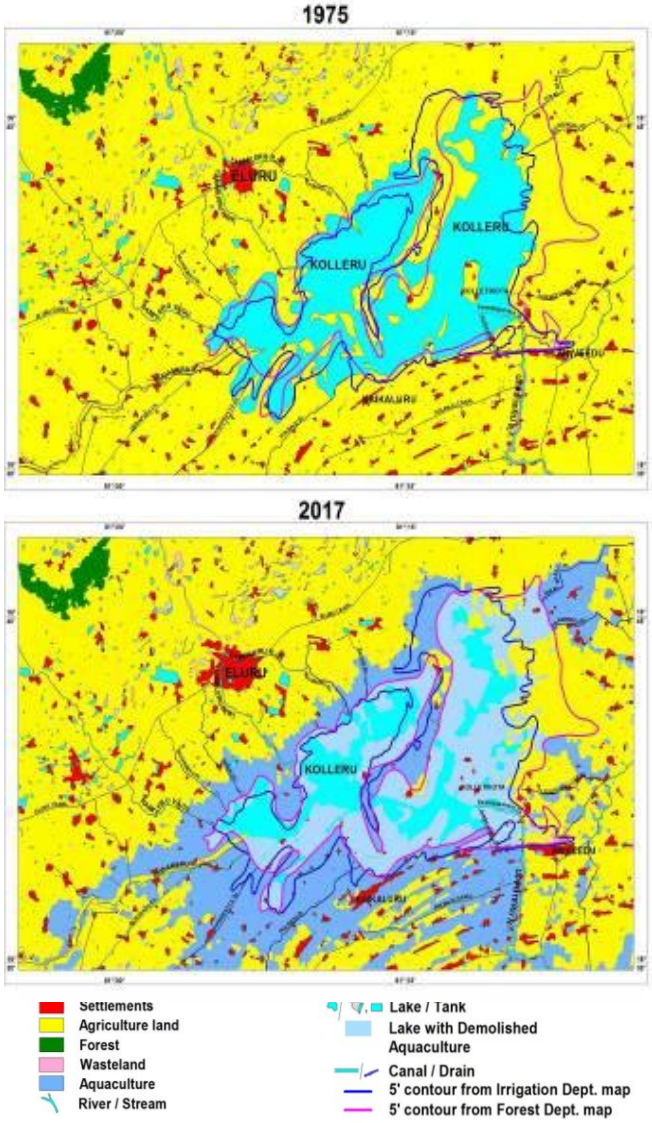


Figure 5 Dynamics of Kolleru Lake

Kolleru Lake is no exception for human habitations that preferred to develop near water resources, particularly along the river valleys, coastal plains and foreshore areas of lakes. Of late, the explosive population growth, decrease in per capita availability of land, hungry for land, increasing demands on food grain production have resulted in the encroachments of margins and foreshore areas of every lake in the world. Agriculture and fisheries were the main activities of the people in the Kolleru Lake area. The morphological changes brought by continuous irrigation around resulted in reduction of the total capacity of the lake.

Further to the agriculture, the lake environs have been subjected to water intensive aquaculture activities particularly in the last two decades. The map showing the land use / land cover changes in Kolleru region has been prepared by using the satellite data pertaining to 1975 and 2017 and also consulting the collateral data is shown in figure 5.

This map clearly shows how this pristine lake and its environs have been changed into an area of innumerous fish tanks. During 1975 the lake was totally in the undisturbed state and extending beyond 5' contour. Only traditional agriculture is practiced around the lake during rabi crop season without causing any environmental impact on this wetland ecosystem. Later on, the aquaculture activity has extended into lake area within 1.52m (5') contour and totally changed the land use / land cover scenario. The area estimates of present land use / land cover within 3.04m (10') contour of Kolleru region is given in table 4. At present, the original lake is confined to small isolated patches and limits to an extent of only 101.729 sq.km. The lake with demolished aquaculture amounts to about 212.799 sq.km. within 1.52 m (5') contour.

Table 4 Area Estimates of Land Use / Land Cover (2017) in Kolleru Lake Region

Land use / land cover class	**Within**1.52m (5') **(sq. km)**	**Between 1.52 -3.04m (5'~ 10') sq. km**
Lake	101.729	0.0
Lake with Demolished Aquaculture	212.799	0.0
Aquaculture	0.0	146.693
Agriculture	53.235	44.12
Settlements	3.083	2.5

With the aim of restoration of lake, the fish tanks within 1.52m (5') contour have been demolished during 2006. This has resulted in moderate increase of inflows into Upputeru for longer periods and maintained some balance against back water intrusion. However, as the bunds of the tanks were not totally removed to the bed level, the tanks with reduced heights still exist. This phenomenon is not allowing the lake to function as natural hydrological system as the lake maintains 0.91 to 1.22 m (3' to 4') for almost 8 months in a year. Hydrologically, the lake with demolished aquaculture within 1.52m (5') contour is to be considered as fish tanks with reduced water holding capacity. The water stored in these tanks during monsoon is not draining freely to the outlet. Agriculture area within 1.52m (5') contour amounts to about 53.235 sq.km. The agriculture and aquaculture between 1.52m (5') ' and 3.04m (10') is nearly 44.120 and 146.693 sq.km respectively.

V. CONCLUSIONS

The generation of extensive and updated datasets, evaluation of land and water resource parameters and the integrated analysis of the present research study have provided tangible evidences on the degradation of these ecosystems.

ACKNOWLEDGEMENTS

Authors are sincerely acknowledging their sincere gratitude to the management, principal, Dean, R&D, Department of Civil Engineering and Water and Environment Technology Research Centre (WET) and Geospatial information Centre

(GIC), S.R.K.R Engineering College, China Amiram, Bhimavaram for their continuous support in publishing this research paper.

REFERENCES

1. Bhuyan B and Sreekesh (2014). Dynamics of land use, land cover and its impact on wetland ecosystem. A case study of Deepor Beel Ramsar site in Guwahati, Assam, India. IGU Regional Conference, Krakow, Poland. 18-22. 2014.
2. Hu S., Niu Z., Chen Y, Li L., Zhanq A. (2017). Global Wetlands: Potential distribution, wetland loss and status. Sci. Total Environ Voulme15:586, pp.319-327.doi: 10.1016/j.scitolen V 2017.02.001. Epub 2017 Feb9.
3. Zati Sharip and Salmah Zakaria (2007). Lakes and Reservoir in Malaysia: Management and Research challenges, Proceedings of Taal 2007: The 12th World lake Conference, pp.1349-1355.
4. NAHRIM (2005). A Desktop Study on the Status of Lake Eutrophication in Malaysia.
5. Chong, G (2007). Tasek Bera: Past, Present and Future, Paper presented at the Colloquium on Lakes and Reservoir Management: Status and Issues, 2 – 3 August 2007, Putrajaya Malaysia.
6. Mushrifah Idris Tasik Chini, (2007). Sustaining Environmentally Sensitive Areas, Paper presented at the Colloquium on Lakes and Reservoir Management: Status and Issues, 2 – 3 August 2007, Putrajaya, Malaysia
7. Abdul Rahim Nik, Alexander K. Sayok, Efransjah and Sapuan Ahmad (2007). Issues Affecting the Sustainability of Loagan Bunut Lake, Sarawak, Paper presented at the Colloquium on Lakes and Reservoir Management: Status and Issues, Putrajaya Malaysia.
8. Edna Chiang, Marian L. Schmidt, Michelle A. Berry, Bopaiah A. Biddanda, Ashley Burtner, Thomas H. Johengen, Danna Palladino, Vincent J. Denef (2018). Verrucomicrobia are prevalent in north temperate freshwater lakes and display class level preferences between lake habitats, PLoS ONE, Volume 13, No. 3, e0195112, 20 p. [https://doi.org/10.1371/journal.pone.0195112].
9. Speight J. G. (1963) Late Pleistocene historical geomorphology of the Lake Pukaki area, New Zealand, New Zealand Journal of Geology and Geophysics, Volume 6:2, pp.160-188, DOI:10.1080/00288306.1963.10420074.
10. Vörösmarty, C.J., Mcintyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C.A., Liermann, C.R. and Davies, P.M. (2010). Global threats to human water security and river biodiversity. Nature, Volume 467 (7315), pp. 555-561. [http://dx.doi.org/10.1038/nature09440. PMid: 20882010].
11. Ramana Murty MV and K Mruthyunjaya Reddy (2010). Flood hazard zonation around the Kolleru lake, Andhra Pradesh, India – A remote sensing and GIS based approach. In Proceedings of the 3rd International Conference on Hydrology and watershed management with a focal theme on climate changes – water, food and environmental security, 3-6 February 2010, Centre for Water resources, Jawaharlal Technological University, Hyderabad. pp.1010-1021.
12. McCartney, M.P.; Masiyandima, M., Houghton-Carr, H.A. 2005. Working wetlands: Classifying wetland potential for agriculture. Colombo, Sri Lanka: International Water Management Institute (IWMI). 40p. (IWMI Research Report 90).
13. Ramarao, R.V. G.mallikarjuna Rao, (1981). Techno economic evaluations of aquaculture at Kolleru lake, Department of Geo engineering and resource department, A.U, Waltair pp.62.
14. Harikrishna, D.Ramprasad Naik, T.Venkateswara Rao, G. Jaisankar, V.Venkateswara Rao (2012). A Study on Saltwater Intrusion Around Kolleru Lake, Andhra Pradesh, India, International Journal of Engineering and Technology (IJET), Volume 4 Number 3, pp.133-139.
15. Asadi SS., Ratnakar P.J., Vuppaladadiyam A.K., Vasantha Rao B.V.T. (2015). Detection of coastal geomorphological changes for effective coastal management using Remote Sensing & GIS, International Journal of Engineering and Technology, Volume 7, No 1, pp. 186-192.
16. Nageswara Rao K. (1985). Evolution of landforms in the area between the Krishna and Godavari deltas. The Indian geographical journal Volume 60(I0), pp.30-36.
17. Sadakata, N., Nageswara Rao, K., Toyama, S. and Kashima, K., (1998). Preliminary note on the geomorphic development of the eastern coast plains of the Peninsula India – with special reference to the age of formation of the Kolleru lagoon and the Krishna delta, Laguna, Volume 5, pp. 247–251.
18. Khlystov O.M., E.E. Kononov, A.V. Khabuev, O.V. Belousov, M.A. Gubin, M.A. Solovyeva, L. Naudts (2016). Geological and geomorphological characteristics of the Posolsky Bank and the Kukuy Griva, Lake Baikal, Russian Geology and Geophysics Volume 57, pp.1759-1767.
19. Laluraj C. M., Girish Gopinath, P. K. Dinesh Kumar, and K. K. Balachandran (2008). Hydrodynamic and Geomorphic Controls on the Morphology of an Island Ecosystem in the Vembanad Lake, West Coast of India, Journal of Coastal Research, Volume 24(sp2), pp.145-150.
20. P Raghuram, T Rambabu, P A.R.K Raju, P.Sankara Pitchaiah. "Geological and Geomorphological Evaluation of Kolleru-Upputeru catchment using Geospatial Technologies", International Journal of Engineering & Technology, (IJET), Volume 7, Issue 3-31, pp. 75-79, **2018** 2018