MAKING EVERY DROP COUNT

Cities are growing faster than they can cope and are growing more vulnerable to extreme weather. With Bengaluru's ever-escalating water problems becoming a recurrent, annual feature, innovative new thinking and plans are the need of the hour if a calamity is to be avoided. Can Bengaluru make room for the rain through sponge city principles?

As the effects of climate change become increasingly severe, many of the world's cities are facing extreme weather events like heavy rainfall and prolonged droughts.

Our planet has already warmed by 1.5 degrees celsius compared to pre-industrial levels. This seemingly insignificant increase has set in motion a cascade of extreme weather events, a phenomenon aptly described by scientists as "loading the climate dice."

Before the 1980s, the climate remained relatively stable, with fewer erratic occurrences. But this changed as temperatures increased, tipping the scales towards more frequent and severe weather anomalies. An Intergovernmental Panel on Climate Change (IPCC) study finds that there will be more frequent or stronger El Niño-Southern Oscillation events which can lead to more floods and droughts.

This shift has profound implications, particularly for urban centres, which are both victims and perpetrators of climate change. Cities, responsible for nearly 70% of global greenhouse gas emissions, face a daunting challenge. As the impacts of climate change intensify, these urban hubs must adapt and evolve to withstand the changing climate.

Bengaluru is an Example of a City that Faces Alternating Floods and Droughts.

In the summer of 2024, India's bustling tech hub has been grappling with a severe water crisis, despite having experienced four consecutive good monsoons. Almost every year, Bengaluru is hit by severe floods, which cause widespread damage and disruption to the city's infrastructure. The city, which was once known for its pleasant climate and abundant water resources, is now a prime example of a city that swings between two extremes.

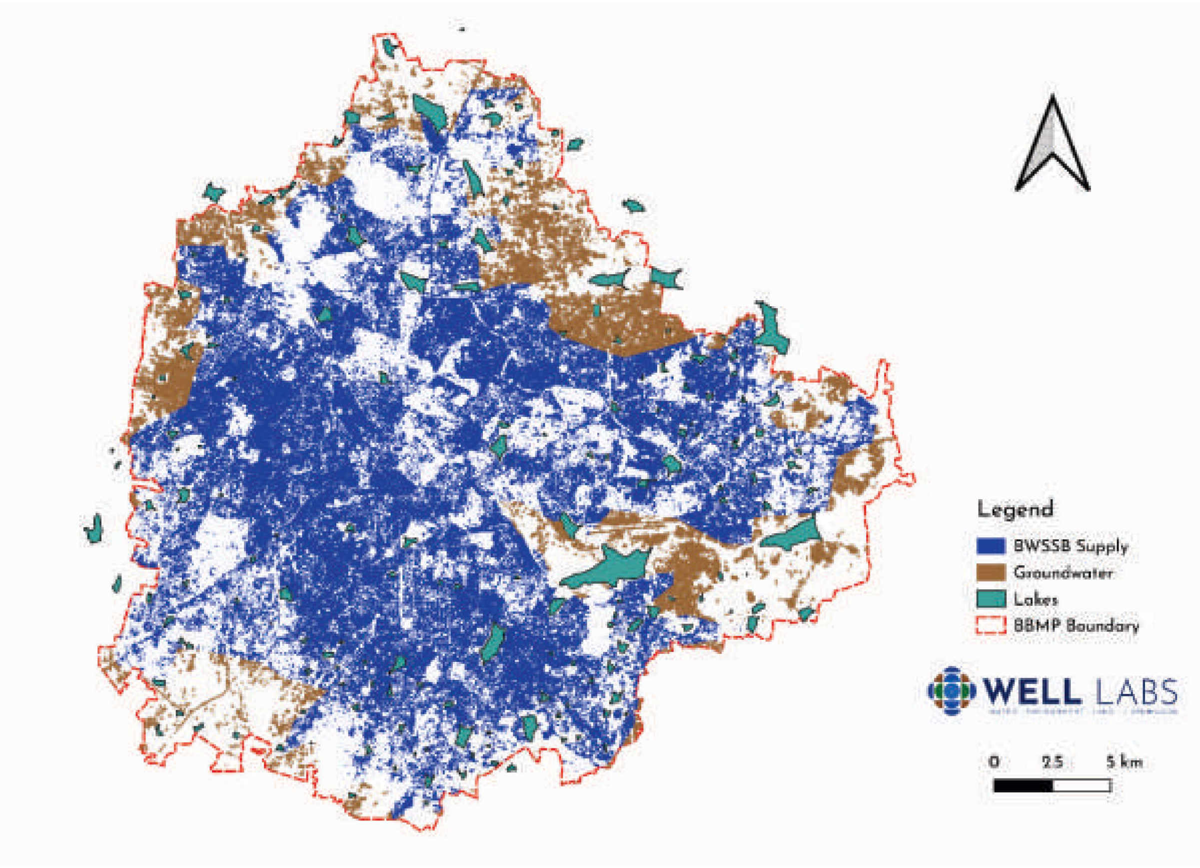
The water crisis this year has led to many areas of the city experiencing severe water shortages, with residents relying on water tankers to meet their daily needs. The situation has been particularly dire in the outskirts of the city, where many residents have been forced to purchase water at exorbitant prices from private suppliers.

In response to the crisis, the government has taken some measures, such as rationing water supply and imposing restrictions on water usage. However, many residents feel that these measures are not enough and that more needs to be done to address the root causes of the crisis.

Bengaluru's Recent Water Crisis was a Groundwater Crisis

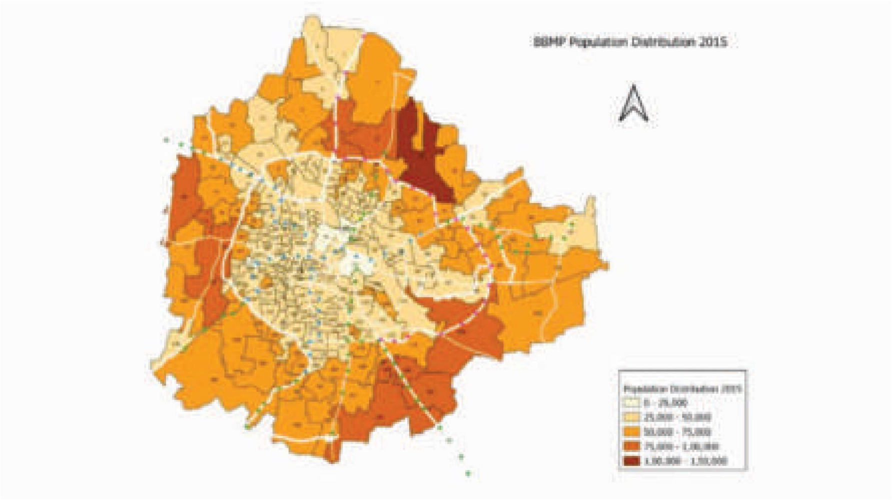
First, we need to understand that the crisis was a groundwater and land use crisis, caused by the development of high-density urban housing dependent on a very shallow unproductive aquifer.

The real culprit is rapid unplanned growth. Cauvery supply to the city actually stayed steady (even increased slightly). The problem is Cauvery water is only supplied to the core city area. Meanwhile, as Bengaluru's population grew from 5.7 million in 2001 to 14 million in 2024, most of the growth occurred in the peri-



Map of Bengaluru's water supply within BBMP Boundary

Source: WELL Labs



Map of Bengaluru's Population Distribution within BBMP Boundary
Source: ADB study on socioeconomic impact of land use policy and metro investment in urban India

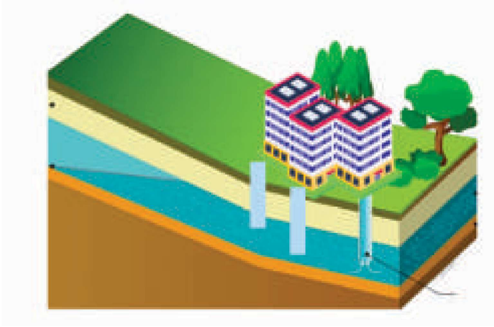
urban areas. Because piped infrastructure did not keep up, the newly added suburbs became groundwater dependent.

But unlike other cities, this growth was not low-density, single-family housing that gradually densified. In fact, the newly-added areas have the highest density of population, as high as 25,000 per sq. km. At 100 litres per capita per day of abstraction, that is 900,000 cu. m. or 900 mm. of abstraction per year. To offset this kind of abstraction, would require every drop of rainwater to recharge the aquifer, when in reality, recharge rates are much lower. Even with aggressive rooftop rainwater harvesting, it would be barely 10% of rainfall or 90 mm. In short, we are abstracting groundwater at 10X the rainfall recharge in these peri-urban areas.

This difference could not be entirely attributed to declining storage. Bengaluru's hard rock aquifers have specific yields of less than 1%. Although we actually had several good years of rain, followed by one bad year, the aquifer simply doesn't have much storage to hold that excess water; the year-on-year deficit is simply too big.

This means that an 800 mm. annual deficit would result in an 80 m. (or more) decline in groundwater levels. While groundwater levels in Bengaluru have steadily declined, they have not been declining quite that fast. So, in all

High density peri-urban growth



25,000 people per sq. km. = 900 mm. abstraction

Low density peri-urban growth

2,500 people per sq. km. = 900 mm. abstraction likelihood, peri-urban areas in Bengaluru are benefiting from subsurface flows from the central parts of the city (water levels in central Bengaluru are high because of continuous pipeline leakage, which probably benefits peri-urban areas). Bengaluru is unique in terms of topography – it is perched high on a plateau and the centre of the city is in fact at a higher elevation. This natural gradient drains water away from the city centre to the suburbs.

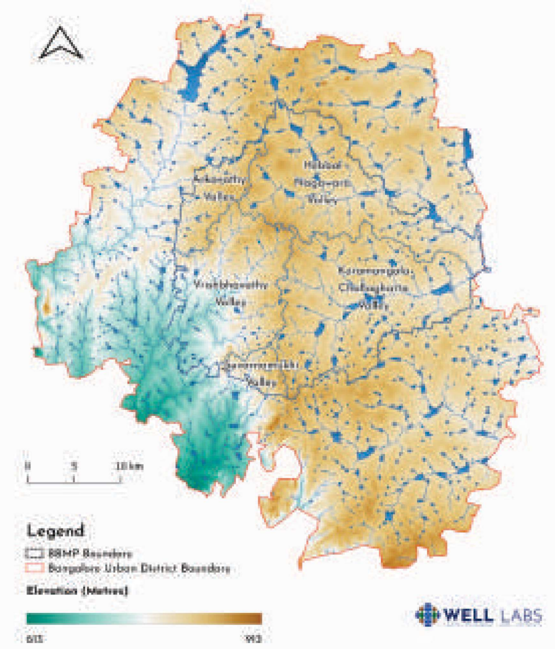
Indeed, recent isotopic studies support the hypothesis that lakes contribute very little to recharge and pipeline leakage is in fact the biggest contributor to groundwater recharge.

To ensure long term sustainability, we have to extend the piped network and use local sources more effectively. We have to be nuanced about how to effectively harness these sources.

Could Rooftop Rainwater Harvesting Solve the Problem?

Bengaluru's rooftop rainwater systems are typically linked to an on-site storage tank. Any excess flow is routed into an open well or recharge well.

The problem is that a typical domestic rainwater harvesting system tank holds only about 3,000 litres of water. 3000 L is the amount of runoff generated from 25-30 mm. of rainfall per day on a 100 sq. m. roof – about a week of water supply for a family of four. The problem is about 25% of the rainy days in Bengaluru exceed this threshold and these heavy storms account for the bulk of the storm water generated in the city.



Lakes map with elevation for Bengaluru urban district

Even if the excess rainwater is diverted into a recharge pit, the rate at which water can actually be absorbed into the ground is a limiting factor. The typical rate of infiltration into pits is around 10 mm/hr. For the rainwater to infiltrate, we need a space to hold the water to allow it to gradually percolate through the fractures.

Could Lakes Solve the Problem?

The really heavy rains need public spaces.

It has been argued that lakes could boost recharge locally. But the typical recharge rates from lake beds are about 10-30 mm/day and lakes occupy only 2-3% of the land area. So, the total contribution of lakes to the city is another 25-30 mm. Thus, lakes could offset some of the abstraction but it would still short of the 900 mm of recharge needed.

An ancient system of cascading tanks was designed for this and continues to be relevant in rural systems. They were sized to hold excess runoff when the whole watershed was unpaved – i.e., most of the rainwater soaked into the soil, only very intense rains generated excess runoff that were captured by the tank.

In urban systems – concretisation means virtually no water soaks in directly. Most storm water finds its way into the lake. Even as Bengaluru's groundwater dependence has grown from 1973 and 2022, forest cover fell from 28% to under 1% while built-up area increased from 8% to 87%. This led to a sharp decrease in aquifer recharge and a sharp increase in runoff – contributing directly to the cycles of floods and droughts.

We need to restore, delay, store and release.

The really heavy rains need public spaces for the water to stay and percolate gradually. Bengaluru's system of cascading tanks was designed for this. But they were sized to hold excess runoff when the whole watershed was unpaved. Most of the rainwater soaked into the soil. Only very intense rains generated excess runoff into the tank. As most stormwater runs off concrete surfaces and finds its way into the city's lakes, flooding has increased and recharge into aquifers has decreased.

By using sponge city principles, it is possible to mitigate the negative hydrological effects of unplanned development and make a serious dent in recharge. Sponge cities recharge rainfall from all of the urban land and reduce the risk of flooding significantly. China, which has retrospectively adopted the sponge city approach has effectively managed to boost recharge in cities from rates as low as 10% to over 70% and reduce flood events.

The sponge city approach is simple:

Restore and protect the city's lakes and tanks.

Delay and make the water go through the subsurface, thereby reducing the pace at which stormwater runs off into the drains. This is done by swapping out non-permeable surfaces with permeable paving and porous concrete for roads, as well as installing green roofs.

Store water by designating some open spaces in areas prone to flooding to capture the peak flows. Most often rainwater harvesting structures are unable to capture peak flows, but the sponge approach allows for this to happen.

Release the stored water into the aquifer by strategically placing recharge wells in the areas designated for flood water capture.

This is not just about installing infrastructure but getting the community and utilities involved to maintain it.

We Need to Recycle Wastewater and Consider Recharging Groundwater with Wastewater that's Treated to at Least Bathing Standards.

Capturing rainwater alone is not enough. 80% of domestic water used, goes back as wastewater. There is huge potential here to meet non-potable needs from treated wastewater; this would make a big dent on the annual groundwater deficit.

There are several promising non-potable uses for this wastewater, such as construction, usage in cooling towers, and industrial-scale laundries. However, another promising solution could be to bring the water up to very high quality, at least bathing standards, and inject it into the aquifer.

Orange County, California, has pioneered this approach to water management by injecting highly treated wastewater into its aquifer. The Orange County Water District (OCWD) operates the world's largest advanced wastewater purification system, the Groundwater Replenishment System (GWRS), which takes treated wastewater that would otherwise be discharged into the Pacific Ocean and purifies it further through a three-step, advanced treatment process.

The purified water is then injected and percolated into Orange County's groundwater basins, where it ultimately becomes part of the region's drinking water supply. Approximately 113 million litres per day of GWRS water are pumped into injection wells to create a seawater intrusion barrier, while another 378 million litres are pumped daily to OCWD's percolation basins in Anaheim, where the water naturally filters through sand and gravel to the deep aquifers of the groundwater basin, increasing the local drinking water supply. This innovative approach allows Orange County to reduce its reliance on imported water sources and enhance the resilience of its water supply in the face of drought and climate change

There Are Co-benefits – Low Carbon Development Pathway

Reusing wastewater and capturing stormwater is a low carbon pathway in the case of Bengaluru. Bengaluru sits on top of a plateau which is 920 metres above sea level, and pumps water from the Cauvery river up an elevation of around 300 metres and across 90 kms. Consequently, there is significant expenditure and emissions involved with pumping this water up to the city. Additionally, the city's aquifer has depleted significantly with the water levels in borewells now reaching depths of up to 2,000 ft. below the ground. This has its own associated energy implications.

By combining blue (water), green (nature-based solutions), and grey (traditional infrastructure) elements, sponge cities create a synergistic and resilient system that benefits both the environment and the people living in urban areas.

Making this Happen will Require New Ways of Financing

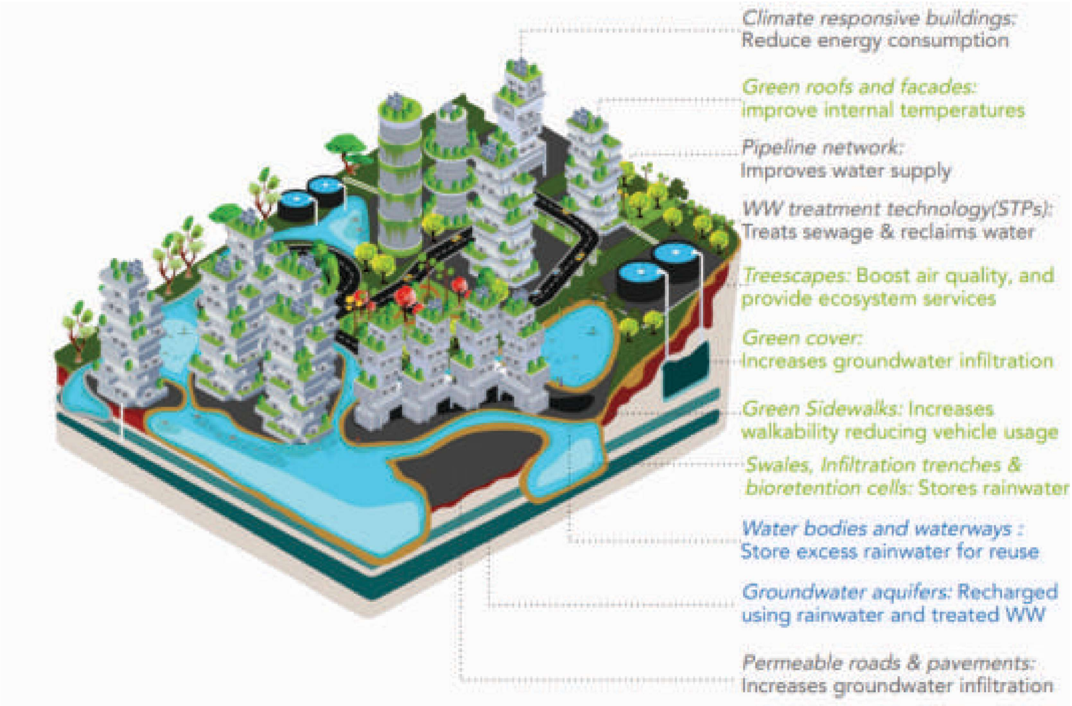
This is a fundamentally new way of managing urban water.

Inter-agency cooperation is crucial for this approach to sustain and scale. While sponge cities might look good on paper, their practical implementation may face challenges in the real-world, especially since water, in the case of a city like Bengaluru, is managed by over 15 different agencies in the city.

To ensure the effectiveness of sponge cities and wastewater reuse, Standard Operating Procedures (SOPs) need to be established. These SOPs will provide a structured framework for the implementation, maintenance, and monitoring and will help in streamlining the processes and ensuring that the desired outcomes of flood resilience, efficient rainwater management, and wastewater reuse are being met.

Data and evidence play a critical role in the implementation of sponge cities, especially in a context where nature-based solutions are less predictable compared to traditional grey infrastructure which is one of the key reasons for their lack of adoption. Setting Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) Level Benchmarks (SLBs) is essential to measure the impact and influence more adoption.

Sponge cities require constant upkeep. While the bulk of funding is currently allocated towards large grey infrastructure capex there is very little left over for operation and



Possibilities of integrating blue-green-grey infrastructure in cities maintenance. Introducing new financing instruments, such as water credits, can provide innovative ways to fund sponge city projects in India. Water credits can pool private money for implementation in public spaces. Water credits have been implemented in other parts of the world like Washington D.C., for stormwater infrastructure. Washington, D.C. is home to the most advanced stormwater credit trading program, which was established as part of the Sustainable DC initiative in 2013. This program allows developers to meet stormwater management requirements which are mandated by purchasing credits. These credits are then used to fund green infrastructure, such as green roofs, cisterns, and bioretention cells, in other projects or public areas of the city.

In the context of India, a similar model could be explored to distribute the costs for blue-green-grey infrastructure and ongoing maintenance among property owners, businesses, and governmental entities. By fostering an integrated approach to water management and collaboration among stakeholders, we can leverage these innovative financing strategies to pay for tangible solutions that mitigate the impact of floods and droughts.

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