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EDITORIAL

Water Stress in Bengaluru, Silicon City

Subhajyoti Das
Geological Society of India, Bengaluru - 560 085, India
E-mail: *subhajyoti_das@hotmail.com*

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A City in Grip of Water Drought

Bengaluru is witnessing an unprecedented water crisis with the citizens struggling to get water for their basic needs. This drought like situation has affected industries, schools, fire departments, apartments, hotels, agriculture, forests, wildlife reserves which according to a report in Indian Express is "Cape Town like situation". The normal water supply system is already crumbling in several parts of the city, borewells going dry, reservoir levels plummeting, no rainclouds in sight with El Nino persisting, as the Bengalureans are bracing for a stressful water future, if not famine. Bangalore Water Supply and Sewerage Board (BWSSB) is pulling all its strings of governance, mustering all available resources. It has come up with plethora of measures like cut in water supplies, prohibiting drilling, desiltation and filling of lakes, tanks with treated wastewaters, capping tanker water price, fixing aeretors on taps, banning use of potable water for non-potable activities, etc., to enforce water conservation in the society. It is high time for the authority and citizenry to have an introspection into the city's water infrastructure and governance, – what went wrong with this burgeoning city, the IT capital of India? The following is a developing story of a fast-growing Metropolitan City in the grip of water crisis, – the city of Bengaluru, – from genesis and nature of its water crisis to its search for an enduring solution, groping for an end to its misery.

Water: Soul of the City

Our constitution has recognised "water" as a basic human right. UN's Millennium Development Goals and Sustainable Development Goals have highlighted its crucial role in development and growth of humanity. The urban water cycle includes stormwater, lake water, river water, groundwater and recycled waste waters. Since its foundation in 1876 Bangalore's primary sources of water supplies had been its lakes, and water bodies followed later by other schemes from the Arkavathy and Cauvery to meet the needs of the growing population. Groundwater constitutes a supplementary source. Management and governance of urban water cycle is cry of the day.

Lakes and water bodies: The city is situated on the divide between the Cauvery and Pennar basins with about 60% of the area lying within the Cauvery basin. The topography is defined by a series of valleys radiating from the ridges on the north of the city hosting innumerable cascading lakes (Fig.1). These lakes, which were the main source of freshwater for the city in the first half of the last century, have mostly vanished or dried up due to the onslaught of urban development. and degradation of their catchment, – removal of green cover, encroachment of land, discharge of untreated sewage, sand mining and breaching of lakes. The Brihat Bengaluru Mahanagara Palike (BBMP, 2011) catalogued 198 lakes within its jurisdiction, but only 88 contain clear water, 44 are polluted, 34 dried up, 21 in different stages of degradation, the rest are filled with garbage or building materials. Land use analysis in Bangalore City shows increase in urban (built-up) area from 8.0% in 1973 to 78% in 2017 with a decline of 88% tree cover and 79% water bodies. Predictably by now the landscape is almost on the verge of saturation (Ramchandra, *JGSI*, 2018, p.260).

Cauvery and Arkavathy: Since 1960s BWSSB has commissioned several schemes, Cauvery Stage I to Stage IV, to meet growing water demands of the population. The total availability of freshwater supply from Cauvery sources stands at 1450 MLD sans Hesarghatta and T.G. Halli schemes (dried up or defunct). With tremendous transmission losses (nearly 42-43%) water supplies fall far short of the water requirement of 1.2 crore population of this city (140 MLD per capita per day), Cauvery Stage V after implementation is likely to bring 775 MLD. With the projected population of 1.3-1.6 crore in the coming decades, say by 2050 the Cauvery sources alone will be totally unsustainable for city's future water needs with improved lifestyle of modern city. The shortage in water supply is rather significant (Fig.2).

Groundwater: Though a supplementary source to meet the shortfall of water supplies it is overstressed. Institute of Social and Economic Changes (ISEC) informs 52 to 85% dependence on groundwater in different wards of Bengaluru (Manasi, *JGSI*, v81, p596). The hydro-geological set-up dominated by weathered and fractured Peninsular gneisses with a patch of Closepet granite comprises three aquifer zones, <25 m & 25-60m depth, tapped by dug wells, and bore wells (yield <2lps) and a deep zone (>60m depth) tapped by bore wells (yield 2-6lps). The depth to water level is comparatively shallow in the core area compared to the peripheral area where it is deep. Aquifers are mostly dry down to 240m depth due to overexploitation resulting in steep decline of groundwater level (Fig.3). As per BWSSB 600 MLD is drawn from its 6332 borewells, but ISEC reports draft of 746 MLD from 3.26 lakh borewells, while any reliable enumeration of private borewells is lacking. Reportedly 6000 borewells are dry. Reduction of recharge due to weeding out of lakes and drainage lines has further contributed to its overexploitation. As per CGWB (2023) the stage of groundwater development in Bangalore is 102 -225%.

Water quality: Though generally of potable quality, sewage pollution is seen in the western part of the city where all the sewage water is let into Vrishbhavati river valley and most of the tanks are polluted. In the Industrial belt of Peenya, Kanakpura Road, Rajajinagar, and Hoskote areas, alarming levels of nitrate (up to 554mg/L) , fluoride

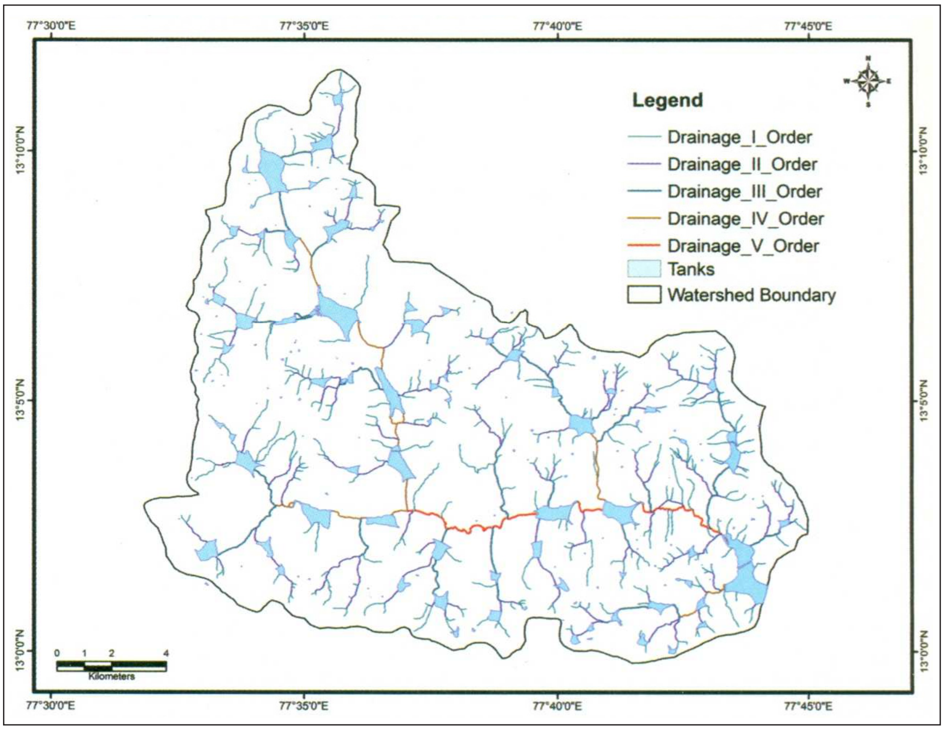


Fig.1. Drainage and water bodies in Yele Malappa Shetty watershed (Mem 79, GSI, p193).

(up to 5.3mg/L) and chromium (up to 17mg/L) in groundwater pose health hazards. Also 88% water samples in the city show presence of coliforms due to bacterial contamination. (CGWB, Geology and Mines Department, Pollution Control Boards) .

In short, the city's water crisis owes to: (1) Weeding out of lakes and water bodies. (2) Insufficient supply from Cauvery due to leakage or Unaccounted Flow of Water (UFW) in transmission lines. (3) Overexploitation and drying up of borewells. (4) Pollution of water mainly due to sewage and industrial wastes. Incidentally, BWSSB tries to cope with the shortage through interrupted water supply. Hence water conservation, and augmentation of water supplies from other available sources is the utmost need of the hour (Fig.2).

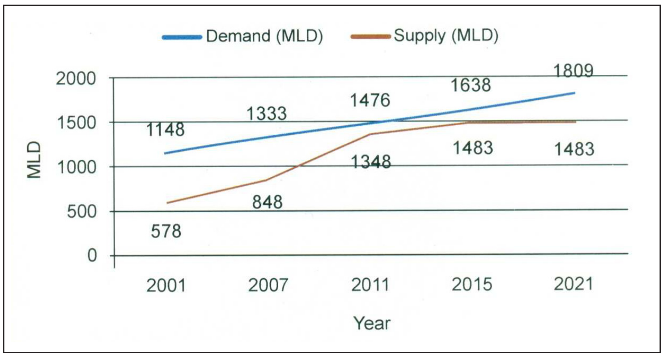


Fig.2. Water supply and Demand in Bengaluru (Mallick and Vasudevan, 2008, Mem 79, p53).

Water Conservation and Augmentation: S&T Innovations.

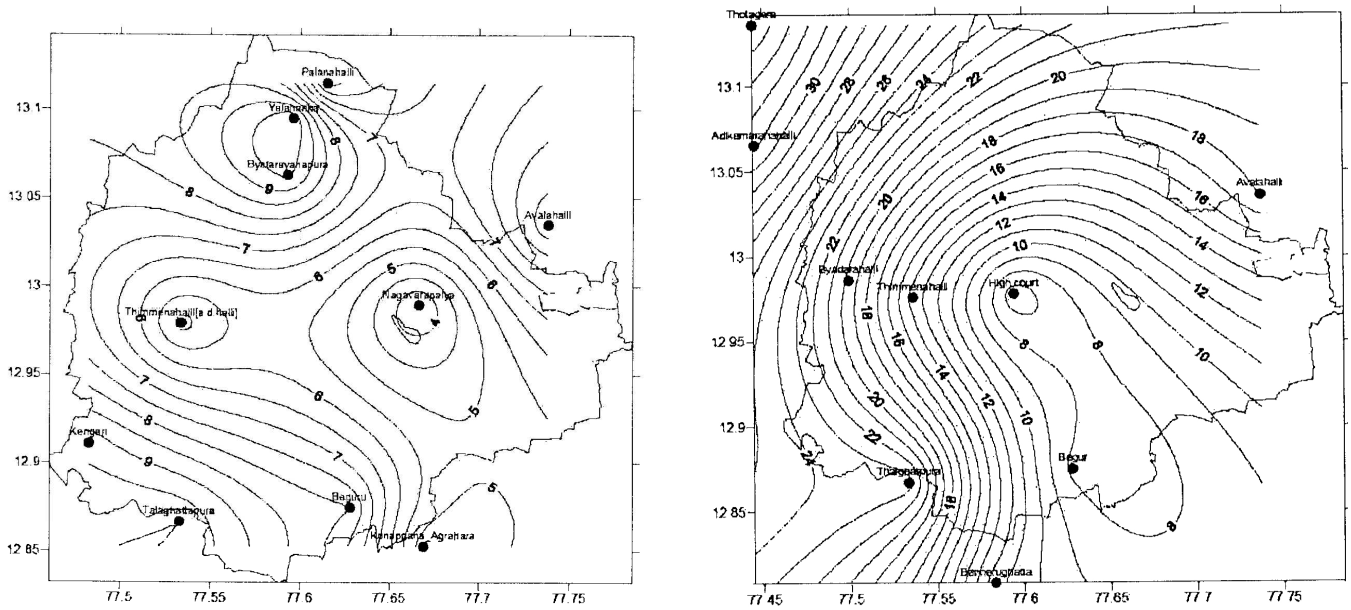
All the elements of the urban water cycle and ecosystem like rains, lakes, rivers, groundwater, forests, landuse, vegetation are interrelated and have strong interactions between them. Hence, "its effective management requires interdisciplinary approach with an integrated vision" (Ravishankar, Sp. Pub. 5, 2016, p.45). In other words it is an integrated approach to manage the entire water cycle starting from source, catchment area, surface and groundwater to various uses and treatment processes. The following are some endeavours of scientists and NGOs in finding sustainable solutions to the water crisis.

Rejuvenation of Lakes, Water Bodies and Arkavathy Basin

Prof. N. Nandini (Bangalore University) and Dr. Yeleppa Reddy, Environmentalist carried out extensive studies on degraded lakes of Bangalore for their restoration (Mem 79, GSI, 2011). Studies suggested a multilateral approach to the problem including catchment treatment, desiltation, afforestation, drainage improvement, prohibiting sand mining, rainwater harvesting, stoppage of untreated sewage disposal, and prohibiting use of lake beds for urban development, filling the dry lakes with treated wastewaters, thereby increasing inflows to the water bodies, and also aiding recharge to groundwater (Fig.4). Accounting and auditing of the existing of the surface water bodies should be undertaken annually by the Minor Irrigation Department regarding the capacity of holding surface water runoff in monsoon, volume of surface water stored for recharge per year and benefits accruing to borewell yields. Mass awareness campaigns should be organised for protection of these surface water bodies.

Topographic advantage should be availed to create more water bodies at different elevations to harvest rainwater and runoff.

Groundwater conservation and protection: While groundwater is recharged from surface water bodies in monsoon, it recharges the surface water bodies in non-monsoon period. It has an important role in the water cycle. It needs to be protected by law which calls for precise estimation of annual groundwater recharge and draft, and hence enumeration of the number of borewells in the city and metering of borewells as there is no reliable estimate of groundwater withdrawal. Another important step is ward-wise microlevel surveys, and preparation of ward-wise water atlases with free access to all stakeholders (Radhakrishna, *JGSI*, v65, 2005, p.387). Further, ward-wise monitoring of rainfall through telemetric rain gauges will enable to realistically compute the runoff and infiltration factors for realistic estimation of rainwater, groundwater, surface water resources of the



*DTW contours in meters below ground level

Fig.3. Pre-monsoon Depth to Water level (DTW) Maps of Bengaluru (Left :1974-1975 and Right: 2008-2009) (Murthy, Mem 79, GSI, p110).

city needed for water management. Care should be taken to restrict groundwater draft around the green belt of the city to save tree population.

Rainwater Harvesting (RWH) and Artificial Recharge: The city receives 970 mm of rainfall in a year generating 473 MCM of runoff or 1296 MLD which may be harvested (Ramasesha, Mem 79, GSI, 2011). and used for recharging stressed groundwater, for domestic uses, as also for reducing water scarcity and flash floods. The common RWH structures include percolation tanks/ponds, checkdams (CD), open lands, parks, storage tanks, perforated pavements. Hydrogeological investigation is a prerequisite for groundwater recharge. Further, close-net telemetry monitoring of rainfall and weather forecasts over the city will enable harvesting runoff at suitable sites. Roof Top Rainwater harvesting is another innovative technique of capturing rainwater falling on the terrace which can be collected through pipelines/drains and stored in a storage tank for direct use or diverted into a well for groundwater recharge. This has been illustrated by Demonstrative RWH and Roof Top Rainwater Harvesting Schemes in the city (Fig.5a & b) (Farooqi, Suryanarayana, Mem 69, 2008; Mem 79, 2011). The onus is on the architects, engineers and planners to integrate rainwater harvesting systems in building designs, landscapes and neighbourhoods (Viswanath, Mem 69, 2008).

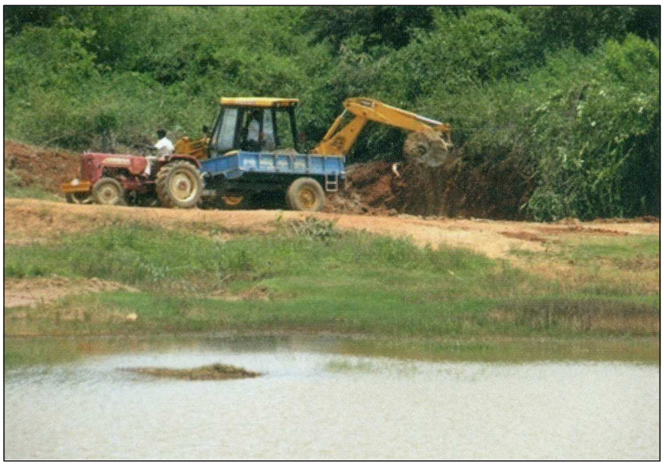


Fig.4. Sand mining in Kenchenpura lake bed.

Arkavathy, a tributary of the Cauvery, has 1775 water bodies in its basin, and 3 big reservoirs, Hesaraghatta, Chamrajasagar and Biramangala, but in a decadent state. Prof. Renukaprasad & others (Bangalore University) presented a work plan (Mem. 79, GSI) for restoration of Arkavathy basin, through rainwater harvesting and artificial recharge in its catchment. An integrated approach was adopted to delineate zones of artificial recharge using thematic maps as generated by Remote Sensing, in conjunction with hydrogeological parameters with the help pf GIS. After integrating, the thematic layers as Poor, Moderate, Good, Very good and Excellent zones for artificial recharge were derived and an action plan was prepared (Fig.6). The recharge structures, namely 3618 check dams (CD), 216 percolation tanks (PT), 1321 point recharge structures (PRS), were decided on the basis of hydrogeological properties. These artificial recharge structures along with 6650 dry dug wells, 1574 dry bore wells, 710 tiny water bodies, 86 Minor Irrigation Tanks and rooftop rainwater harvesting (60 sq.m) may be used for artificial recharge to the tune of 328.2 MCM annually, effecting a rise of 3 - 5 m of groundwater table.

Wastewaters Treatment & Recycling: About 70% of water supplied for domestic consumption comes back as wastewaters which can be put back in natural cycle with proper treatment to primarily cater to the non-potable usage in big housing complexes, industries, commercial buildings or even in gardening and car washing thus reducing the demand for freshwater. Everyday 1440 MLD of sewage

Fig.5. (a) RWH structure in Gyan Bharati Campus. **(b)** Roof Top Rain Water Harvesting in Bengaluru

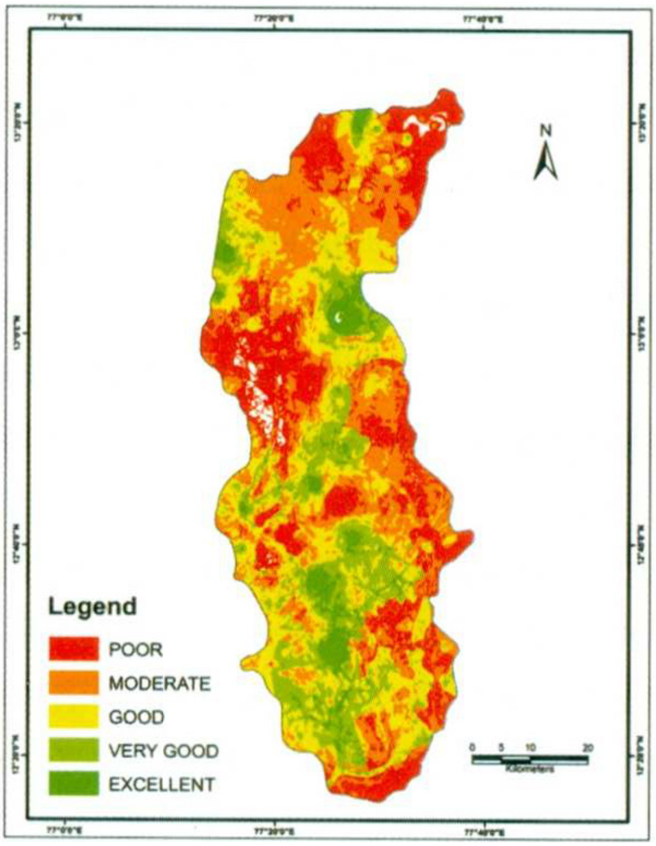


Fig.6. Artificial Recharge Zones in Arkavathy basin (Renuka Prasad, Mem 79, p.207).

is generated in the city. Following Master Plans of BBMP, BWSSB, and LDA/BDA Y.D. Manmohan of STUP Consultants Pvt. Ltd, planned to restore drainage network of the city, segregating storm runoff from sewage by remodelling storm water drains, and rejuvenate the city's water environment through micro-watershed treatment. After segregation, 70% sewage waters may be available for storing in the lakes, as also in surface reservoirs or in aquifers for reuse after treatment. Nearly 500 MLD of storm rainwater will be available as runoff after filling the lakes, which may be stored. (*JGSI*, 2013, p596). He proposed pilot projects in four selected areas, namely Yelahanka, Herohalli, K.R. Puram and Kaikndanahalli, to be followed up in other parts of the city. Success of rejuvenating Jakkur and Marathahalli lakes showed that a substantial part of the sewage waters may be salvaged through decentralised and domestic STPs for reuse. Presently 1220 MLD of wastewater is treated and 750 MLD is reused after treatment. There is need for increasing sewage treatment capacity and tertiary treatment of sewage water for bimodal distribution in the city.

Pollution mitigation: Pollution Control Boards should periodically monitor water quality and proactively enforce adherence to the prescribed standards before use. STPs, Bioremediation, Reverse osmosis and SAT technologies are common methods of remediation of polluted water before use. RWH and Artificial recharge too are cost effective means for remedial treatment of water pollution through dilution.

Civil Society Shows the Way: Integrated Water Management

Water is people's resource. Hence, no conservation measures will be successful without people's wholehearted participation. This necessitates engaging with the community at all stages, training and educating them about the need for water conservation and its techniques.

Rainbow Drive Layout Project: It is a private gated residential layout which has no formal water supply from BWSSB. It was dependent on borewells which were overstressed creating water scarcity. The layout suffered from flash flooding during the rains. Plot Owners Association (POA) worked with the resident community on integrated water management: demand management through education and appropriate tariffs on water, rainwater harvesting and groundwater recharge for flood control and groundwater sustainability, and wastewater treatment and reuse to reduce freshwater demand and ensure responsible discharge of wastewater. Through these measures the layout successfully moved from being dependent on groundwater overdraft to being a source of artificial rainwater recharge in excess of withdrawal (Fig.7). New water tariffs were introduced to cover production costs of water, and incentivize households that do rainwater harvesting, and also for frugal use of water. As part of the project several recharge wells and production borewells were constructed financed by the community or households as also several STPS financed by POA for sewage treatment. (Krishnamurthy, Sp. Pub 5, GSI, 2016, p.64). The success story encourages all urban communities

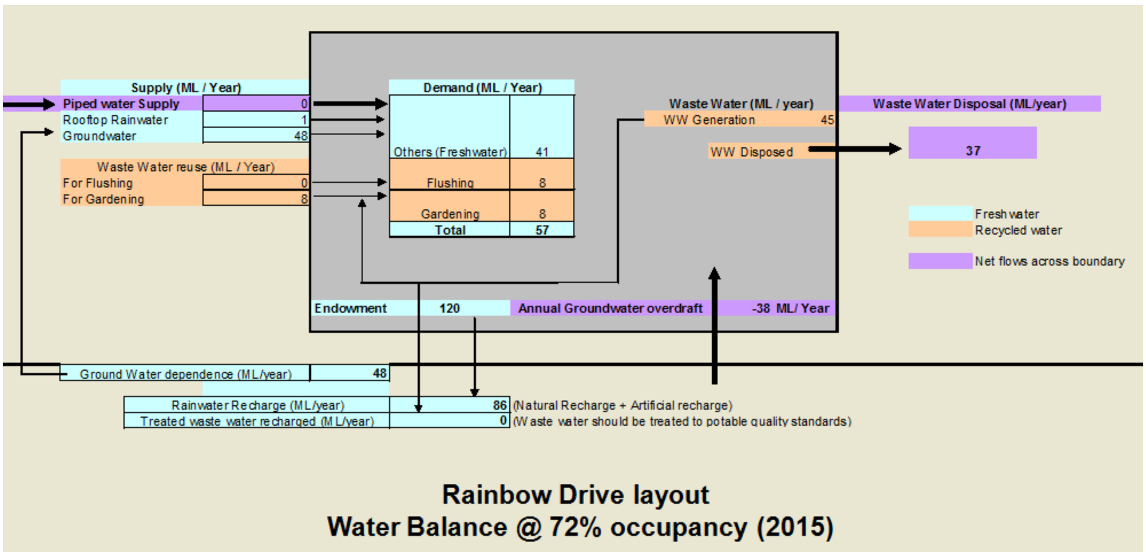


Fig.7. Estimated water balance of Rainbow Drive Layout in 2015 (Sp. Pub. 5, p.65).

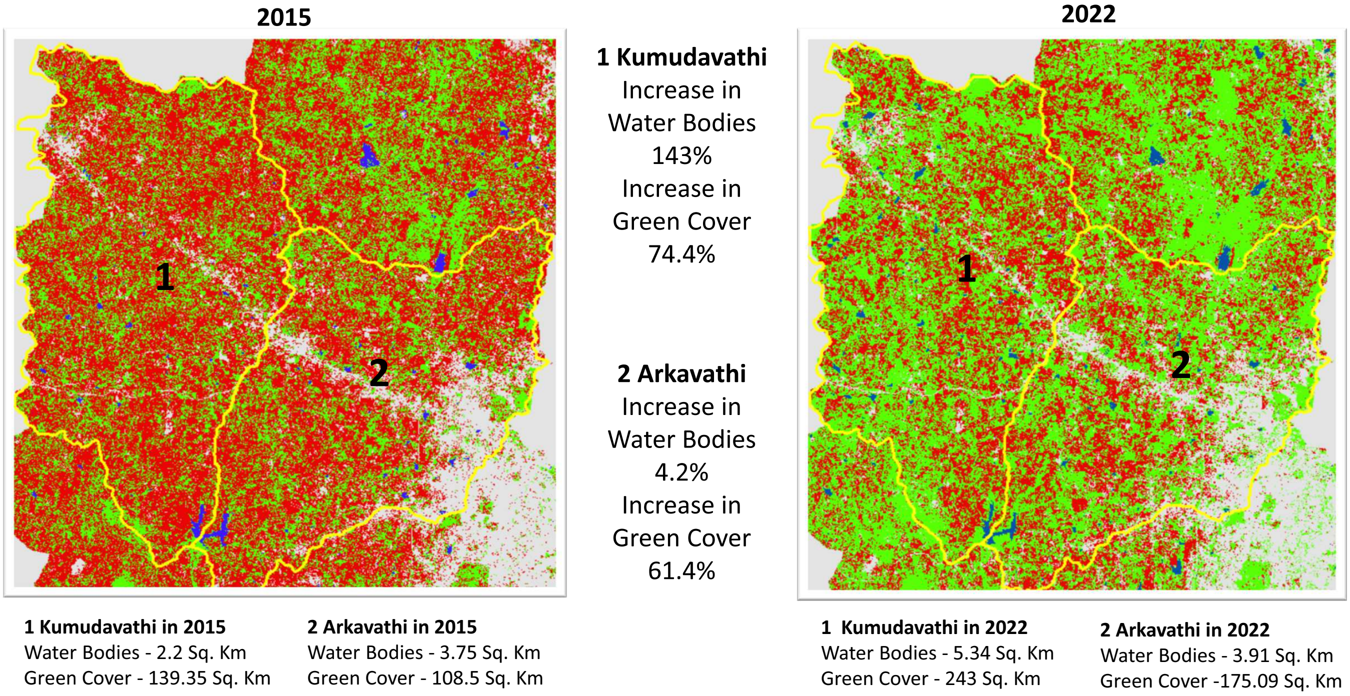


Fig.8. Satellite imageries showing effects of watershed treatment in Kumudvathi (Lingaraju, **pers.commu**).

to emulate this model of integrated water management at decentralized scale.

Kumudvathi Regeneration Project: In 2013, Volunteers of Art of Living (AOL), Bengaluru under the leadership of Dr. Y. Lingaraju launched village level micro-watershed surveys and treatment (jointly with Corporates) for revival of Kumudvathi, a tributary to the Arkavathy, in Nelamangala and Magadi talukas, encompassing 270 villages,. The scheme involved the participation of motivated villagers aiming at regenerating degraded geohydrological processes. and in turn Kumudvathi river. Groundwater recharge structures were constructed along stream network harvesting rainwater during monsoon and recharging the shallow and deep aquifers. The structures included boulder checks 1182, Recharge wells 1115, Recharge borewells 125, Water pools 91, Planting trees 95,000, and Desilting 5 tanks 1,00,000 cubic meters. Over the last 8-9 years it has led to significant rise in groundwater levels and continuous stream flow even after rainfall ceases. It has also contributed to replenishing T.G.Halli reservoir which remained dry for extended period. Satellite imagery processing has revealed notable changes in greenery and expansion of water spread areas contrasting with adjacent watersheds where similar treatments are lacking (Fig. 8, Lingaraju, *pers. commun.*). Similar work is planned in the catchment of Suvarnamukhi reservoir in the peri urban areas of South Bengaluru to ensure drinking water security to 70 villages (source: Art of Living).

Water saving in domestic arena: Wasteful use of tertiary treated e water for gardening, car washing, sanitation etc, should cease. Use of water efficient devices like water efficient taps, toilet fittings is also an important conservation measure. There is much scope of water economy in daily chores, too, such as: Bathing: (Used) Shower 100L / (Needed) Bucket 18L; Washing clothes: (U) Running tap116L/ (N) Bucket 36L; Watering plotted plants: (U) Running tap 100L/ (N) Water can 10L; Car washing (U) Running hose 400L/ Buckets 18L etc.

Water Reforms and Governance: Resuscitating Bengaluru

"Access to water with quality, quantity and equity constitutes a fundamental human right. The states with the participation of the communities shall make efforts at all levels to guarantee this right to their citizens within their respective countries" (4^{th} World Water Forum, Mexico, 2006).

The shortcomings of Bangalore's water supplies failing its citizens in water security can be addressed through reforms of its water management and governance policy. The uncontrolled growth of the city resulting in increasing water demand calls for shifts in planning process of urban development: "Controlled growth and expansion of Bengaluru; Efficient infrastructure and service provision to Bengaluru; Promotion of balanced regional development by diverting Bengaluru's growth to neighbouring growth centres" (Source: Access to Water in Urban Areas: Indo-Frech Experience, French Embassy in India, 2012). The obvious fall out of the unregulated growth is a huge gap between water supplied and consumed. Reportedly 56% of the water supplied is consumed by the citizens. The resultant water tariff reflects heavily on the lower income group which constitutes 70% of the citizens. This combined with intermittent supplies compels them to resort to water tankers at high price and unauthorised tapping of water supply lines resulting in Unaccounted Water Flow/Non Revenue Water and overexploitation of groundwater. Bengaluru is way behind meeting the water accessibility criteria of UN Habitat and UNESCO: security, sufficiency, regularity, accessibility and availability at a reasonable price. Hence is the necessity of reform of urban water infrastructure and efficient management of its available water resources.

Integrated management of all waters (surface water, groundwater, rainwater and treated wastewaters) should be the call of the day. While rejuvenation of lakes and water bodies is a primary necessity, conservation and protection of groundwater playing a stabilising or balancing role in the water cycle are equally important. Hence their protection and conservation by law combined with demand and supply measures, and wholehearted support of the bureaucracy, politicians and consumers are vital. Auditing and budgeting of water bodies, groundwater monitoring, census of borewells, ward-wise microlevel surveys, ward-wise telemetric guaging of rainfall, runoff, infiltration (V.S. Prakash, *pers.commun.*) should be part and parcel of water management. Monitoring, review and proactive guidance form the bedrock of water governance. "New technologies such as modelling and decision support systems should be implemented by water agencies for efficient management of water resources and supply" (Mohankumar, Mem. 79, GSI, 2012).

All these water sector reforms should be brought under a legal frame. For this all the diverse water related institutes should be brought under one regulatory authority, Urban Water Management Institute empowered by law to develop, manage, control and monitor all waters to ensure adequate availability of water to all citizens. People's participation should be central to this multidisciplinary program, - in planning, implementing, monitoring and maintenance including self-financing/community financing of the schemes.

Water Resilient Bengaluru: Future Trajectory

The Geological Society of India has been steadfastly advocating for for water sustainability, equity and security for Bengalureans since '90s of the last millennium through this journal, seminars and workshops. The Panel discussions on this iseue in 2009 and 2012 with the participation of experts from CGWB, GSI, Bangalore University, State Environment Department, Karnataka Pollution Control Board, Karnataka Remote Sensing Cell, State Ground Water Department , Indian Institute of Science, Karnataka Drought Monitoring Cell, BWSSB etc, cast a set of strategic actions covering all aspects of this complex issue (Das, *JGSI*, 2013, v 81,p598). It holds a beacon of light on the road to water secure future.

Summing up, the paradigms of water management are as below

1. Integrated management of Cauvery water, lake water, borewell water, rainwater and recycled wastewaters holding key to the solution of water crisis in Bengaluru.
2. Plugging leakages in transmission lines of Cauvery water supply.
3. Restoration of decaying lakes water bodies, and Arkavathy basin through desiltation, catchment treatment, storing treated wastewaters and harvested rainwater, prohibiting mining in lake beds, and discharge of untreated waste waters.
4. Protection of groundwater by law and artificial recharge combined with Demand and Supply measures.
5. Roof Top Rainwater Harvesting to be enforced vigorously.
6. Rainwater harvesting and recycling of treated wastewaters to make substantial freshwater available for city's need.
7. Adoption of Integrated Water Management model in Rainbow Layout to be encouraged.
8. Ecorestoration model of Kumudvathy watershed needed to be replicated in other parts of the city for improving its hydrology, ecology and environment.
9. Modern management tools like groundwater monitoring, auditing and budgeting of water bodies, ward wise microlevel surveys to prepare water atlases, telemetry monitoring of rainfall and weather forecasts over the city, and digital modelling for generation of hydrological scenarios needed to ensure successful water management.
10. Enhancement of water treatment capacity needed with tertiary treatment of water for domestic use.
11. Pollution Control Boards to vigorously monitor water quality and enforce adherence to prescribed standards.
12. S&T innovations to be encouraged for reviving degraded water systems.
13. Water economy to be practised in all activities including domestic chores.
14. All water related institutes/organisations to be brought under a single regulatory authority empowered by law.
15. People's participation essential in all water management programs from planning , implementation to maintenance and monitoring.
16. Mass awareness about conservation and protection of water to be generated through media campaigns, seminars etc..
17. A data base for all water related information has to be created on website for free access to the public. A common platform may be created where data, skill, knowledge, technology may be shared by all stakeholders and public.

BWSSB has since decided to form a water management task force, a welcome step towards constitution of a regulatory authority, Urban Water Management Institution.

Concluding, "a world class city should efficiently manage its water resources through conservation, optimal utilization, and treatment and recycling of its waste waters, ensuring equity and sustainability for all sections of city dwellers which form the foundation of all round growth of the city (Chiranjeevi Singh, IAS, 2013)".

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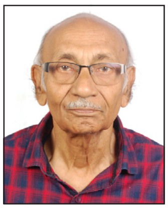

Subhajyoti Das, former Regional Director of Central Ground Water Board, is a versatile hydrogeologist having a rich experience in hydrogeological surveys, exploration, development and management in varied terrains of India. He is a prolific writer, having to his credit 150 research papers in national and international journals, 26 books (edited/authored), 6 book chapters and a significant number of unpublished technical reports.