

SLOW DEATH OF LAKES IN THE HERITAGE CITY OF MYSURU, KARNATAKA STATE, INDIA THROUGH GEOSPATIAL APPROACH

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ABSTRACT: Lakes of urban regions contribute greatly towards ecological protected zones and true indicators for urban developmental strategies and its sustainability. Mysuru is the second biggest city in Karnataka blessed with dozens of lakes and attracts varieties of migratory birds, water fowls with lush green and being tourist destinations. The city is one of the tier II in the state and is a hub of industrial activities due to salubrious climate and availability of natural resources. Mysuru is known for its memorable annual Dasara celebrations which is an unforgettable events in the History of Karnataka. The notable waterbodies are Karanji, Kukkarahalli, Lingambudhi, Dalvoy and Devanoor lakes. Most of the streams belong to first order and few belong to second and third order. The study area portray decent greenery shelter and lakes enhances the beauty of the heritage city and also improved the groundwater table. Mysuru had over 30 lakes few decades ago, but at present only few lakes are surviving. During Maharaja's rule of 19th century, most of the lakes were built to fulfil the purpose of water supply for domestic, industries, irrigation and other works through urban runoff and rainwater as main sources. The present study aims in the mapping of spatio-temporal detection of Mysuru lakes through manual and digital extraction of data in GIS environment. An attempt have made to analyze the changes of lakes coverage area using SoI toposheet, LISS-III, Sentinel-2A and Google Earth image by adopting Visual Image Interpretation Techniques (VIIT) through Erdas Imagine software. This study demonstrates the change detection and deterioration of lakes in Mysuru city due to human pressures and for future implementation strategies.

Keywords: Lakes; Change Detection; Mysuru; Geospatial technology.

I. INTRODUCTION

Lakes play great role in supporting system for human life through regulating the recharge of hydrological regimes and aquifer restoration (Khare and Jadhav, 2008; Adarsh et al, 2019). These have favourably governed the city's microclimate and replenish groundwater resources in the locality. City lakes are vigorous ecosystem that review the change in climatic conditions, global warming (?), basin characteristics and biological factors (Adarsh et al, 2019). Karanji, Dalvoy, Devanoor, Lingambudi and Kukkarahalli are the 5 human-built lakes in Mysuru urban area that had considered for rejuvenation during the year 2002 under ADB (Asian Development Bank) through KUIDFC (Karnataka Urban Infrastructure and Finance Corporation). The River Cauvery was supplied to Mysuru city through pumping using electricity in 1910 to reduce the dependency of drinking supply from these 5 lakes (Sahana and Jagannatha, 2006). The undulating landscape and valleys furnish the perfect development of lakes that catch and deposits rainwater (Krishne Gowda, 2014). Each of these lakes stock rainwater from its catchment area and excess water flow towards next lake of downstream areas (Krishne Gowda and Sridhara, 2013).

In India, lakes of both urban and rural area play a great role in supply of potable water for domestic, industries & irrigation end to end, but wetlands in the vicinity have been neglected and systematically encroached upon by human forces. Lakes of Mysuru city are at the boundary of elimination (Fig.2) and the water contains dissolved oxygen below desired limits by organic pollution (KSPCB). Surface waterbodies reveal great ecological diversity with regard to plankton and biochemical activity (Udayashankara et al., 2013). The main factors behind the pollution are the effects of waste inputs, decay of algal blooms; whereas the anthropogenic activity such as the use of sewage and fertilizers in agricultural field, and letting of industrial sewage in the catchment area are the reasons for the pollution. Siltation, encroachment, discharge of effluent from industrial & domestic, sewage contamination, storm water carrying sewage through drains and infestation by variety of weeds causing high pollution (Krishne Gowda and Sridhara, 2013). Sewage flow, garbage from many sources and silt inflows have devastated and leading to slow death of Mysuru lakes.

Natural diversion of rainwater runoff, cutting of foreshore trees causing soil erosion, land encroachment near the lake's vicinity and illegal constructions of buildings are the major issues faced by Mysuru lakes (Sahana and Jagannatha, 2006). Bogadi is one of the lakes have witnessed the dumping of untreated garbage and sewage from Western parts of the city by the lack of scientific management approaches by planners with comprehensive action plans (Sahana and Jagannatha, 2006). Mysuru Urban Development Authority (MUDA) has focusing mainly to give the city a top-class infrastructure, so that the City can enhance centres for education, tourism and industrial hub. Many lakes were recorded in the base maps such as village maps, SoI toposheets earlier, but physically do not exist at present. At least 25% of lakes in Mysuru had been converted for the sake of city's growth and development. Recently, major & minor roads, playgrounds, malls, parks, bus stands were constructed on nearly 37 lakes around Mysuru-Nanjangudu local developmental planning zone. This covers an area of 495 km² and more than 80 small & medium tanks are at the verge of extinction in the vicinity near future. Study on Mysuru Urban development from the Environmental Impact Assessment (EIA) portray serious issues leading to the loss of valuable tanks as water resources and the future damages on irreversible economic and ecological factors.

II. METHODOLOGY

A. Study area: Mysuru city is famous for its cleanliness, beauty, educational, commercial, & administrative and is known for tourists' destination such as world famous palace, art galleries, temples, churches, mosques, museums, tree lined boulevards, many well laid gardens, magnificent majestic buildings, and waterbodies (Krishne Gowda and Sridhara, 2013). It is also known for its rich culture and heritage which are reflected in the artifacts, handicrafts, woodcrafts, silk sarees and sandalwood products and ivory works. Recently, Mysuru had underwent extensive and unplanned expansion of urban areas (Krishne Gowda and Sridhara, 2013). Unbridled urbanization and population rise in Mysuru city encroached many lakes causing removal of green spaces with rapid horizontal urban expansion (Manjunatha and Basavarajappa, 2022). The study area is observed in between 12^o 18' Northing and 76^o 12' Easting with an altitude of 700 to 725 mts above MSL and portray mild slope along the South direction (Fig.1a & b). A prominent majestic Chamundi Hill is located towards SE part with the elevation of 1060 mts where the temple of Goddess Chamundeswari is present. Northern regions drains river Cauvery through subsurface flow; while southern part by river Kapila which is a tributary of river Cauvery (Krishne Gowda and Sridhara, 2013). Temperatures ranges from 18^oC and 37^oC with always pleasant with an average annual rainfall of 798mm and enjoys cool and equable temperature.

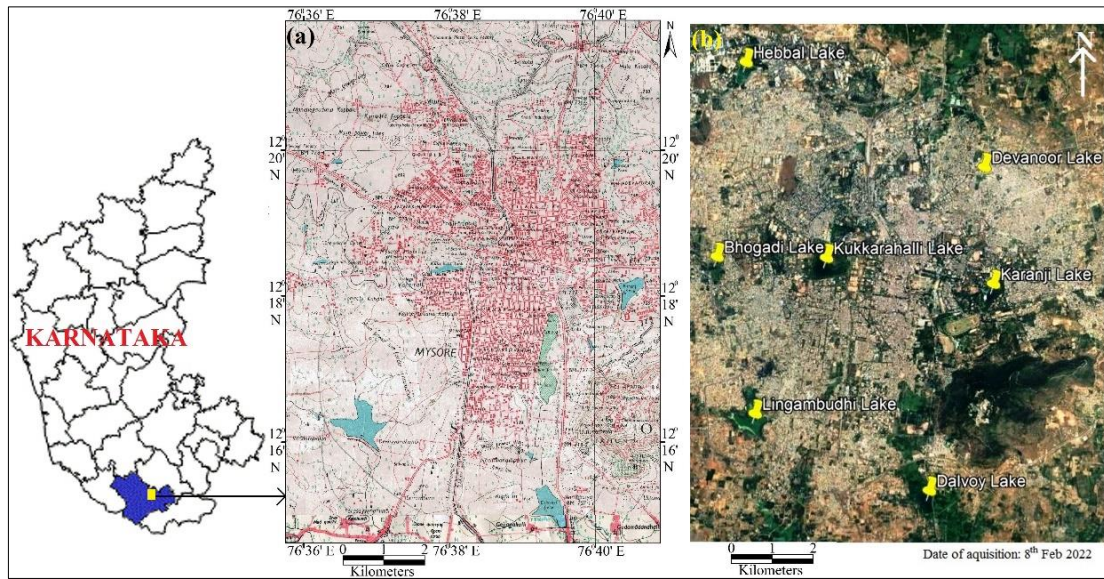


Fig.1. (a) Topomap and (b) Google Earth map of Mysuru city

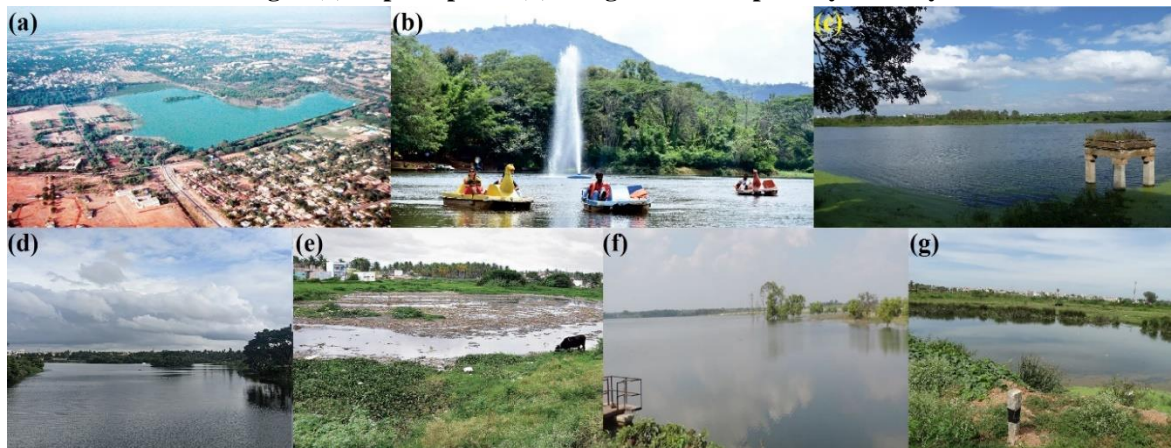


Fig.2. Aerial & Field Photograph of (a) Kukkarahalli lake; (b) Karanji lake; (c) Lingambudhi lake; (d) Hebbal lake; (e) Devanoor lake; (f) Dalvoy lake; (g) Bogadi lake

B. Methods: Surface waterbody maps are generated through satellite data in conjunction with Survey of India (SoI) topomap by analysing the permanent objects of major roads, power-lines, temples, drainages, settlements and railways. SoI toposheet of 1:50,000 scale are acquired for satellite image geo-referencing using GCP (Ground Control Points) through ArcGIS v10. The aerial extents of each lake are digitized and temporal changes are mapped and recorded (Fig.3).

C. Materials used

- i. **Toposheet:** 57D/11, 57D/12 (1:50,000 scale) of the year 1978 (Fig.1) and 2011, Survey of India, Bengaluru.
- ii. **Satellite images:** IRS-1D, PAN+LISS-III of 5.8m Resolution of Path: 99, Row: 64, ISRO-NRSC, Hyderabad and Sentinel-2A of 10m Resolution, Earthexplorer, USGS.
- iii. **Software:** ArcGIS v10 & Erdas Imagine v2011.
- iv. **GPS:** A handheld GPS (Garmin-eTrex 10) had well utilized during limited field visits to record exact boundaries of each lakes.

III. RESULTS AND ANALYSIS

A. History of Lakes: The city population were depended on the small wells and tanks to provide water supply (Basavarajappa et al, 2012). Constructing the lakes of Kukkarahalli and Karanji by Dewan Poornaiah in 1864 under the

aegis of the then Maharaja of Mysuru Sri Chamarajendra Wodeyar, augmented the water supply through iron mains (Farzaneh Shaikh et al, 2008). After 1910, the water dependency of many lakes in the city were reduced, once river Cauvery was ensured with the establishment of electrification and water supply through pumping. However, the Mysuru lakes continued to give traditional livelihood in the vicinity like Kukkarahalli and some areas (Ravikumar et al., 2000). Birdlife International has included the lakes of Karanji, Kukkarahalli and Lingambudhi in Mysuru within 38th position as important conservation sites in Karnataka State. More than a dozen of sites attracts varies species of birds within a few kilometres from Mysuru that have also declared as priority conservation sites (Kumar, 2005). These lakes in the city provide economic welfare like nature viewing, water flow regulation, boating, recreation, carbon sequestration, climate amelioration etc (Chaudhary et al, 2013). Lakes in Mysuru are being vanished since from many years gradually as a consequences of human neglect & other issues that could not sustain human forces and the present non-potable water do not meet human's daily needs (Ravinder Kumar et al, 2018).

B. Benefit from Lakes: Few decades ago, these lakes were treated properly keeping them as a view of reliable sources for fresh water supply throughout the year (Krishne Gowda and Sridhara, 2013). The need of potable water has diversified as well as gone up with increased human forces in urban areas, increase in water demand for industries and rise in population (Krishne Gowda and Sridhara, 2013). The city treat these lakes as lung for the surrounding environment that help quench the thirst of the bovine population, groundwater recharge, types of livestock and supply, support fishing and grazing, and other the water needs of wild birds and animals (Krishne Gowda and Sridhara, 2013). Urban lakes control floods during heavy rainfall and provide a habitat for water birds and strengthens the symbiotic links with nature (Krishne Gowda and Sridhara, 2013). Lakes must be treated as a part of our resources of natural landscape as our cultural habitats (Krishne Gowda and Sridhara, 2013). Conserving these for future needs is a primary task at present that can plan simply by rainwater harvesting, making overflow seep into the subsurface zones and other techniques (Krishne Gowda and Sridhara, 2013). Harvesting the rain water is a simple cost effective practice that reduces the demand for water (Krishne Gowda and Sridhara, 2013).

C. Study of Lakes in Mysuru

i. Kukkarahalli Lake: It is located in the focal point of Mysuru city with water spread area of 55 hectares. The lake portray scenic beauty for public entertainment like jogging path, space for walk, boating facility, park and an island for variety of migratory birds visits during winter season (Farzaneh Shaikh et al, 2008). Many public visit the lake only for bird watching and observing every day. Many years ago, the lake providing potable water to the city limits, but the sewage supply through drains, illegal waste dumping, and obstructions of water inflow had distress the water quality. University of Mysore has taken up many necessary initiatives to improve the quality of the lake and to provide better environment to the public who visits the lake.

ii. Karanji Lake: Karanji Lake is one of the recreational lake of the Maharaja's family and also called as India's largest walk-through aviary maintained by Mysuru Zoo authority. Herons and egrets are the migratory birds that are the favourite haunts of this Lake. Grey Pelicon, Painted Stork, Ibis, Cormorant and Bulbuls are the other common migratory birds found here. Presently the lake is surrounded by the bird watch tower, boating jetty, a butterfly park, Nature Park and a largest walk-through birdcage in the state. Drainage pipes from nearby residential zones letting sewage into the lake from many years now causing pollution and annihilation of aquatic life (Adarsh et al, 2019). The pollution with sever causes made the migratory birds to move away from the lakes for the search of food sources. Hence a proper scientific way of approach is required before the destruction of this wonderful tourist attractive places and nature's gift to the mankind (Anima Upadhyay et al., 2016).

iii. Lingambudi Lake: This covers an area of 52 hectares and being preserved & developed by Minor Irrigation Department and Zoo Authority. It's one among the huge and elderly lakes giving shelter to a wide variety of aquatic birds. This consists of minor amount of rainwater even during heavy rainfall conditions. Six number of islands were observed within the tank that encourage wildlife and bird's habitation. The lake served as a source of water for fisheries, agriculture and other household uses for more than 150 years in the vicinity. This lake is located in the South-western parts of Mysuru city, and attracts several hundred nature lovers every day.

iv. **Hebbal Lake:** It is considered as one among the high polluted lake located near the existing Hebbal industrial area. It is surrounded by industries and one side by agriculture. As it is located in the vicinity of industries, human influences are high leads to dumping with solid waste particularly constructional debris. Two sewage pipes were observed that inlet effluents from surrounding industrial area and also being continuously contaminating by its untreated sewage for many years now (Basavarajappa et al, 2015).

v. **Devanoor Lake:** Devanoor Lake is located in between the areas of Narasimha Raja Mohalla and Udayagiri. It is one more high contaminated lakes that turned into mosquitoes’ breeding. Illegal dumping of plastic papers, bottles and solid waste blocks the canal during rainfall season causing blockage for fresh water movement. Sewage from the adjacent layouts and apartments were often carried by the storm water channels causing augmentation of weeds and disturbs lake visibility. Sewage entering into the lake through drainage system from the eastern side from the storm water is the major issue causing lake pollution.

vi. **Dalvoy Lake:** It is situated 5kms south of Mysuru city towards Nanjanagudu on the Bengaluru-Nilgiri road. The major source of water for this lake is the precipitation and urban runoff from higher altitude areas through storm water drains. This lake has a very unique ecosystem not only helpful for the survival of aquatic life but also for irrigating the lands of downstream farmers. As it is located near the national Highway, human influences are more to this lake. The largest quantity of sewage and municipal untreated effluents also add into the lake from one of its drain inlet impacting the pollution level that can be seen from the outflowing water.

vii. **Bogadi Lake:** It was constructed as a tank in 1963, for conserving urban storm water. It has a water spread area of 2.0 hectares with very limited biodiversity. The inflow of water to this lake was controlled due to urban sprawls over the upstream catchment. Bogadi lake water is mainly used for domestic consumption by the adjacent dwellers. Irrigation return flows also contribute to the nutrient dynamics. The lake become alive when there is continuous inflow of water from sequential showers. This is the major groundwater recharge point for entire Vijayanagara and Bogadi. A few water birds and juvenile zoo planktons survive in this lake. Untreated sewage is entering into this lake from the adjacent areas.

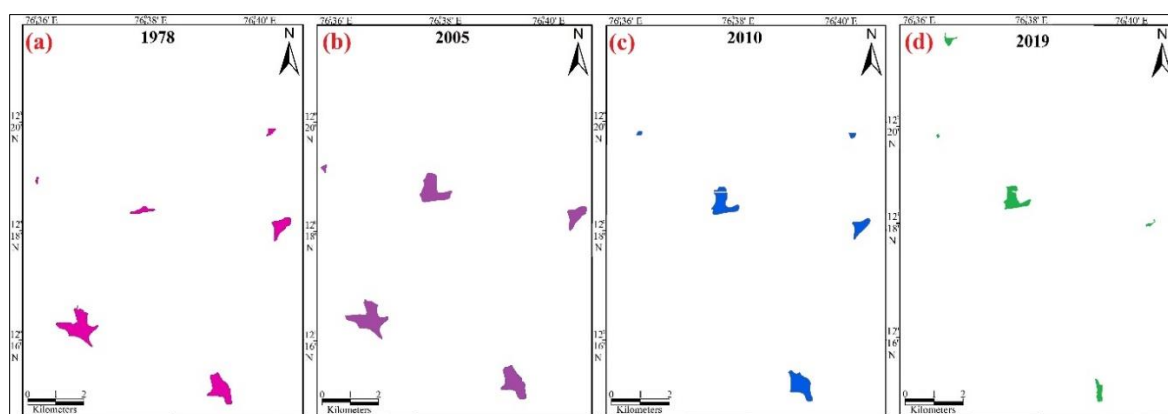


Fig.3. Aerial extent of Selected Lakes in Mysuru during (a) 1978 (b) 2005 (c) 2010 (d) 2019

Table.1. Water Spread Area of Lakes in Mysuru city (in Hectares)

Sl. No	Name of the Lakes	1978	2005	2010	2019
		Toposheet	LISS-III	Toposheet	Sentinel-2A
1.	Kukkarahalli	9.516	40.502	41.759	35.722
2.	Karanji	24.433	1.436	19.526	2.608
3.	Lingambudhi	67.449	50.958	-Nil-	-Nil-
4.	Hebbal	2.244	6.602	-Nil-	7.310
5.	Devanoor	4.325	-Nil-	3.248	-Nil-
6.	Dalvoy	46.001	18.971	46.882	13.172

7.	Bogadi	4.206	5.467	-Nil-	-Nil-
	Total	158.174	123.936	111.415	58.812

D. **Change Detection Analysis:** Lakes and small tanks were reduced from 72 to 34 around the city due to growing population, high-raised buildings, illegal dumping and burning of solid wastes, sewage inlet etc. The present day conditions of well-known Doddakere lake is a landmark of famous Mysuru-Dasara Exhibition and play/ parking ground (Fig.5a & b). Subbarayana Lake (Fig.5d) beside Chamaraja Double Road and Jeevanna Rayana Lake (Fig.5c) near City Railway Station had both dried up due to poor management and became freedom-fighter’s park and playground respectively. All lakes of Mysuru show great variation in their aerial extent over large time period due to immense human forces. Significant changes reveal the maximum fluctuation especially in Kukkarahalli Lake and Karanji Lake. These changes indicate decreasing trend of all lakes, except Hebbal Lake (Fig.4).

Table.2. Change Detection Analysis of Lakes in Mysuru city (in Hectares)

Sl. No	Name of the lakes	1978 - 2005	2005 - 2010	2010 - 2019
1.	Kukkarahalli	+30.986	+1.257	-6.037
2.	Karanji	-22.997	+18.090	-16.918
3.	Lingambudhi	-16.491	-50.958	-Nil-
4.	Hebbal	+4.358	-6.602	+7.310
5.	Devanoor	-4.325	+3.248	-3.248
6.	Dalvoy	-27.030	+27.911	-33.710
7.	Bogadi	+1.261	-5.467	-Nil-

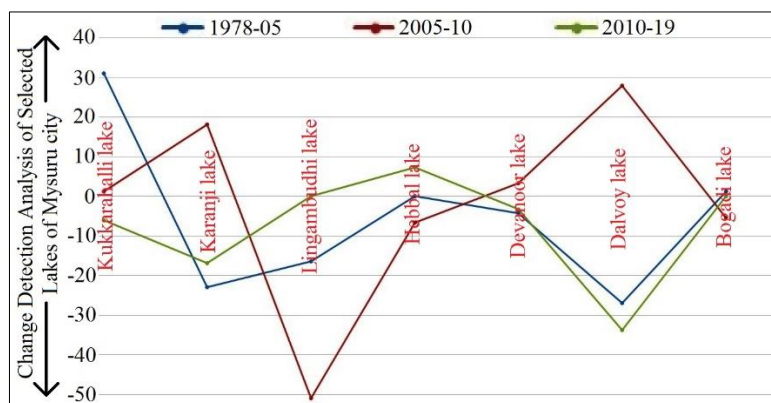


Fig.4. Line graph depicting the Change Detection Analysis of Lakes in different years

IV. DISCUSSION

All lakes in Mysuru city are being managed by Minor Irrigation Department, MUDA (Mysore Urban Development Authority) and MCC (Mysore City Corporation). These lakes were benefited for irrigation purposes for many years now (Manjunatha and Basavarajappa, 2020) and need proper recreational purposes like boating, bird watching, morning & evening walk, Nature Park etc. Karanji and Kukarahalli were the only two lakes which were desilted and considered for enhancement and reclamation activities by the authorities; while other lakes were kept at rest due to ownership and sustainable maintenance problems. Major issues regarding lakes include severe siltation (Basavarajappa et al, 2014), encroachment of tank areas, loss of catchment area, weed infestation, indiscriminate dumping of debris, large quantity of raw sewage inlet and dense vegetation growth resulting in deterioration of lakes. Mysuru is presently Karnataka’s second key city for investment in the educational, tourism sectors and industries that will take off as the latest destination.

Karanji, Dalvoy, Kukkarahally, Devanoor and Lingambudhi were the 5 human constructed lakes which are being polluted and deteriorating due to urbanization pressures, changing land use patterns, illegal waste dumping, inflow of sewage water & industrial effluents and variety of weeds infesting major portions of the lakes. Bogadi Lake dried two years ago and Hebbal Lake is highly polluted due to human specific forces. In addition to this there were two small lakes one of them, (Farzaneh Shaikh et al, 2008). Devanoor Lake become a cesspool owing to lack of maintenance and

release of untreated sewage. Rapid urbanisation had taken away 20% of agricultural lands, which gave way for the formation of residential layouts. A thrust towards residential development, changing the land use patterns rapidly that cover a greater portion in the city and expected to rise highest in the coming years. Unplanned and unauthorized areas of the City do not have specific sewerage inlets and thus discharging sewage into the drains. Fractures, joints & lineaments are controlled by the river system (Manjunatha et al, 2021) in the study area that discharges sewage through drains causing serious problems of subsurface water blockage (Basavarajappa et al, 2013; Manjunatha and Basavarajappa, 2017). The groundwater depletion is recorded about 36mts in industrial and 18mts in residential areas respectively during the last 2 decades (Chandrashekara Mutt, 2000).

A. Dried lakes: The storm water flow through drains carry sewage into the lakes causing high pollution. Sewage and excessive land encroachments (mostly illegal) and blockage of water flow sources almost led to the eutrophication of the lake over many years (Krishne Gowda and Sridhara, 2013). There are many lakebeds which are examples for such casualty at Mysuru urban area (Sahana and Jagannatha, 2007). The land patterns of the study area changing rapidly and growing economically as well as demographically. The fast growing Mysuru city depicting the urban expansion on all directions and impacting the waterbodies negatively since from past 2 decades. There is no specific harvesting strategies for rainwater among domestic, industrial and service sectors, since aquifer recharge play crucial role in lakes restoration and groundwater improvement. For many years now Kukkarahalli, Karanji, Hebbal and Dalvoy lakes had been polluted due to sewage water inflow. Hebbal and Dalvoy lakes had greatly contaminated, and no serious actions were made to protect the water sources. In 2014, hundreds of fishes of Karanji Lake were found dead due to heavy inflow of sewage water from the overflowing manholes of Siddartha Layout. Doddakere was one of the oldest lakes in Mysuru have dried and degraded due to improper management and converted into famous Mysuru Exhibition area and football playground now (Fig.5a & b); while Subbarayana lake is a park now (Fig.5d). Jeevanna Rayana Lake near railway station was once a large lake, was converted to playground due to improper management (Fig.5c). Illegal dumping and burning of municipal solid wastes were observed around Bogadi Lake causing respiratory problems to local residents (Fig.5e). Unabated inflow of sewage, dumping of solid waste and illegal encroachment were affected the city and its lakes greatly.



Fig.5.(a) Exhibition ground and (b) Playground/ Parking area on Doddakere lake; (c) Playgrounds on Jeevanna Rayana lake; (d) Freedom Fighter's park on Subbarayana lake; (e) Dumping & burning of solid wastes near Bogadi lake; (f) Drainage net to reduce rubbish to lakes

B. Restoration of Lakes: Treatment of catchment area, avoiding sewages from entering the lake, removal of restoration of feeder channels, de-weeding of the lake surface, polluted silt, construction of a bridge, construction of a jetty to start boating facility and 'butterfly park' may help in restore the great aesthetic pleasure of lakes (Krishne Gowda and Sridhara, 2013). Watch towers construction for bird watching & studying the behaviour, a giant fountain of 40 feet height, Children Park and nursery of medicinal plants may add as an attraction. Preventing the point-source

pollution by intercepting, chain fencing for lake protection, diverting pollution loads before entering into the lakes are very much necessary for its sustainability. Fish fingerlings may be introduced periodically and being monitoring to enhance fish population that may result in attracting more water birds especially during their nesting seasons. People participation is the top-most priority in conservation of natural areas, specifically lakes. Drainage nets are the simple pollution solution that are sock-like net that fits over a storm water drain or sewage pipes that collect rubbish before it enters the lakes (Fig.5f).

IV. CONCLUSION

The beauty of the Mysuru city lies in its colourful gardens, green plantations and the number of lakes located within and outside the city, but these lakes are getting deteriorated behind the point of recovery due to anthropogenic activity. Gradual increase in built-up land are observed due to population rise, urban sprawl, transportation networks are badly impacting our biodiversity and also disturbing the natural land pattern. Illegal encroachment, weed infestation, siltation, discharge of effluent from both domestic and industrial are knelling the death of lakes. Illegal dumping of old construction wastes, domestic wastes, sewage pipe leakages nearby lakes, extreme summer conditions, industrial and hospital wastes were affecting the groundwater movement and recharge. Major decrease in surface water bodies shows negative impact moisture content and groundwater point of view. This helps to record the probable modification of land pattern in future studies, so that the policy makers, resource managers and scientists can establish a specific portray in human-lakes interactions, ecosystem impacts and future sustainability.

AUTHOR'S CONTRIBUTION: First author did the manuscript write-up, generated GIS analysis & change detection analysis; Second & Third author collected the field photographs & literature review; Fourth author reviewed the paper and added valuable suggestions.

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