

UNPLANNED BANGALORE CITY GROWTH: THREAT TO LAKES, CONTRIBUTING TO HYDROLOGICAL DROUGHT

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Abstract

Bangalore city, growing fastest in Asia, fifth largest city in India has a decadal population growth of 39%. Geographically of Bangalore is on the Deccan plateau that falls in the rain shadow region. Number of lakes constructed along the streams in the undulating topography by the rulers of Mysore kingdom for the purpose of drinking, fishing, irrigation and domestic needs which compensated the absence of perennial water sources. Local people maintained the lakes as the custodians of these resources. With the growing demand for uninterrupted water supply, the erstwhile rulers thought of dams having larger catchment areas. Over time, this dam-reservoir concept slowly began to replace traditional lakes and ponds. The availability of pipe-lined water supply in the urban areas are sourced mostly at large dams, has reduced the utilization and value of lakes, Led to poor maintenance of the lakes, ultimately became sites for dumping waste in the urban area. The unplanned sprawl of the city and loss of lakes has resulted in many problems like urban floods, urban heat island and depletion of ground water. The few existing lakes became dry, polluted by making the situation severe. In terms of strategic planning, findings from this observation can be used in creating a self sufficient Eco friendly sustainable urban development which can prevent the further transformation of lakes. Thus by giving prime importance to improve the overall geography of lakes, the solution to water scarcity problem can be solved.

Key words: *Lakes transformation, unplanned city, loss of ecology, Hydrological Drought.*

Introduction

Bangalore, the city growing fastest in Asia, fifth largest city, in India, has a decade population growth of 39% (with 87,49,944 populations as per 2011 census. Source: census of India). The average annual total rainfall is about 931 mm with about 60 rainy days (Source: Indian Meteorological Department). The city enjoys a pleasant climate throughout the year. Its 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. Bangalore enjoys a salubrious climate all round the year as the summer temperature ranges from 18° C to 38° C during the winter temperature ranges from 12° C to 25° C (Santosh Kr. Singh., 2009, Sudhira et al., 2007). Settlements around the city have a recorded history that dates at least as far back as the fifth century. Urban settlements made their first appearance only in the sixteenth century by establishing Bangalore as the capital of the local king Kempe Gowda's kingdom (Harini Nagendra, 2010, Jumbe Aboud and Nandini, 2010).

Local people maintained the lakes as the common property and each one of them enjoyed its resources. Structure of lakes depended on the need for water, available rainfall, catchment area and material used for construction. Lakes have formed by constructing dams along the natural valley system. Height of dams depended on the material used for construction. Dams constructed up to 3 metres height with of earthwork. Stone embedded earthwork dams have constructed for heights from 3 to 8 metres, and dams above 8 metres of height were masonry constructions. Depth and area of the lakes were proportional to the

slope of the region. Eastern Bangalore has a gentle slope in this region the lakes are shallower and larger whereas in the western side of Bangalore because of the steep slope lakes are deeper and smaller.

Human settlements established after construction of tanks in the non perennial river, undulating topography. 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 agricultural activities 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 development, population growth, urbanization 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 (Herold et al., 2003, Liu and Lathrop, 2002, Mahdi Sabet Sarvestani et al., 2011, Mehdi Fazelbeygi and Gholamreza Yavari, 2013). Some of the problems associated with urban expansion include climate change (Grimm et al., 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 and Sabet Sarvestani, 2009, Mahdi Sabet Sarvestani et al., 2011).

Bangalore's new phase of urbanization witnessed its dawn with India's gaining independence and the unification of the cantonment with the old city (Malini, 1988). Post 1957, the government embarked on a state led industrialization, emphasizing on heavy industrial growth. Increased the migratory population and thereby the need for land. Industrialization led to alternate employment, and reduced the dependency on agriculture and tanks, resulting in negligence and encroachment of tanks, leading to the scarcity of water (Ramesh and Krishnaiah, 2013). Bangalore's inorganic growth constantly caused its urban areas to merge with the peripheral rural fringes, engulfing the existing water-bodies and settlements, as urban villages (Fathima and Rajesh, 2012). Loss of lakes and vegetation has caused urban heat islands (Ramachandra and Uttam Kumar, 2013).

Groundwater is not a sustainable resource anymore. It is susceptible to the vagaries of rainfall. It needs to be considered only as a stand-by 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 and Subash Chandra, 2012). Long term discharge of untreated domestic and industrial waste waters, storm water runoff, accidental spills and direct solid waste dumping influenced the urban aquatic ecosystems (Harini Nagendra, 2010). 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 et al., 2012, Upadhyay et al., 2010). Lakes are the dynamic ecosystem having complex interrelationship of hydrology, soil and vegetation. Sewage drains completely eutrophicated the lakes, and weeds like hycarnia species and Buffalo Grasses grow up here. Dry lands are the category where there is the marked absence of vegetation and moisture, termed as open lands, which are very vulnerable for convenient occupation of human inhabitants (Priya Narayanan and Ashok, 2009).

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

Objective

The objective of the study is to create a lake database, account the loss of water bodies (lakes) within the city limits (Bruhat Bangalore Mahanagara Palike), categorise their spatiotemporal transformation, classification of the lakes based on different criteria, using visual image interpretation techniques.

Materials

Survey of India Bangalore guide map surveyed during 1960. Survey of India (SOI) topographic maps of 1:25,000 (surveyed during 1973-74). Survey of India Bangalore guide map (surveyed during 1979 and 1999). Survey of India (SOI) topographic maps of 1:50,000 (surveyed during 1998-2000). Latest cartographic satellite imagery from Bhuvan has used in generating base layers and data collected with a handheld GPS during field visits. Many associated problems exist with spatial, social data; their availability is not uniform globally and often unavailable in developing countries. Spatial, social data may be classified or available only through private or restricted government sources; they have poor temporal accuracy and consistency, and they often contain the wrong thematic representations for objective urban analysis. Research has explored using remote sensing in concert with other sources can be used to develop urban land use change models (Acevedo et al., 1996, Herold et al., 2003, Meaille and Wald, 1990). Remote sensing techniques is an established method in mapping urban areas, and as data sources for the analysis and modelling of urban growth and land use change (Beighley et al., 2009, Clarke et al., 2002, Donnay et al., 2001, Herold et al., 2001, Martin Herold et al., 2003, Jensen and Cowen, 1999).

Methodology

Visual interpretation techniques make use of the excellent ability, of the human mind to evaluate spatial patterns in the image. The ability to make subjective judgments based on selective image elements is essential in many interpretation efforts. However, visual interpretation techniques have certain disadvantages, in that operator require extensive training and are labour intensive. In addition, spectral characteristics are not always fully evaluated in visual interpretation efforts. Because of partial, limited ability of the eye to discern tonal values of the image and the difficulty for an interpreter to simultaneously and analyse numerous spectral images (Lillesand and Kiefer, 2002, Sudheer and Panda, 2000). The image interpretation has done manually to create a lake database by using the cartographic satellite imagery available from the Bhuvan website. 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 coordinate system of UTM projection in world geodetic system 1984 datum. Accuracy assessment has made with field visits and revering Google Earth (<http://earth.google.com>). Latest cartographic satellite image available on Bhuvan website has used to create a lake

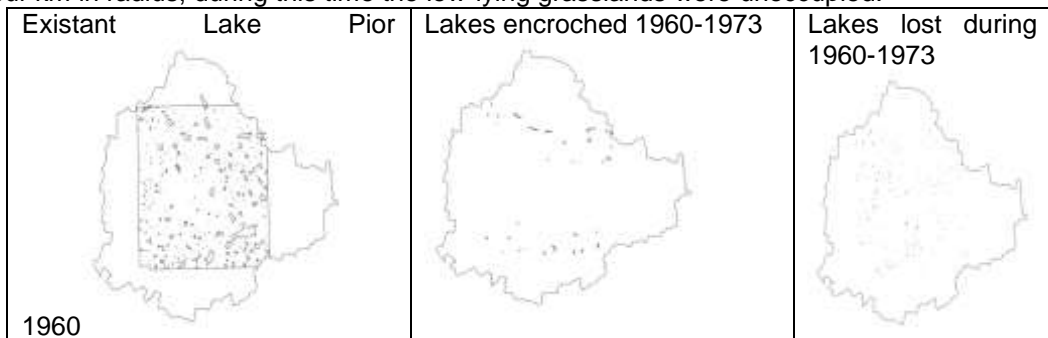
database of 2012 by applying the visual interpretation technique. The lake database of 2012 has compared to the lake databases generated from the survey of India guide and topographical maps. Overlay analysis used to determine spatial differences. The lakes have classified on the basis catchment area. Accounting lake transformations by identifying the structures present in existing place of lost lakes. Calculation of lake encroachments by overlay analysis for different temporal data.

Results

Phase 1 transformation from 1960-1973

Man could not survive without nature, and nature could not escape the influence of humankind (Lee and Heaney, 2003). 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 this period the Bangalore city becomes the capital of Karnataka and administrative buildings established 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 main 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 of perishable goods has met by the marginal agricultural fields in the Bangalore city. Agricultural fields, the vegetable gardens and the number of lakes formed as 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 km in radius, during this time the low-lying grasslands were unoccupied.



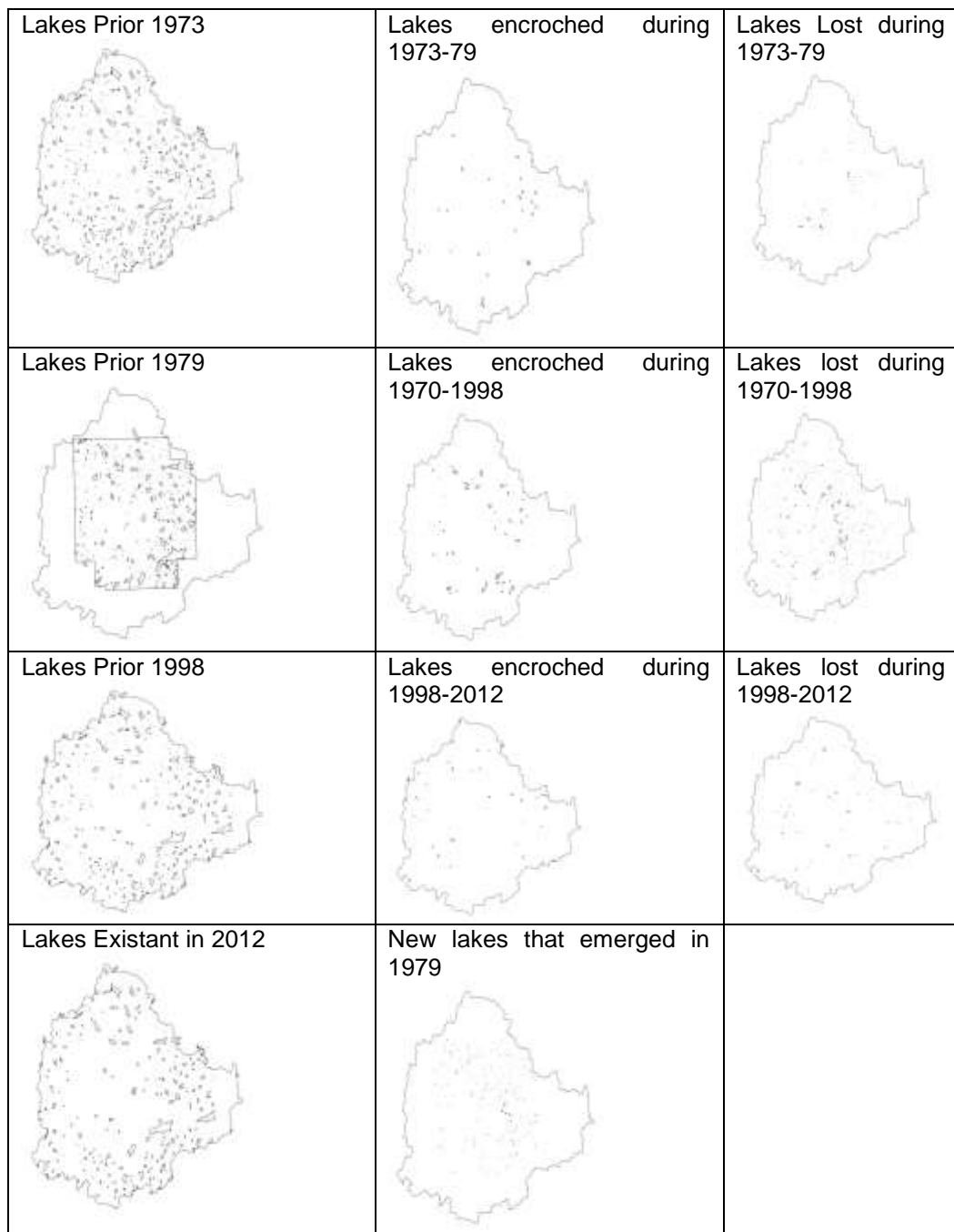


Figure 1. Transformation of Lakes from 1960-2012

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

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

Phase 2 transformations from 1973-1979

During this period, 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. Many people migrated to work 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. During this period, the development resembled Von Thunen model of agricultural land use theory (Robert et al., 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.

Phase 3 transformations from 1979-1998

During this period, 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 fuel wood 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 from agriculture, domestic and industrial fields commenced. During this period, a comprehensive city development plan has implemented, and regions of green belt and yellow belts have identified for non 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 made the nearby lakes and open wells dry. Dry lakes have transformed to 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.

Phase 4 transformations from 1998-2012

During this period 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 establish 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.

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 organization 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 lakes. Three lakes have leased out to develop and operate to private companies, but the act has subsequently criticized for leasing 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 Caluvas) have restored.

Loss of forest affected the traditional brick industries, which used to de silt 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 urbanization 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 built by ancestors in this undulating topography. Lakes still exists even after many of their transformation. Around fifty seven lakes with 8% of lakes area have become completely dry, affecting the agricultural activities. Lakes became dry due to loss of connecting storm water drains, over exploitation of ground water in these areas, reduced capacity to store rain water due to siltation, increased recharge and evapotranspiration. Many such lost dry lakes pose a threat of flooding in low lying areas, recharge of ground water, stabilizing microclimate. Approximately one hundred seventy four 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 have 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 de silting, 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 divided 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 heavy 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.

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 in the impervious surfaces also damaged the dams of the lakes.

Table 3. Classification based on Catchment areas:

	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

Discussions

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, April 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 makes people understand the use of lakes and can bring awareness about the importance of lakes in urban life, are achieved through a series of public awareness programs. Lack of maintenance of lakes took place when the rights of common property resources have been taken over by 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 modifications have seen in a decrease of forested stream buffer and wetland areas that provide capacity for retention and purification (Robert et al., 1925). 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 (Mackinder, 1904, Batty and Howes, 2001, Limin Yang et al., 2003). Rain water 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.

Space for civic amenities must be reserved in all the new layouts. Banning of piecemeal development of small residential layouts as it is a threat to sustainable growth, and the Government should take the responsibility of developing the residential layouts. 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 the lake can be fetched by clean water. Supporting technological innovations to reduce the runoff and increase the infiltration should be encouraged. Adoption of water conservation policies in all spheres is must for Bangalore. Appreciation of more innovative and practical use of treated water. Development

of other middle order towns reduces the force per unit area along the existing crowded city of Bangalore.

Conclusion

Understanding multidimensional utilities of lakes helps in conservation of all the dry lakes to as they have the high ground recharging capacity. Encouragements of recreational activities around the lakes like pedal boating and other water sports. 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 ground water recharge apart from stabilising the micro climate of urban regions and reducing floods in low-lying areas.

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