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DETECTION OF DECLINE IN THE EXTENT OF LAKES IN BANGALORE CITY USING GEOSPATIAL TECHNIQUES

N. N. RAMAPRASAD[1] & PRIYA NARAYANAN[2]

[1]Research Scholar, Department of Geography, School of Earth Science,
Central University of Karnataka, Gulbarga, India

[2]Assistant Professor, Department of Geography, School of Earth Science,
Central University of Karnataka, Gulbarga, India

ABSTRACT

Bangalore city, fifth largest and fastest growing city in India, has a decadal population growth of 39%. Geographically Bangalore lies on the Deccan plateau of rain shadow region. Number of lakes constructed along the streams in the undulating topography by the rulers of Mysore kingdom and local people for their daily needs. Lakes compensated the absence of perennial rivers. The present study is carried out by using Geospatial techniques by archived Survey of India maps and Cartosat imageries to delineate the lakes, pace and pattern of their depletion in the Bangalore city. The study reveals that the extent of water bodies has declined almost by 17 %, since 1961 due to unplanned urban sprawl. This loss of lakes has resulted in many problems like urban floods, urban heat island and depletion of groundwater. The few existing lakes became dry, polluted by making the situation severe. The observation in this paper helps in establishing a self-sufficient, eco-friendly sustainable smart city that conserves lakes. Thus by giving prime importance to lakes, the water scarcity problem can be managed.

KEYWORDS: Geospatial Techniques, Groundwater Recharge, Lakes, Urban Sprawl, Smart City

INTRODUCTION

Lakes have formed by constructing dams along the natural valley system. Height of dam depended on the material used, terrain slope, average rainfall and water requirement. Depth and area of the lakes were proportional to the slope of the region. The lakes are shallower and larger in Eastern part of the Bangalore due to the gentle slope, whereas western part of Bangalore are deeper and smaller due to the steep slope. Local people maintained the lakes as the common property resource and each one of them enjoyed its fruits.

Human settlements established after construction of lakes in the undulating terrain of nonperennial river. Many small lakes also constructed on the high grounds and near the agricultural fields. Lakes in the high grounds used to recharge the ground water and reduce the surface runoff and erosion, also supported farming and animal husbandry. Catchment areas of each lake have reserved for forest and grazing lands at higher altitudes and devoid of settlements. Rich mineral silts depositions of the lakes have used as the fertile soil in agricultural fields.

Unplanned urban sprawl, population growth and economic development have set the stage for environmental and social problems in modern cities. Though urban areas cover only 3% of the earth's land surface, their ecological footprint is much more extensive (Liu & Lathrop, 2002; Mahdi Sabet Sarvestani, Latif Ibrahim, & Pavlos Kanaroglou, 2011; Martin

Herold, Noah, & Keith, 2003; Mehdi Fazelbeygi & Gholamreza Yavari, 2013). Some of the problems associated with urban expansion include climate change (Grimm, Grove, Pickett, & Redman, 2000), the destruction of vegetation and agricultural lands, air pollution, and the pollution of surface and underground water sources. All these contribute to decreasing the quality of life in both urban and rural societies. Widely accepted fact is that urban growth in the global scale continues apace. Simultaneously, it is necessary to protect natural resources (Latif & Sabet Sarvestani, 2009; Mahdi Sabet Sarvestani et al., 2011).

Industrialization led to alternate employment and reduced the dependency on agriculture and lakes, resulting in negligence and encroachment of lakes, leading to the scarcity of water (Ramesh & Krishnaiah, 2013). Bangalore's inorganic growth consistently caused its urban areas to merge with the peripheral rural fringes, engulfing the existing water-bodies and settlements, as urban villages (Fathima & Rajesh, 2012). Loss of lakes and vegetation has caused urban heat islands (Ramachandra & Uttam Kumar, 2013). The interconnectivity that is an important feature of the waterways has been threatened and even losing its characteristics. Many lakes and ponds are lost, and the surviving lakes are polluted with sewage in the process of urbanisation.

Groundwater is not a sustainable resource anymore. It is susceptible to the vagaries of rainfall. It needs to be considered only as a standby resource during scarcity or drought. Groundwater table should be allowed to revive up to the unconfined aquifer horizon. Also, there should not be exploitation of groundwater resources beyond 60% of the corresponding annual groundwater recharge (Hegde & Subash Chandra, 2012).

Stagnant water bodies have more complex and fragile ecosystem; they lack the self-cleaning ability, hence readily accumulate high amount of pollutants. Increased anthropogenic activities in and around the water bodies adversely damage the aquatic ecosystems and ultimately the physicochemical properties of water (Sripathy, Harish Raju, Renuka, & Thuppil, 2012; K. Upadhyay, Mishra, & Gupta, 2010).

Some lakes lost their lives in malaria eradication programs (Tippaiah, 2009). Many lakes lost their catchment area as the connecting stormwater drains carry the sewage waters and diverted. Stormwater drains are used to carry domestic wastewater in urban areas. These storm water drains have diverted as they are polluting the lakes. Lakes became dry due to diverted streams and reduced catchment area. Residential buildings and urban utilities established along the dry lakes and the dry portion of the lakes. Loss of lakes and increased impervious surfaces affected low-lying areas by flash floods and ground water recharge. Ignorance of maintenance of lakes and lack of agricultural activity nearby lakes has devastated the lake ecology.

The objective of this research is to create a lake database, account the loss of lakes within the city limits Bangalore. Categorise the spatiotemporal transformation of lakes. Classify the lakes based on different themes, using visual image interpretation techniques.

STUDY AREA

Bangalore, the fifth largest and fastest growing city in India, has a decadal population growth of 39% (with 87,49,944 populations as per 2011 census). The average annual rainfall is about 931 mm with 60 rainy days (Source: Indian Meteorological Department). The city enjoys a pleasant climate throughout the year. The summer temperature ranges from 18° C to 38° C. The winter temperature ranges from 12° C to 25° C. The tree-lined avenues, parks and abundant greenery have made Bangalore the "Garden City" of India. Situated at the altitude of 920 m above mean sea

level (Santosh Kr. Singh., 2009; Sudhira, Ramachandra, & Bala Subrahmanya, 2007). The study area consists of a total geographical area of 742 sq-km. And lies between 77˚24' E - 77˚48' E longitude and 12˚46' N - 13˚11' N latitude, covering in Survey of India topo sheets 57G/8,12,16, 57H/5,9,13 on 1:50,000 scale. The location of study area is shown on the map(Figure 1).

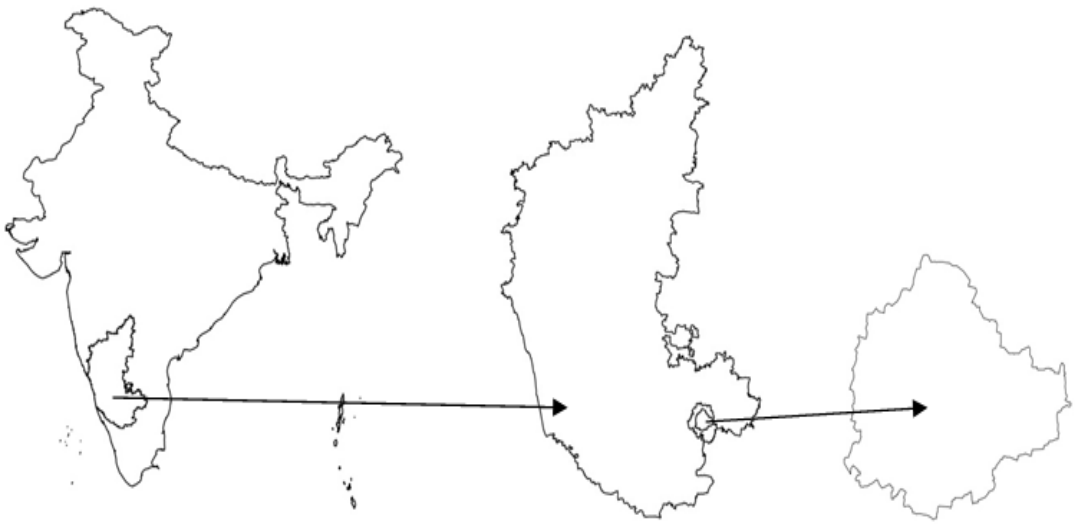


Figure 1: Study Area Bruhat Bangalore Mahanagara Palike

MATERIALS AND METHODS

Survey of India Bangalore guide map surveyed during 1960, Survey of India topographic maps of 1:25,000 (1973), Survey of India Bangalore guide map (1979 and 1999), Survey of India topographic maps of 1:50,000 (1998-2000). Base layers generated from the latest cartographic satellite imagery from Bhuvan. Primary data collected with a handheld GPS during field visits were integrated to geodatabase. Remote sensing, and GIS is an extensively used techniques for mapping urban areas. And they are data sources for the analysis and modelling of urban growth and land use change (Clarke, Parks, & Crane, 2002; Donnay, Barnsley, & Longley, 2001; Herold, Goldstein, & Clarke, 2003; Jensen & Cowen, 1999).

Visual interpretation techniques make use of the excellent ability (Lillesand & Kiefer, 2002; Sudheer & Panda, 2000). Latest cartographic satellite image available on Bhuvan website has used to create a lake database of 2012 by applying the visual interpretation technique. The image interpretation has done manually to create a lake database. The image interpretation has done on the basis of shape, size, pattern, tone, texture, shadows, site and association. Geo-referencing of acquired topographical maps, guide maps and remote sensing data with UTM coordinate system of world geodetic system 1984 datum. Accuracy assessment has made with field visits and revering Google Earth (http://earth.google.com). The extent of the lakes of 2012 has compared to the previous years Lake extents. Overlay analysis was used to determine spatial differences. The lakes have classified on the basis catchment area. Accounting lake transformations by identifying the structures present in existing place of lost lakes. The loss and extent of encroachments of lakes are measured temporally.

RESULTS AND DISCUSSIONS

The extent of lakes has been delineated using the various data sources from 1960 to 2012 (Figure 2). The loss of lakes due to urban transformations are presented in the table (Table 1).

Table 1: Loss of Lakes from 1960 – 2012

	1960-1973			1973-1979			1979-1998			1998-2012		
	No. of Lakes	Sq m	%	No. of Lakes	Sq m	%	No. of Lakes	Sq m	%	No. of Lakes	Sq m	%
Agricultural	9	17153	4.2	2	1868	0.4	15	22092	1	7	35856	3.3
Industrial	11	17983	4.4	4	11712	2.4	15	173228	5	5	37750	3.4
Open area	21	32711	8	15	64121	13	160	650693	19	24	262979	24
Park & play ground	10	63113	15	5	27532	5.7	19	523409	16	14	536514	49
Residential	130	272833	66	40	372008	77	244	1547238	45	23	131410	12
Utility	4	7521	1.8	4	7781	1.6	34	348547	10	7	94601	8.6
Forest	-	-	-	-	-	-	5	152196	4	-	--	--
Total	185	411314	100	70	485022	100	492	3417403	100	80	1099110	100

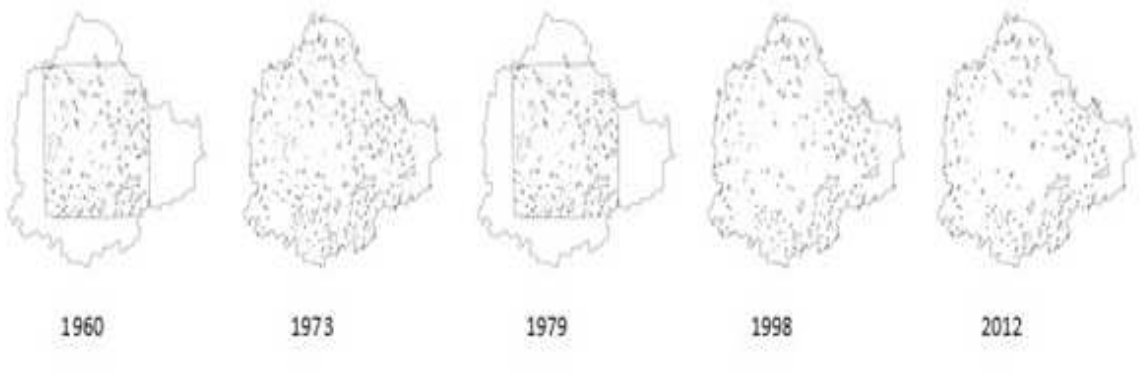
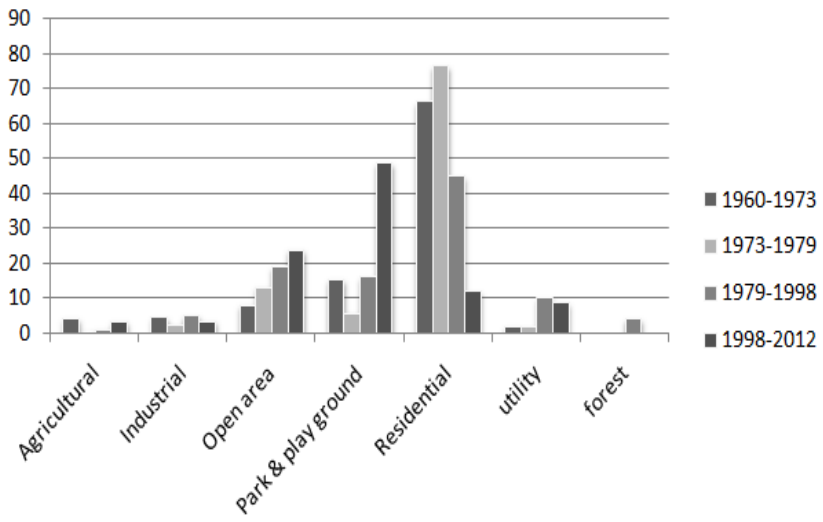


Figure 2: Distribution Pattern of Lakes in Bangalore City



Graph 1: Transformation of Lakes in Percentage

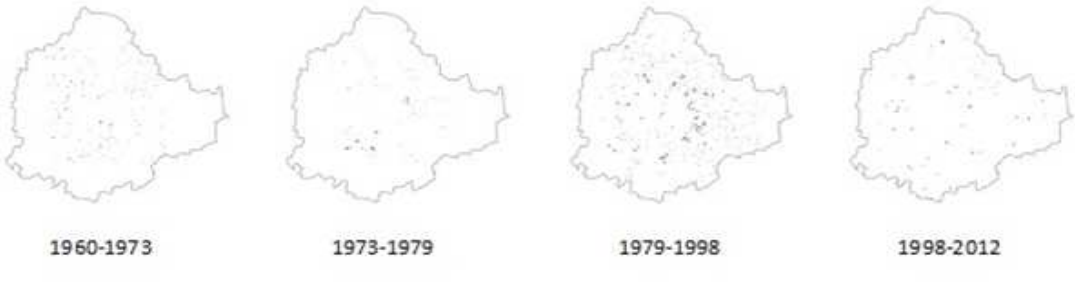


Figure 3: Loss of Lakes from 1960-2012

Table 2: Encroachment of Lakes from 1960 – 2012

	No. of lakes	Area
1960-1973	38	1021989
1973-1979	29	785631
1979-1998	52	1726135
1998-2012	41	900799
Total	159	4183560

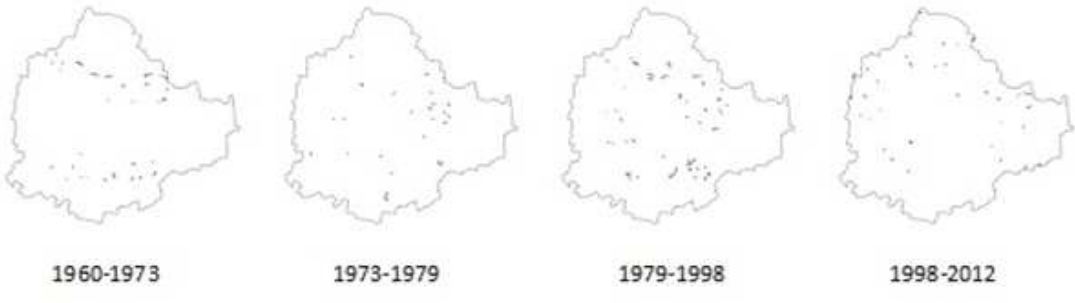


Figure 4: Encroachment of Lakes from 1960-2012

Man has created lakes for his survival in the regions of non-perennial rivers. As and when the demand increased the new and larger dams have built to ensure uninterrupted water supply, ignoring the small and seasonal lakes. Technological growth facilitated to bring far away water resources. Unplanned cities growth lead to misuse and destruction of local resources, loss of ecology, and dependency on distant resources such urban growths are not self-sufficient and sustainable.

During the period from 1960 to 1973, the Bangalore city became the capital of Karnataka. Many administrative buildings and major public sector industries such as BEL, BEML, ITI, HMT have established. Well before 1960 the Bangalore had textile industries like Binny Mill, Ramakumar Mills. Trading of Cloths was one of the leading businesses during this time. Urge to land for the residential purposes of migrated employees increased and many catchment areas, lakes have converted to residential layout. Transport network was in its infant stage with limited, narrow roads and fewer vehicles than compared to the present state of affairs. Tongas and bullock carts have used to transport goods and passengers. People liked to establish themselves in the vicinity of their working regions. Supply and demand for perishable goods have met by the marginal agricultural fields in the Bangalore city. Agricultural fields, the vegetable gardens and the number of lakes formed by a genuine sense of garden city and pensioner's paradise during this time. Residential areas like Rajainagar, Malleshwaram, Chamarajpet, Ulsoor, Cox Town and the city limit was around four kms in radius, during this period the low-lying grasslands / floodplains were unoccupied.

Figure 5: New Lakes 1973-1979

During the period from 1973 to 1979, the industrial production increased and with a large number of small scale industries developed which supplied by products to major industries. Industrial labour force increased, and the construction of small housing societies and houses for these labourers also increased. Migrated people worked in industries and construction disciplines. Land value during this time was also low; people began settling down permanently. Many large layouts have developed by converting agricultural fields and lakes with higher dimensional sites in the Jayanagar, Sadashivanagr and Koramangala layouts. No significant improvement in the transport has seen during this time, and the supply and demand of perishable goods have met by the marginal agricultural fields in the Bangalore city. No fallow lands have left; the policies like uluvvanige bumi (ownership of land for one who ploughs) and conversion of Gomala (grasslands) to agricultural fields have made the farmers cultivate their land. Two hundred seventy-seven small lakes and many open wells have built to support the farming activities (Figure 5). During this period, the development resembled Von Thunen model of agricultural land use theory (Robert, Ernest, & Roderick, 1925). Sustainable growth of the city took place in all round developments with agricultural and industrial having giving equal importance. Firewood has supplied from the nearby forests for cooking purposes during this time.

Whereas during 1979-1998, much of the transport network has risen for the industrial supplies. Growth of educational institutions took place. Power production increased, and the loss of forests affected the fuelwood supply. Hence, people switched to better alternative fuels like Kerosene and LPG for cooking. Era of using electric appliances like the motor pumps in all spheres of agriculture, domestic and industrial fields commenced. During this period, a comprehensive city development plan has implemented. Regions reserved for forest and farming as green belt and yellow belt for void of development and many satellite towns like Yelahanka, Kengeri and White Field have developed beyond the city limits. Low lying areas floodplains, grasslands, have occupied by slums and other low-income housing colonies giving accommodation for the migratory people. Bore wells that occupied little spaces replaced the traditional wells. Over exploitation of ground water, led to nearby lakes and open wells dry. Dry lakes have transformed into either housing layouts or other urban utilities. Dry portion large lakes have encroached. Sequentially many lakes have lost one by one creating a hydrological drought. Increase in impervious surfaces resulted in faster runoff, causing floods in low-lying areas.

Subsequently during 1998-2012, number of software and biotechnological industries established with the emerging outcome of young scientists, from bioscience, engineering colleges. Revolution of Information Technology and computer fields with lucrative salaries attracted many software industries to establish here. Comfortable climatic condition with many of pull factors like education, health and employment opportunities helped to create the footloose industries. Bangalore became the “Silicon City of India”. Unplanned residential layouts developed earlier with no space for civic amenities spaces, demanded the transformation of dry and polluted perennial lakes. As a result, 48.8% of lost lakes have converted to parks and playgrounds during this time.

In the mean time transport networks improved. Many ring roads and peripheral roads connecting the satellite towns and industrial hubs have built. Growth of the city took place in the regions reserved for forest and agriculture purpose (green and yellow belt areas). City's growth was much on the periphery of main roads, in contrast to the interior regions. Increased transport network facilitated to get the perishable goods from far away countries. Cold storage technologies preserved perishable goods for a longer period. Many malls have built giving a sense of the cosmopolitan city. Vertical growth of the city has initiated during this time. Many community living areas have introduced rainwater harvesting strategies for conservation of water. Simultaneously with global awareness, Medias support and nongovernmental organisation like the Environment support group, Ashoka Tree and courts helped to protect a few lakes to restore. Lake Development Authority has established, to protect and improve the status of lakes. Three lakes have leased out to develop and operate to private companies, but the act has subsequently criticised for hiring the common property resource. Developments made by the leaseholders were not up to the mark. Many lakes have protected from encroachments, parks, and playgrounds have built on banks, dams have stoned; beds were the silted and storm water drains (locally called as Raja Caluves) have restored. Loss of forest affected the traditional brick industries, which used to desilt the lakes regularly. Demolition and reconstruction of old houses built while 1960's has increased the dumping of building materials in the lake bed region.

CURRENT SCENARIO OF LAKES

Rapid urbanisation has transformed many lakes into urban utilities. Approximately two hundred and thirty-one lakes are present in the Bangalore City (BBMP area) due to the large number of lakes were built by ancestors in this undulating topography. Lakes still exist even after many of their transformation. Around fifty-seven lakes, i.e., 8% of lakes area have become thoroughly dry, affecting the agricultural activities. Lakes became dry due to loss of connecting stormwater drains, over exploitation of ground water in these areas, reduced capacity to store rainwater due to siltation, increased recharge and evapotranspiration. Many such lost dry lakes pose a threat of flooding in low-lying areas, recharge of groundwater and stabilising microclimate. Approximately one hundred seventy-fours perennial lakes, covering 92% of total lakes area, exists in Bangalore city (BBMP area). There are many large lakes, only a few lakes as Ulsoor; Sankey Tank and Hebbal lakes have used for amusement purposes. Most of the lakes water has polluted making it unsuitable for domestic use. Nutrient discharge of domestic wastewater is causing the lakes to eutrophicate, decrease in dissolved oxygen level, affecting the aquatic life and lake ecology. Sequential degradation of quality of lake water is resulting in its transformation to urban utilities. Polluted Lake water is recharging the groundwater and contaminating it. Lake water in fringe areas has still used for irrigation; fishing and washing of cattle. Lakes also contributed in regulating the climatic condition by balancing the humidity. Many migratory birds arrive here during the November month.

Bangalore has only four sewage treatment plants, and their geographical location is not in a commanding position with respect to lakes. Most of the lakes are sewage fed; the storm water drains have used to carry untreated sewage waters. Twenty-four lakes covering 25 % of the total lake area have rejuvenated by desilting, constructing the stone walls, creating artificial islands for the birds and habitats. Out of this, state of eight lakes has not improved even after restoration as the untreated sewage water has expelled into the lakes. Road and railway networks divided seven lakes, out of these two lakes have lost the storm water connection and become dry. Smaller portion of the isolated lakes dried up early and became extinct in due course. Smaller portions of lakes have ignored as maintaining it becomes a costly affair. Three lakes in the catchment area of agriculture area are getting the untreated water and eutrophicated. Thirty-five lakes in the catchment area

of semi-urban area are eutrophicated by receiving the untreated water. Lakes under the semi-urban are under massive threat as the underground sewer line does not exist in these areas, and the open drainages have used to carry the domestic waste water, leading to the lakes. Twenty-six lakes in the catchment area of urban have eutrophicated by untreated water from residences and industries flowing in the storm water drains.

CLASSIFICATION BASED ON CATCHMENT AREAS

Table 3: Catchment Area of Lakes

	No of lakes	Lake area in Sq m	%
Agriculture	47	3831891	13
Forest	6	234566	1
Open area	15	432832	2
Semi urban	99	13317339	46
Urban	64	11039755	38
Total	231	28856383	100

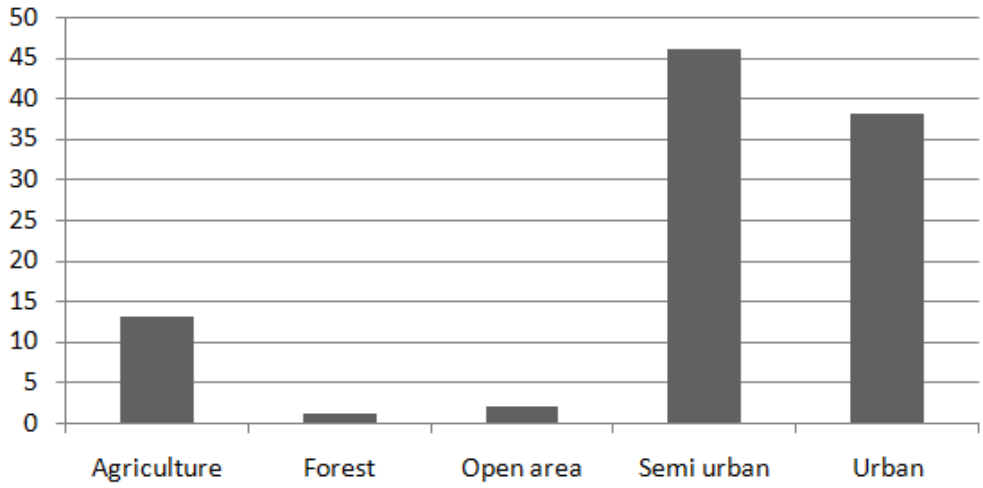


Figure 6: Catchment Areas of Lakes in Percentage

Lakes have constructed by sparing the catchment, for the forest, grasslands and open areas. Presently 3% of such lakes exist in the urbanized environment. Loss of catchment has greatly influenced by the quality of input water to lakes. Loss of vegetation and grassland has increased the soil erosion and silting, increased impervious surfaces in the urban areas have reduced the infiltration and aquifer recharging. Faster run off on the impervious surfaces also damaged the dams of the lakes. Proper planning has to be adopted to pump the tertiary treated water to dry lakes. Increasing the number of sewage treatment plants would be the need of the hour. The large scale fish mortality in Sankey Tank in June 1995 owing to falling in Dissolved Oxygen levels considerably in a few locations (due to sewage let into the lake) resulting in asphyxiation are the example of the damage to lake ecology (Benjamin et al., 1996). Installation of aerators in all the lakes would save the lakes to restore the lake ecology (Rajshekhar Rao, 2009). Constructions of silt arresters at the entry point of each lake would reduce the cost of lake maintenance. Construction of sluice to drain off the stagnant water and replace with recycled/fresh water saves the lake from pollution by keeping the lake alive. Utilization of lakes in urban areas for recreation and amusement purposes, along with public awareness programs brings awareness among people in understanding the importance of lakes in urban life. Lack of maintenance of lakes took place when the rights of common property resources have been taken over by the government, and the bureaucratic system showed no interest in preserving it as they had no relation with it. Maintenance of lakes to be handed over to local people along with the resource rights.

Land cover modifications alter the watershed hydrology and affect both, surface and subsurface water bodies. These changes have seen in a decrease of forested stream buffer and wetland areas that provide capacity for retention and purification (R. Upadhyay, Pandey, & Upadhyay, 2013). The impacts of urbanisation include reduced infiltration, increased surface runoff, higher peak discharge in streams, shorter travel time, and more severe pollutant loads influencing both surface water quantity and quality (Batty & Howes, 2001; Limin Yang, George Xian, Jacqueline, & Brian Deal, 2003; Mackinder, 1904). Rainwater harvesting in lost lake areas and all open areas should be made mandatory. Separate pipelines should be laid to carry the untreated waters. Restoration of storm water drains should be on top priority and restrict its use for storm waters only. All the new layouts must reserve space for civic amenity. Banning of piecemeal development of small residential plots as it is a threat to sustainable growth, and the Government should take the responsibility of developing the residential zones. Protection of lakes by leaving a space of 30 m surrounding the lakes and storm water drains. Catchment areas should be Exclusive allocated for the public purpose such as Government Office, Schools; Hospitals with at least 80% free space so that clean water can fetch the lake. Supporting technological innovations to reduce the runoff and increase the infiltration should be encouraged. Adoption of water conservation policies like innovative and practical use of treated water in all spheres is must for Bangalore. Development of other middle order towns reduces the force per unit area along the existing crowded city of Bangalore.

CONCLUSIONS

The study investigated the extent of urban water bodies in Bangalore city has shown a decreasing in its spatial extent by 17 % from 1960 to 2012. The multidimensional utilities of lakes like groundwater recharge, balancing the humidity, water reservoir, potential flood controller, helps in conservation of all the dry lakes to as they have the high ground recharging capacity. Recreational activities around the lakes like pedal boating and other water sports must be encouraged. Lakes are the only sole source of water in the regions dendritic drainage system. Protection of Lakes has a long-term advantage with respect to groundwater recharge apart from stabilizing the micro climate of urban regions and reducing floods in low-lying areas. The study demonstrates that use of GIS and Remote Sensing techniques helps in analyzing the problems, for Decision Support System and implement the policies.

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