Strategies to Mitigate Urban Flooding and Build Climate Resilience: Lessons for Indian Cities

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Introduction

One of the recent Intergovernmental Panel on Climate Change (IPCC) reports cautions that India will see increased heat waves and heavy rainfall, while glaciers will melt further, along with more compound events from rising sea-levels like flooding; furthermore, South Asia and India will experience increases in flood frequency or magnitude, and coastal floods that happened once in 50 years are projected to occur around 3 times a year by the end of the century.[1] Indian cities are already prone to floods, and this has become a recurrent phenomenon. On average, every year 7.5 million ha of land are affected, 1,600 lives are lost and the flood damage caused to crops, houses, and public utilities amounts to INR 18,050 million. Major floods occur in India more than once every five years.[2]

In 2005, a cloudburst that gushed 944 mm of rain on the suburbs of Mumbai, the financial capital of India, brought the city to a standstill. The casualty list also included 24,000 animals, with 20,000 cars, 2,500 buses, and more than 100,000 ha of inhabited land suffering damage. The incessant rains lashed the entire state of Maharashtra in 2021 as well. When the coastal city of Chennai was struck by torrential rains in 2015, the death toll exceeded 280. The city battled huge economic losses.[3] Chennai also witnessed a cloud burst and very intense rains in 2021. The unprecedented extremely heavy rainfall of over 200 mm within a span of seven hours paralysed the city on December 30, 2021.[4]

Many of the underlying issues for urban floods in India are emerging due to conversion of water bodies and wetlands to the concrete jungle. The reasons for such conversion are numerous: urbanisation, a poorly managed stormwater drainage network, encroachments on catchment areas, poor or lost interconnectivity between lakes, occupation of low-lying areas, and, most importantly, constantly changing climate. Hence, the key question is: What can be done effectively yet innovatively to manage abovementioned concerns? This study identifies suitable strategies for Indian cities to handle urban floods and battle climate change.

[1] Pörtner et al. eds., *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.*

[2] National Disaster Management Authority, Government of India, "Floods."

[3] Nai and Janardhanan, "A tale of two cities."

[4] ABP New Bureau, "Chennai Rains 2021."

Sponge City: An innovative concept for water management

[5] World Future Council, "Sponge Cities: What is it all about?"

[6] Tomorrow's build, "China is Building Sponge Cities to Fix Its Flood Problem."

[7] Turenscape Landscape Architecture, "Yanweizhou Park in Jinhua City."

Many global cities have adopted innovative initiatives to mitigate climate change and manage urban floods, including wetland restoration in the American Midwest, flushing systems using collected rooftop water in Oregon USA, bioswales in Singapore, and public spaces as flexible water retention facilities in the Netherlands. Most recently, the concept of 'sponge city' has gained much importance. As the word implies, a 'sponge' absorbs rainwater and releases it as and when required instead of draining it away. The stored water is then naturally filtered by the soil and allowed to reach urban aquifers. This concept aims to reuse about 70 percent of the rainwater. This is a nature-based solution that solves the woes of urban flooding and can store water during the dry season. A sponge city needs to be amply provided with spaces that allow water to seep through them. Instead of only impermeable concrete and asphalt, the city needs more contiguous open green spaces, interconnected waterways, channels and ponds, green roofs and porous design interventions across the city.[5] To mitigate urban floods, the Chinese Government has chosen thirty urban areas as pilots for the implementation of innovative water management strategies that would gradually transform them into 'sponge cities':[6]

- In Lingang, the largest planned sponge park in Shanghai's Pudong district, many roads have been renovated and concrete sidewalks replaced with water-absorbent bricks allowing water to drain into the soil, while central reservations have been filled with soil and water for use as rain gardens.
- Wuhan, a city on the Yangtze River, experienced massive flooding in 2016, so the city took several measures to improve its design including the improvement of Xinyuexie Park, which has been extensively transformed from a drainage ditch to a green space with rain gardens, permeable pavements, and storage ponds for stormwater drainage.
- Chongqing, one of the first sponge cities, has an embedded stormwater control system to allow officials to monitor their sewer and stormwater drainage networks and help authorities mitigate the risk of flooding in the future.
- A new park in the Tongan district developed in 2020 would help recover from floods/storms for the next hundred years as is has been constructed on wetlands built over 99 hectares that boast an impressive network of native plants, trees, ponds, islands, and elevated walkways, making the park more than a place to drain away excessive waters.
- To mitigate flooding, the Yanweizhou project used a cut-and-fill strategy to balance earthwork by creating a water-resilient terraced river embankment covered with flood-adapted native vegetation, hence showcasing a replicable and resilient ecological solution to large-scale flood management.[7]

Chennai: Towards nature-based interventions?

One of the largest metropolises in India has traditionally numerous water bodies (Figure 1). According to a recent study by the Greater Chennai Corporation, the area covered by water bodies in the city and its suburbs had shrunk from nearly

12.6 sqkm in 1893 to about 3.2 sqkm in 2017, mainly due to urbanisation. The 1893 map indicates the presence of a crescent-shaped body of water stretching from present-day CIT Nagar to Teynampet and the Gemini Flyover, on to Nungambakkam, and along what was then Mount Road. The water bodies, namely Mylapore and Nungambakkam Tanks, covered a distance of nearly 7 km. Lake Vysarpadi, Perambur Tank, Medavakkam Tank, and Spur Tank, were some of the large water bodies replaced by buildings after the 1950s. While Nandanam was along the lakefront, the site of the present-day CIT Colony was occupied by a body of water in the 1950s. Kilpauk also had large water bodies.[8] The development of several residential neighbourhoods surrounding the lake has curtailed the natural hydrological flow of water over the past decades. Most of these locations were identified as flooding zones in the recent floods of 2015 and 2021.

[8] Chennai Smart City Limited, "Chennai: good old days."

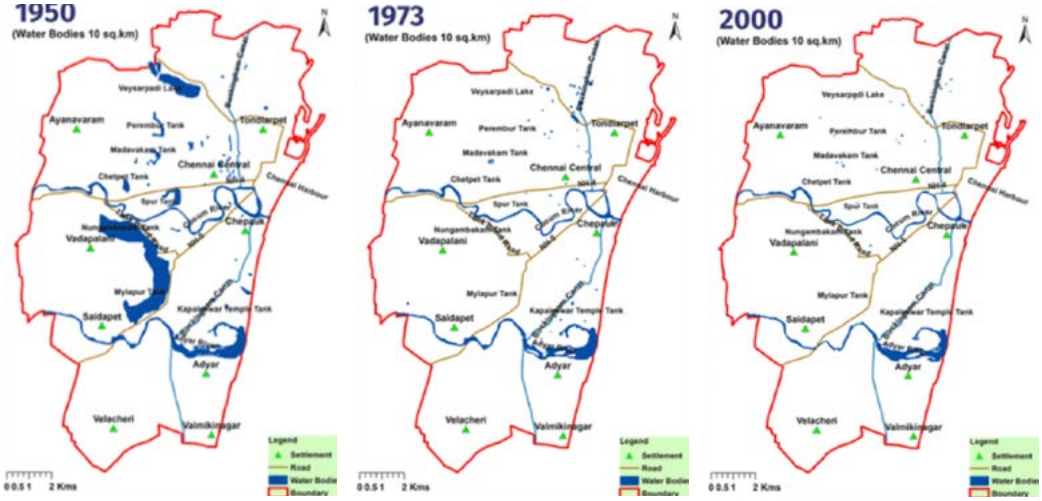


Figure 1 : Disappearance of water bodies in Chennai over the decades. © Chennai Smart City Limited

Another challenging part of the city is its topography (Figure 2). Chennai has a flat terrain and is very close to sea level. Being completely urbanised and located on this flat site, it is very vulnerable to floods, whilst growing urbanisation in the southern suburbs of the city worsens the initial conditions.

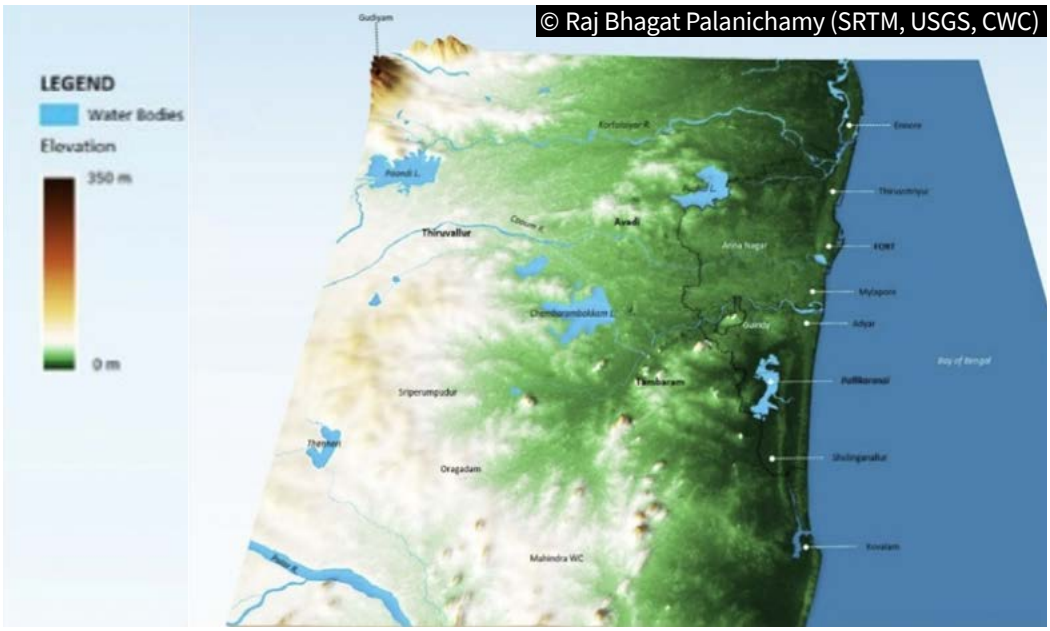


Figure 2 : Topography of Chennai.

Smart City Mission in Chennai

[9] Chennai Smart City Limited, "Restoration of Water Bodies – Transforming Chennai."

[10] Ibid.

Through nationally funded schemes, Indian cities have taken up several initiatives to mitigate flooding. One such initiative is restoration of water bodies. Through its Smart City Mission, the urban local body Greater Chennai Corporation has identified 210 water bodies across 15 zones in its jurisdiction for rejuvenation. Of these, 32 have been restored and 57 more are expected to be rehabilitated.[9] The devastating floods that struck the City of Chennai in 2015, followed by severe drought in 2017, have brought together the public in a collective effort to help restore and rehabilitate the city's water bodies. Restoration works have already been initiated in many of the lakes and ponds and many have been successfully implemented in 2018 and 2019. These water bodies range from 0.1 to 19 ha in area. The restoration plan broadly includes:

- In-situ cleaning measures such as desilting and weed clearance
- Increasing overall storage capacity and thereby improving ground water recharge
- Strengthening of embankment, lake fencing, and shoreline development
- Public awareness and active public participation through focused events
- Prevention of pollution from non-point sources by providing low-cost sanitation
- Development of walking trails with native plantations on both sides has been proposed around ponds to improve connection between nature and human beings

Madipakkam Lake

Madipakkam Lake (Figure 3) is surrounded by residential suburbs of the Chennai Metropolitan Area (CMA), such as Puzhuthivakkam, Kilkattalai, Ram Nagar, and Velachery, and is well connected with transportation facilities.[10] Madipakkam Lake is surrounded by residential areas. Numerous settlements have sprouted along the northern, southern and eastern shores of the lake. The area of the lake is around 45 acres. The Lake View Road on the western side has been provided with a walker's pathway along the lake boundary, creating a beautiful stretch of recreational grounds along the western side. Besides walking paths, supply and surplus channels have been strengthened to prevent any further flooding.

Figure 3 : Madipakkam Lake, before and after restoration. © Google Earth Pro

Puduchery Keni

Puduchery Keni (Figure 4) is located in Sholinganallur, a predominantly residential area in South Chennai surrounded by mixed-use and primarily residential areas. Puduchery Keni is both a local catchment and an intercepted catchment area. The main source of water supply to the reservoir is from its own catchment. At present, water flows through a culvert constructed across the embankment in the western side of the lake. The pond has been restored using Chennai Smart City project funds, and works have included desilting, provision of walkways along the embankment construction of a supply channel for letting water from nearby residential areas, etc.

[11] Chennai Rivers Restoration Trust, "Cooum River Restoration."

Figure 4 : Puduchery Keni, before and after restoration. © Google Earth Pro

Cooum River

The Government of Tamil Nādu began integrated restoration of Cooum River after the devastating floods of 2015. The river runs east for about 65 km and flows into the Bay of Bengal downstream of Napier Bridge, traversing 20 km within Chennai city limits.[11] Being one of the city's major rivers, it acts as the major flood carrier for Chennai City. When it enters the city, the river is essentially an urban sewer receiving municipal and industrial wastewater and solid waste (especially near bridges) and refuse from slums. Multiple stakeholders are involved in this project, mainly to improve the flood carrying capacity of the river and prevent further pollution. Many stretches of the river in the Cooum basin have undergone interventions, such as removal of encroachments, canal widening, strengthening of embankment, solid waste removal, fencing, and desilting (Figure 5). This alone has largely prevented residential areas from being inundated during the recent floods of 2021.

Coimbatore: Smart City

In Smart City flagship lake-restoration project (Figure 6), Coimbatore, the second-largest metropolis in Tamil Nadu after Chennai, aims at the regeneration of lakes. The goal of the eight-lake project, which covers Kurichi, Krishnampathi, Valankulam, Selvampathy, Kumaraswamy, Selva Chinthamanikulam, and Periyakulamunder

[12] Natarajan et al., "Case Study and Analysis."

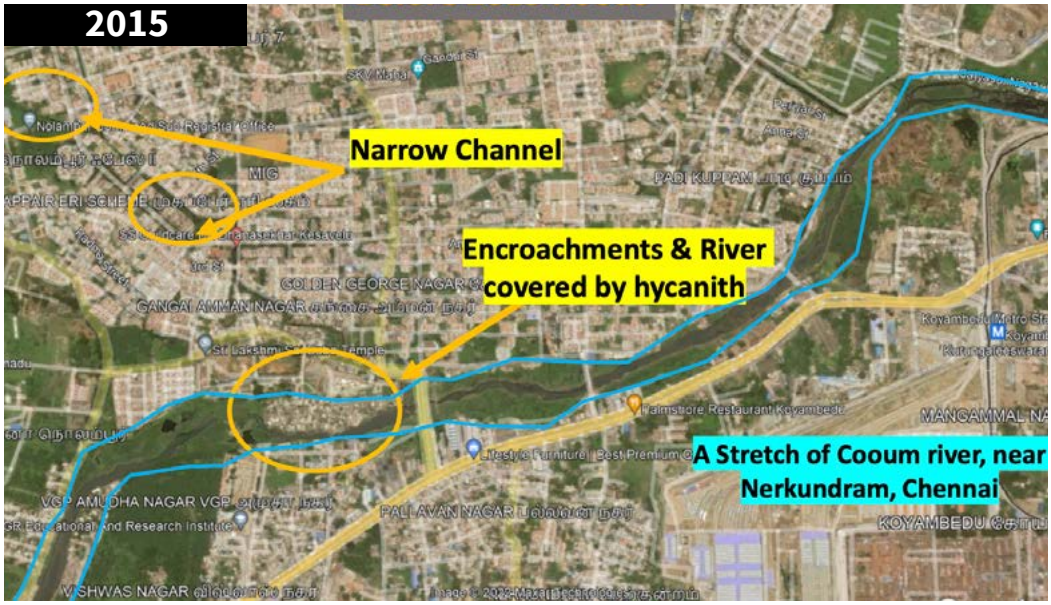
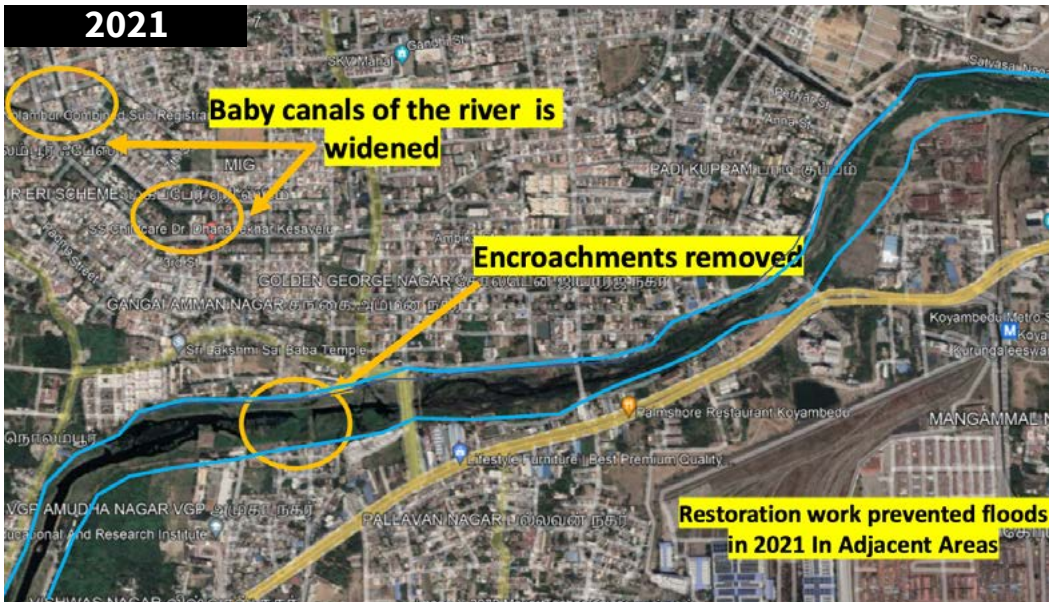


Figure 5 : Coum River, before and after restoration. © Google Earth Pro



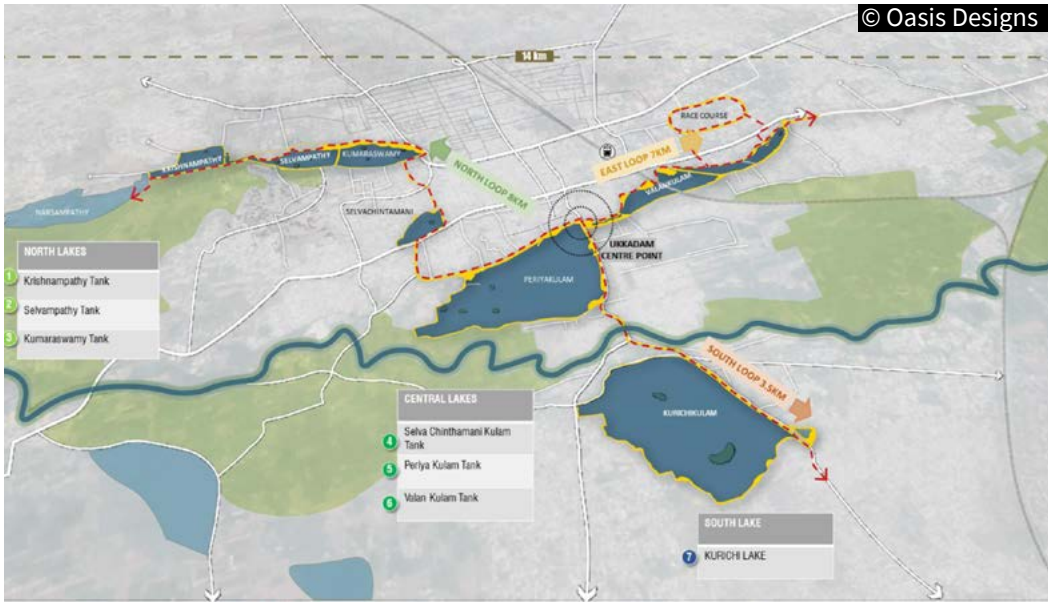


Figure 6 : Plan of eight lakes and its interconnectivity.

as part of the Smart City Mission, is to bring about social change by creating environmental awareness, skill development, and better quality of life in the city. The city is located in the Noyyal river basin and has an extensive lake system fed by the river and rainwater runoff.[12] These eight lakes are the largest reservoir areas of Coimbatore. These lakes have served as agriculture irrigation channels to the city and have been restored.

The city has cleared all the encroachments from all the lakefronts, reclaiming the space to create a new visible and accessible lakefront for people to connect with. All lakes now store more water than they did historically, with the additional depth helping to increase the total water volume of each lake. As part of a decentralised waste-water treatment approach, all lake inlets are planned to be equipped with suitable treatment facilities, which will ensure that all non-monsoon flows into the lake pass through a series of screen chambers that ensure all floating debris is captured before it enters the lake. Non-monsoon waste will subsequently go through a diversion chamber into the treatment facility, and then the treated water will be brought back into the lake.

All the stormwater is also designed to enter a green buffer area, filtered, and sent to a stormwater swale or raingarden, and the overflow directed back to the lake. This will ensure that all the rainwater falling on land around the lakes can also soak into the ground, as the lakes, once full, will maintain full reservoir level regardless, while all excess water will flow out and finally be taken away into the river.

The overflow weirs, sluice gates, and other installations at all lakes, which were old a have been repaired to receive a new lease of life. The new embankment slopes have been designed as ‘green infrastructure’ with natural rocks and plants, in sharp contrast with ‘grey infrastructure’ arrangements previously used to stabilise the slopes. The green slopes with natural rocks provide habitat for native biodiversity, which in turn helps regenerate the lake ecosystem. Several wet floating wetlands are provided in each lake to ensure consistent quality of water.

With the use of floating pontoon structures for all jetties and walking platforms in the water, the design attempts to avoid the use of concrete inside the water area of each lake. Only hydraulic structures such as sluice gates or overflow weirs are constructed in concrete as part of lake infrastructure requirements.

Lake lagoons and vegetated islands have been restored and will be kept intact to attract birds. To ensure that the lakebeds that typically dry up during summer also manage to retain some level of water, water from the inlets is routed through a specially terraced lakebed. This technique works as a stepped flow-through wetland and provides shallow depths of smaller ponds that first fill up and then overflow into the deeper areas of the lake.

A 20-km long cycle-walk connector greenway is being developed to connect all lakes with Ukkadam junction as the centre point (Figure 7 a,b,c). The East Loop

connects to Valankulam and Sungam Junction, then continues eastwards towards Singanallur, along Trichy Road. The South Loop goes along the eastern bund of Periyakulam to cross the River Noyall and join the Eastern Esplanade at Kurichikulam. The Northwest Loop goes westbound along the Periyakulam North Promenade from Ukkadam, then connects to Selvachintamani along the road, and then, after going around, heads further north to connect to the North Lakes of Kumaraswamy, Selvampathy, and Krishnampathy, and, finally, reaches Narsampathy.[13]

[13] Oasis Designs, "Eco Restoration of 8 lakes, Coimbatore City."

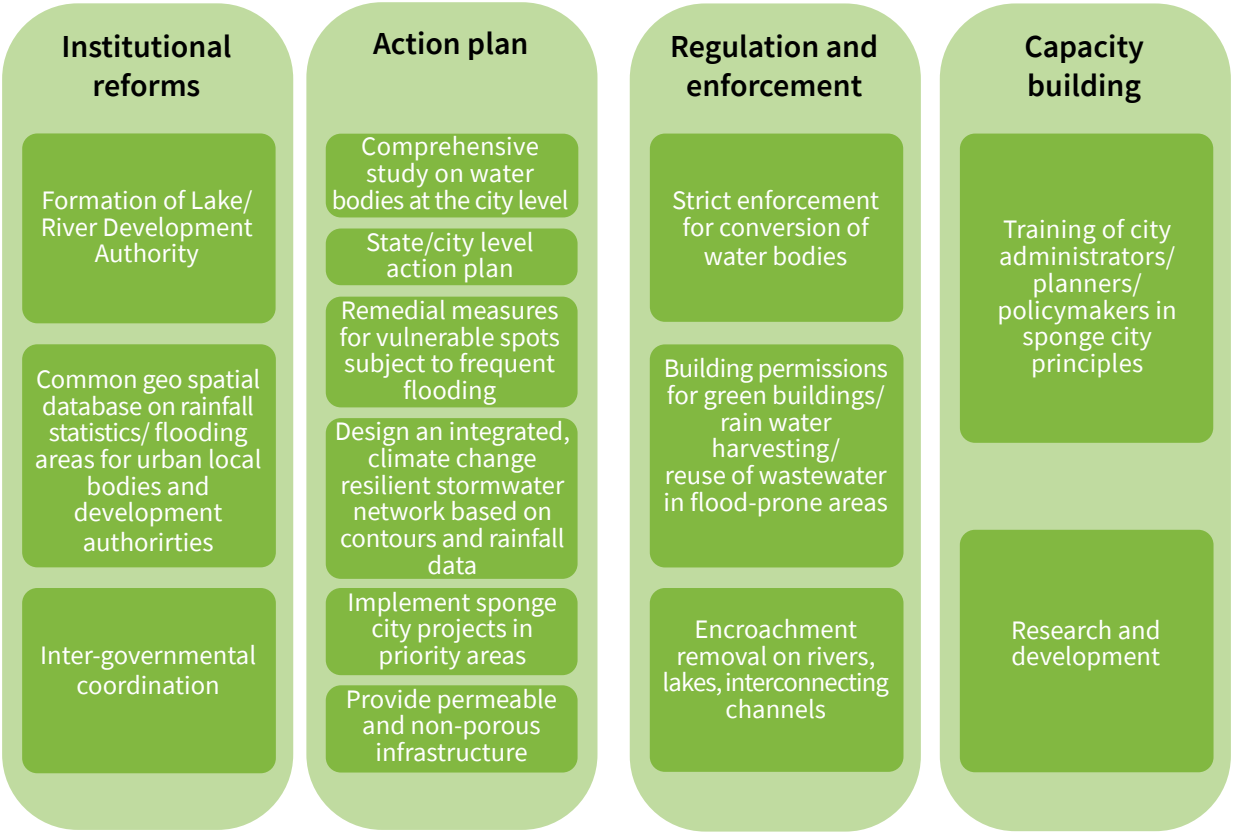
Figure 7 a,b,c : Views of a restored lake.

Upcoming actions

To improve the groundwater table and prevent flooding, the Greater Chennai Corporation has proposed setting up a sponge park with an artificial pond and rain gardens at the Kargil Nagar flood water pumping station in the Manali zone. The project is part of the integrated stormwater drain network in the Kosathilaiyar basin. This will act as a park during dry seasons, and wetland, rain gardens, and storage ponds during rainy seasons.[14] Similarly, in a new proposed inter-city bus terminal for Chennai, the development authority is planning to create a sponge park consisting of blue-green infrastructure to collect, filter, and store the runoff on a pilot basis at Kilambakkam. Following suit, Mumbai City has also initiated to employ the sponge city principle to address the distressing floods the city has been experiencing in last two decades. The Brihanmumbai Municipal Corporation (BMC) development plan is focused on regulations for new buildings, including green rooftops and vertical gardens. Other measures include permeable footpaths that store excess runoff water, water-absorbing concrete, wetland restoration, and rainwater harvesting.[15]

[14] TNN, "Greater Chennai Corporation plans to set up sponge park."

[15] Bhalerao,"BMC to adopt 'sponge city' initiative to tackle urban flooding during extreme rainfall."



How can Indian cities mitigate climate change and become resilient?

The sponge city concept holds more promise in coastal cities like Chennai and Mumbai. The key factor here is going back to nature and creating more porous permeable surfaces in the city that can absorb excess water and facilitate its use when required. The Smart Cities Mission has set up many micro and pilot projects. The impact of flooding is yet to be fully addressed.

Figure 8 : Guidelines for Indian cities to mitigate climate change and handle urban floods. © Author

Warnings of climate change crises and emergencies call for immediate action to find possible solutions. Open Space Reservations could be utilised as sponge parks, especially near areas vulnerable to flooding. Restoring water bodies, green building, rainwater harvesting, artificial rain gardens, wetlands, and storage reservoirs will be ideal solutions against floods. Permeable pavements will be a readily implementable solution for recharging groundwater along massive road networks in metro cities. Some broad guidelines for Indian cities to mitigate climate change and handle urban floods are given in (Figure 8).

Nature-based solutions like those employed in the Sponge City Programme are cost-effective and sustainable alternatives to conventional carbon-intensive urban development. And, aside from their contribution to sustainable water management, they generate a host of social and environmental co-benefits, including improved mental and physical health linked to public green spaces, biodiversity conservation and natural cooling, and helping cities move towards more holistic, transformative, and climate-proof urban water management.

Chennai and Coimbatore are two major cities in the state of Tamil Nadu which have deployed the sponge city concept under the national Smart Cities Mission scheme. While there has been initial success in implementing this concept, its efficacy in combating floods and droughts can only be assessed in the coming years. Rainwater harvesting structures must form part of any building plan that is part of development regulation in metropolises such as Chennai. Open Space Reservation is mandatory for large-scale development. All such parcels of land across the urban area could be potential sites for deploying the sponge city concept. Apart from constructing stormwater drain networks conforming to the contours of the urban area, which is not the case now in most cities, the drains can carry excess floodwater to sites identified for sponge parks along its network.

The range of measures to combat the climate emergency can include development of sponge parks for purposes such as rainwater harvesting, vertical farming, urban-farming, reforesting, green mobility, and the like. Scaling up of these arrangements in accordance with rainfall patterns and floods in urban areas is now essential. Urban planners, policymakers, and administrators must switch to nature-based solutions for any urban problem to make cities sustainable and achieve SDG 11.