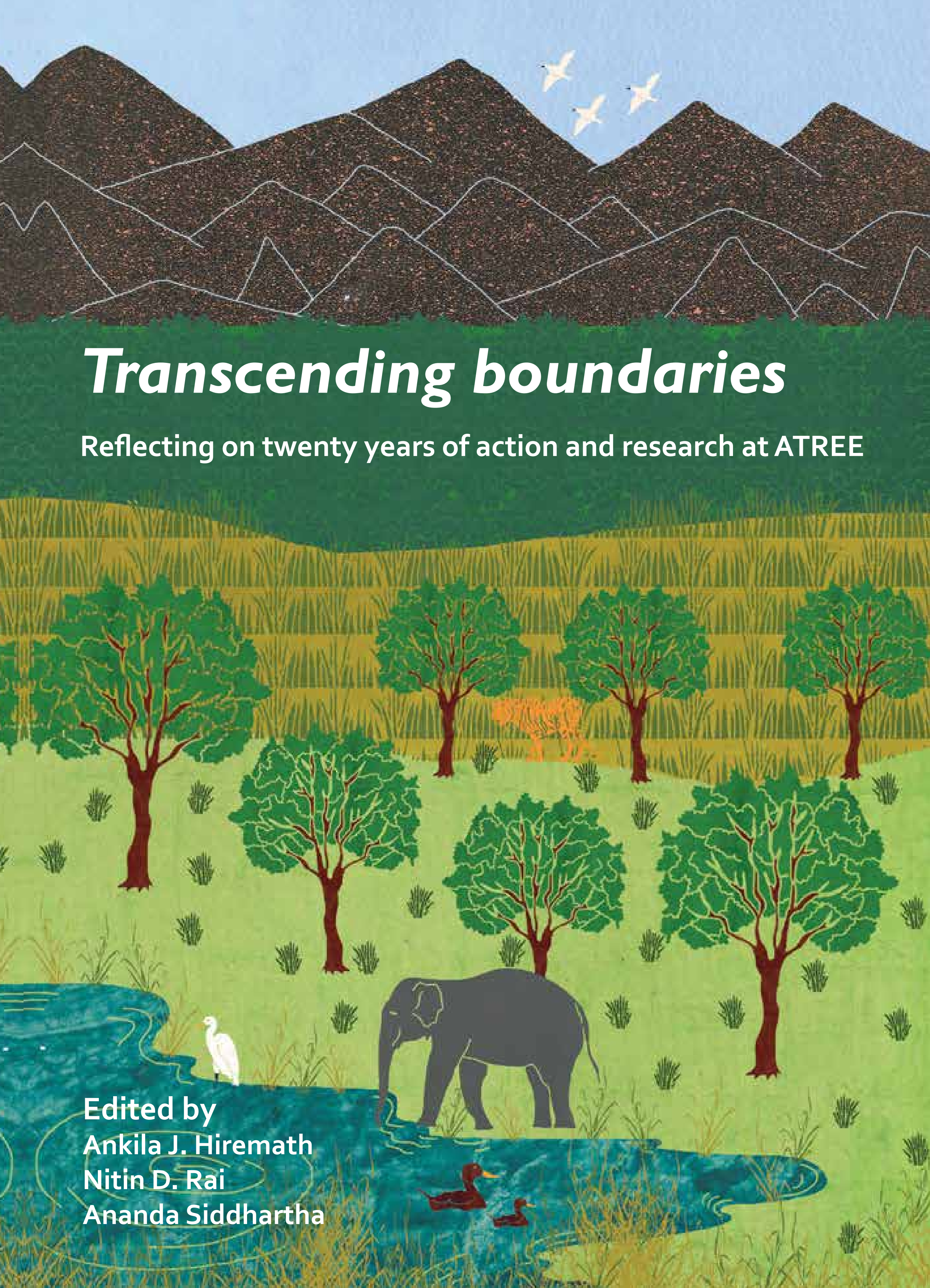

Transcending boundaries

Reflecting on twenty years of action and research at ATREE

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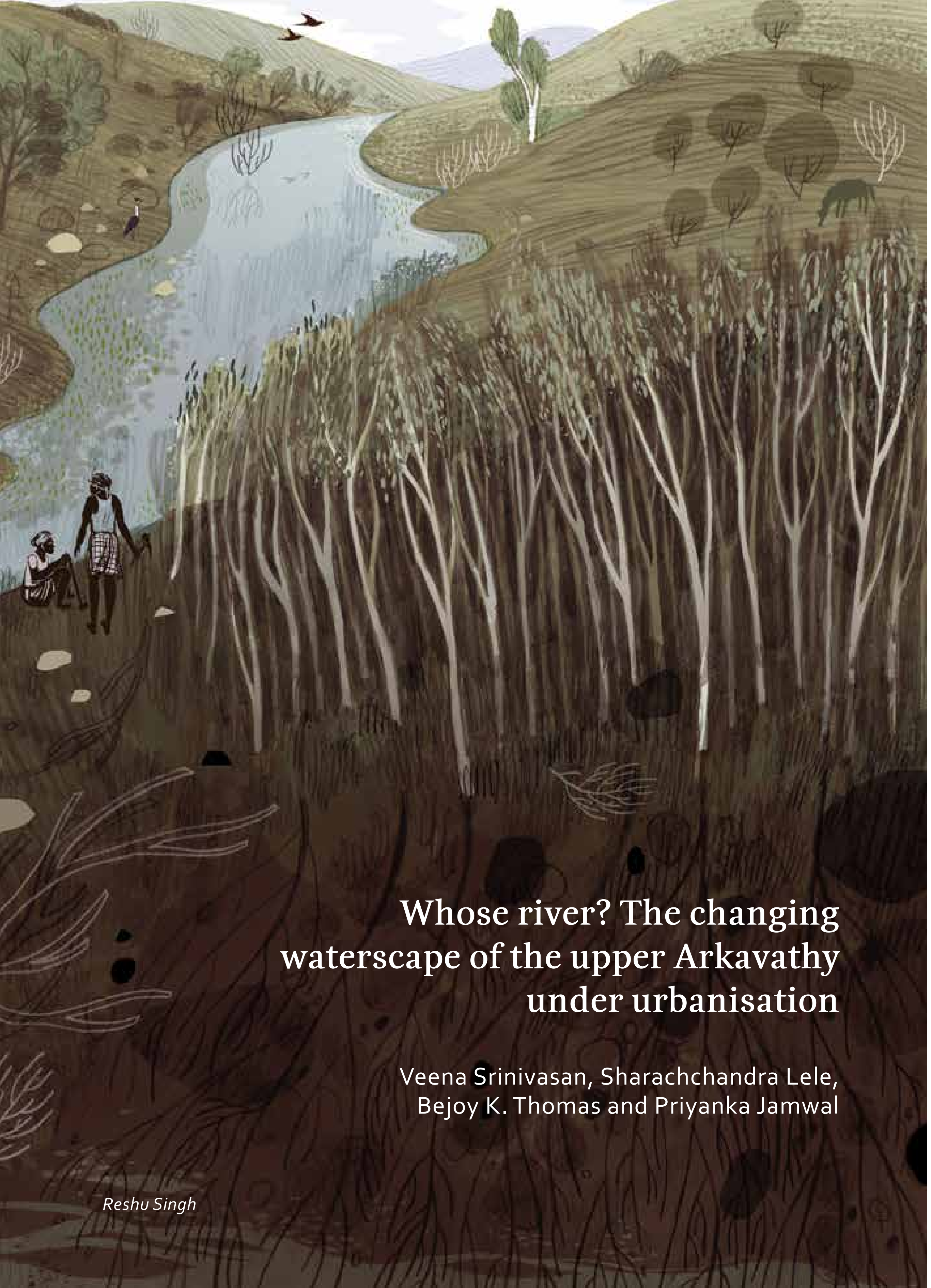


Reshu Singh

Whose river? The changing waterscape of the upper Arkavathy under urbanisation

Veena Srinivasan, Sharachchandra Lele, Bejoy K. Thomas and Priyanka Jamwal

INTRODUCTION

Urban areas in India have been experiencing unprecedented population and economic growth in the last decade. As cities grow and incomes rise, a new challenge has arisen: that of supplying domestic water reliably, and of reasonable quality, to this rapidly growing urban population, while ensuring that the well-being of future generations is not jeopardised.

The implications of this unprecedented urbanisation on water resources are only beginning to be understood. The story of the Arkavathy sub-basin, on the outskirts of Bengaluru city, offers rich insights into the complex interactions between urbanising areas and their surrounding hinterlands. A semi-arid catchment with an average annual rainfall of 830 mm, it overlaps with the western portion of the rapidly growing metropolis of Bengaluru. The main tributary of the Arkavathy river has its headwaters in the Nandi Hills, north of Bengaluru, and is joined by its first major tributary, the Kumudavathy river at Thippagondanahalli (TG Halli) village. At this confluence, the TG Halli reservoir, with a catchment area of 1447 km2, was constructed in 1933. The reservoir's current storage capacity can supply 149 MLD (million litres per day) to Bengaluru city. An older reservoir, Hesaraghatta, constructed in 1896 to supply 36 MLD to Bengaluru, is located further upstream on the Arkavathy river[1] (see Figure 1).

THE CHANGING WATERSCAPE

Historical development

The original scrub forest of the Arkavathy catchment was gradually cleared to make way for cultivation as early settlers moved in, probably several thousand years ago. The rulers between the 10th and 17th centuries constructed a series of small earthen bunds on the tributaries to store runoff in small water bodies or 'tanks' to create sources of water for irrigation and other domestic water uses. The catchment has an estimated 617 such tanks. These tanks would capture part of the surface flows in the stream, and the overflow would cascade to the next tank in the chain. In effect, this system of small, cascading tanks captured some of the streamflow for providing irrigation to the local community while also allowing significant flow to downstream communities.

For many centuries, irrigation was only possible in the command areas of these tanks, agricultural land adjacent to streams and rivers, and areas where the groundwater table was shallow. Groundwater was accessed via large open wells about 10–20 m (about 30–60 feet) deep. Typically, wealthier, upper-caste farmers owned land in tank command areas and used the tank water to irrigate paddy, sugarcane, and other crops. The tanks themselves were communally managed, and the sluices were operated by *neergantis* (village watermen). The *neergantis*, a hereditary post, received a share of the harvest for their efforts. On the one hand, tanks reinforced the existing social hierarchies, albeit while increasing the total agricultural surplus in the villages. On the other hand, the productivity of the landscape was limited by the amount of runoff that could be captured and stored in these tanks.

Contemporary changes

The most significant and visible change in the Arkavathy catchment over the past 3–4 decades is that the inflows into TG Halli reservoir have gradually declined by almost 80–90%. Other tanks in the catchment also exhibit a drying trend, and in fact interviews with *neergantis* suggest tank-based irrigation has

[1] Lele, S., V. Srinivasan, P. Jamwal, BK. Thomas, M. Eswar, and TMd. Zuhail. 2013. *Water management in Arkavathy basin: a situation analysis.* Environment and Development Discussion Paper No.1. Bengaluru: Ashoka Trust for Research in Ecology and the Environment.

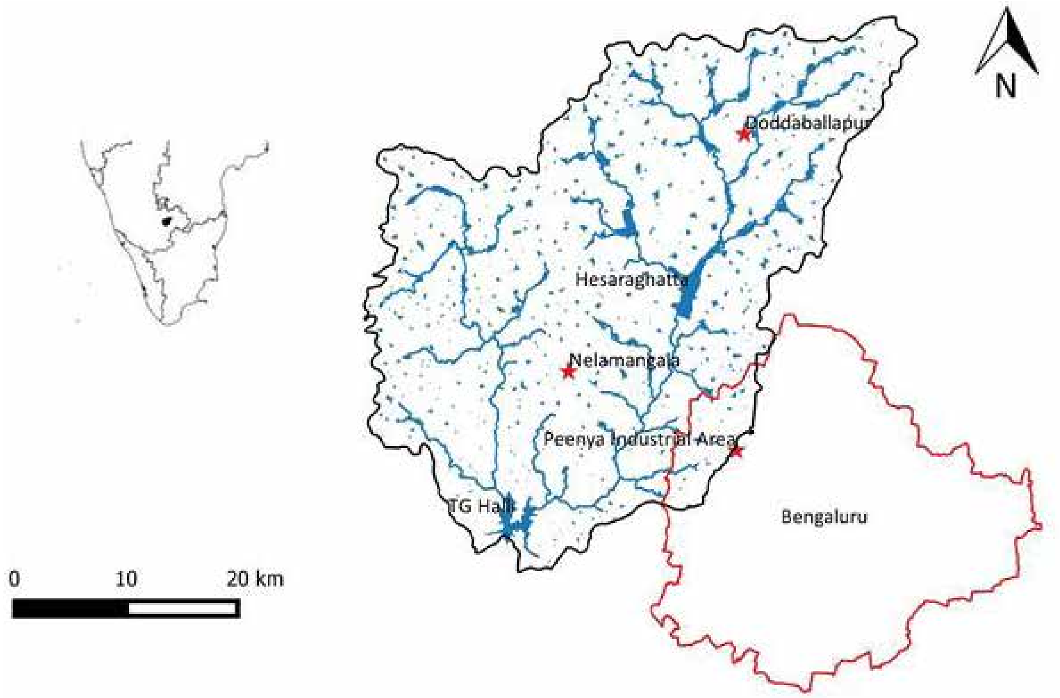


Figure 1. Map of TG Halli catchment showing TG Halli and Hesaraghatta reservoirs. The catchment includes the towns of Nelamangala and Doddaballapur and a part of Peenya Industrial Area in Bengaluru city.

completely stopped over the last 2 decades. What might explain the complete disappearance of surface water irrigation and concomitantly, the inflows into TG Halli reservoir? There are several possible causes of decline, or some combination thereof (see Figure 2). We examined all possible causes of this decline[2]. There could be a decrease in water coming into the catchment (i.e., declining rainfall over the years); or there could be an increase in water leaving the catchment (increased temperature and land use change leading to greater evapotranspiration through plantations or irrigation).

Analysis of the historical rainfall from 4 rain gauge locations within the catchment suggests that neither annual average rainfall nor daily rainfall intensities have changed significantly. Potential evapotranspiration also did not change significantly, so the inflow decline could not be explained by the higher temperatures causing trees to take up more water. Rather, direct anthropogenic factors are to blame.

The rise of borewell irrigation

Our analysis suggests that groundwater over-exploitation has played a key role in the disappearance of the Arkavathy River. The region is underlain by hard-rock aquifers with the upper aquifer highly weathered and water-bearing, but 50–60m below ground level (BGL) there are mostly massive rock formations with fewer fractures. The frequency of occurrence of these fractures decreases with depth.

Till the 1960s, well drilling was severely constrained by the ability to drill into hard rock formations. A new borewell drilling technology called 'down-the-hole' (DTH) drilling that arrived in the late 1960s completely altered the waterscape. The DTH technology decreased both drilling time and costs, allowing farmers to drill deeper in search of water. This meant that farmers' choice of crops was no longer limited by the amount of rainfall in a particular season. They could access groundwater recharged in previous years, or even previous decades.

[2] Srinivasan, V., S. Thompson, K. Madhyastha, G. Penny, K. Jeremiah, and S. Lele. 2015. Why is the Arkavathy river drying? a multiple-hypothesis approach in a data-scarce region. *Hydrology and Earth System Sciences* 19(4): 1905–17.

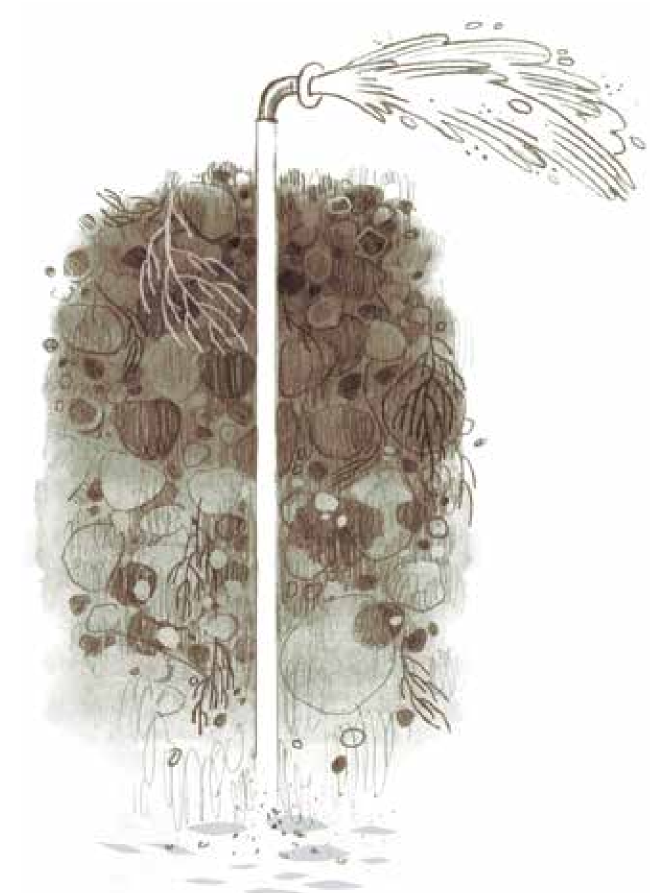
Groundwater irrigation also became the great leveller. Previously, irrigation was only available to land owners (usually the upper-caste elite) in tank command areas, for a limited period, and according to customary rights. Borewells allowed farmers outside the valleys and canal command areas access to irrigation. Indeed, early government schemes offered free or subsidised borewells to Scheduled Caste and Scheduled Tribe (SC/ST) individuals, who tended to own farmland outside the tank command areas. Even within the tank command areas, many farmers drilled borewells and were no more dependent upon the communally managed tanks, and the timing and quantum of water released from them.

To promote groundwater 'development,' the government introduced a low flat rate electricity tariff in the 1980s, which meant that the farmers did not have to worry about either the depth from which they were pumping water or the volume of water they pumped. Empowered with electricity subsidies, borewell drilling grew rapidly in the 1980s and 1990s. The early borewells drilled in the late 1970s report the groundwater table at 5–7 m BGL. These were typically drilled up to depths of 10–20 m. But with no restrictions on pumping, groundwater tables across the Arkavathy catchment began to rapidly decline. By the early 1990s, the shallow weathered aquifer had completely become de-watered. Farmers began to drill deeper to tap the increasingly infrequent water bearing fractures below, and this slowly led to frequent failure of borewells.

Despite the declining water table and high rate of failure, borewell drilling has not slowed. In fact, paradoxically, the number of borewells continues to increase rapidly even today. Borewells in rural areas of the catchment currently average 250–350 m BGL. Interestingly, analysis of secondary data suggests that despite the increase in the number of wells, irrigated area has actually declined in the last decade. There are indications that borewell yields have declined significantly as the borewells have gotten deeper, consistent with the geology of declining fracture densities. This has led to adoption of water-efficient irrigation technologies such as drip and sprinkler systems to some extent.

The rise of eucalyptus

In the early 1980s, another set of pertinent, but unrelated developments took place. Under a World Bank aided scheme called the "Social Forestry Programme," farmers



began to get interested in eucalyptus trees in a big way. While the original intent of the Social Forestry Programme was to promote fodder, timber, fuelwood, and horticulture species on village common lands, eucalyptus as a species (in this case *Eucalyptus globulus*) only provides small timber and softwood for the paper and synthetic fibre industries. The area under eucalyptus plantations in 1973, as indicated by Survey of India topo-sheets, was only 11 km², all of it within the boundaries of State Reserve Forests. By 2001, the area under eucalyptus plantations had increased to 104 km², and by 2013 almost 280 km² of the catchment area was under eucalyptus plantations, the vast majority of it on private lands. The motivations for farmers to shift from agriculture to eucalyptus plantations has very little in common with the original goals of the Social Forestry Programme. Most farmers cite the difficulty in obtaining labour for agriculture, and the desire for upward mobility to white collar urban jobs, as the reason.

Evidence of the impact of eucalyptus on water resources is quite well established through numerous studies in South India conducted in the 1990s. The studies suggest that eucalyptus has a very high transpirational efficiency, in the sense that it is able to convert water absorbed into biomass very efficiently. However, in the absence of water and nutrient limitations, eucalyptus trees grow very fast and use a lot of water overall, per unit land area. In all sites studied in South India, eucalyptus water use far exceeded that of the rain-fed millet. In deeper soils, eucalyptus roots can penetrate the soil at a rate of >2.5 m per year, and if water is available in the soil column, the transpiration can exceed rainfall in a given year. Thus, there is every reason to believe that the large-scale conversion of rain-fed agricultural land (annually transpiring 300–400 mm of water) to eucalyptus (transpiring between 600 mm to as much as 1300 mm of water, if the roots are able to access groundwater) has increased total evapotranspiration and decreased the amount of water making it past the root zone and reaching the groundwater table, i.e., groundwater recharge.

Watershed development as a silver bullet solution

Starting in the late 1990s, alarm bells were raised over rapidly declining groundwater tables. The solution that emerged to address this was 'watershed development'. Check dams—small masonry structures, 1–2 m in height—were constructed along the first and second-order streams to arrest runoff and allow water to percolate into the ground. Indiscriminate construction to increase recharge has meant that today, the check dam density in parts of the catchment is ~2 structures/km² of catchment area. Our preliminary studies show that much of the runoff is being trapped, especially in low rainfall years. About 20% evaporates and the rest is redistributed in the unsaturated zone. Only a fraction reaches the groundwater table.

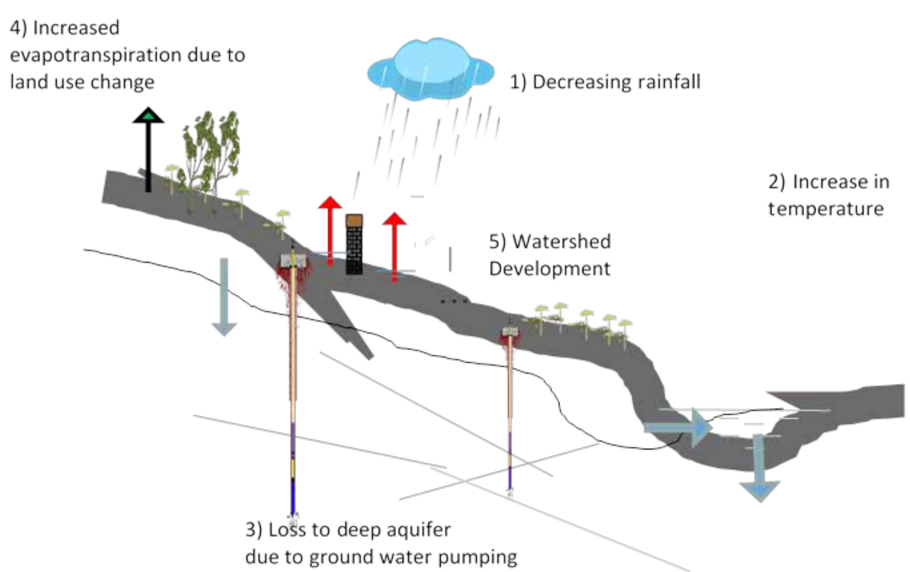


Figure 2. Climatic factors alone cannot explain the decline of inflows into TG Halli reservoir. Groundwater pumping, eucalyptus plantations and watershed development also play a major role

DRIVERS OF CHANGE

Although electricity is free or subsidised, farmers nevertheless have to make large investments in groundwater abstraction technologies (drilling the borehole, submersible pumps, piping, casing, etc.), and in the case of eucalyptus, they have to forego regular returns from seasonal crops for 6-yearly returns. Yet, the number of borewells and the area under eucalyptus is continuing to rise. What might be driving this behaviour? The answer lies in the growth of Bengaluru as a thriving 'global city' and its economic influence that extends far beyond its borders to the peri-urban and surrounding rural areas.

As job opportunities became available in the city and the surrounding industrial areas, rural youth became less interested in agriculture. As labour and groundwater for agriculture disappeared, farmers were left with two options. Many farmers switched to eucalyptus plantations, as it required far less labour and investment. They were able to obtain returns from their land comparable to rain-fed agriculture (~Rs. 10,000/ha/year), but it freed up their time to pursue alternative occupations. Other (usually wealthier and risk-taking) farmers went deeper for groundwater but could only justify the capital expenditure by switching to horticulture or floriculture[3]. The proximity of a major city like Bengaluru opened up new markets for these high-value cash crops.

SHIFTING MANAGEMENT STRATEGY

The story of the Arkavathy in TG Halli catchment has been about the complete transformation of surface water, a public resource controlled by the government, to groundwater, a common pool private resource abstracted by individuals. This has been driven by technological change as well as the changes in employment opportunities and agricultural product markets due to the proximity of a major, growing city like Bengaluru.

Authority over the water resources of TG Halli is spread between many different agencies, each with its own mandate and stakeholders. As stakeholder interests have changed with the changing economic circumstances and water resource availability, agency responses have also changed.

Phase 1 (1975–1995): Shift to groundwater, plantations

Stakeholder interests

Farmer stakes shot up after the 1970s as groundwater became accessible through borewell technology. While earlier, irrigation was only an option for farmers in command areas of irrigation tanks, lower cost of fast drilling technologies allowed irrigation to become a viable option for all farmers.

Policy responses

In the early phase of groundwater exploitation, the main policy objective was to promote "groundwater development." The

3 Thomas, BK., M. Eswar, SD. Kenchaigol, V. Srinivasan, and S. Lele. 2015. Enhancing resilience or furthering vulnerability? Responses to water stress in an urbanizing basin in Southern India. In: *Fourth Global Meeting*, Organised by: University of Illinois at Urbana-Champaign, May 7-9, 2¬015

government of Karnataka adopted the policy of low, flat-rate electricity tariffs to allow groundwater irrigation to increase. Independently, as Bengaluru's demand for domestic water grew beyond the capacity of TG Halli reservoir and TG Halli inflows declined, BWSSB (Bengaluru Water Supply and Sewerage Board, responsible for water supply and sewerage within Bengaluru city) increased its withdrawals from the far-away Cauvery.

Phase 2 (1995–2005): Commercial agriculture, deep groundwater extraction

Stakeholder interests

Over time, farmers' interests in the type of agriculture also changed. Traditional, subsistence food grain crops that were predominantly rain-fed, declined, to be replaced by commercial horticultural crops and vegetables, all of which are water-intensive. The irrigated area continued to expand both in absolute terms and as a fraction of cultivated area, despite depleting groundwater levels, and borewell failure. Farmers began to drill many more, and deeper wells. Simultaneously, the area under eucalyptus also continued to expand.

Policy responses

By the mid-1990s, BWSSB got really alarmed about declining stream flows into TG Halli. In 2000, the Bangalore Metropolitan Region Development Authority (BMRDA) commissioned the Indian Space Research Organisation (ISRO) to diagnose the problem. ISRO's study also found steady declines in tank inflows, attributable to a range of causes including inadequate wastewater treatment, and direct discharge of pollutants from industry and domestic sewage into storm drains and streams. It recommended the creation of 4 zones around TG Halli reservoir and the main river channels, and the placing of restrictions on new constructions, eucalyptus plantations, and groundwater extraction. However, these were never implemented, as lack of jurisdiction limited what BWSSB or BMRDA could do in the Arkavathy catchment. A decade later, most of these regulations remain unimplemented.

Dry bed of TG Halli Reservoir. (Photo: T. Zuhail)

As groundwater levels declined and wells began to fail, the groundwater department and village panchayats increasingly began to invest in watershed development projects in response to farmer concerns over groundwater depletion, inadvertently causing further reductions in streamflows.

Phase 3 (2005–2015): Expanding urbanisation

Stakeholder interests

With expanding urbanisation, stakeholder interests in the catchment gradually shifted from agriculture to urban, commercial interests. Since 2005, for the first time, the region has seen a decline in irrigated agriculture, both in absolute terms and as a fraction of cultivated area. The proximity of Bengaluru to the peri-urban and rural parts of the Arkavathy catchment has created diversified income opportunities. So, rainfed farmers diversified their dependence on non-agricultural activities, and many farmers in peri-urban areas abandoned cultivation in anticipation of high land prices.

Over this period, as the multiple stages of water supply from the Cauvery were commissioned and inflows into TG Halli simultaneously declined, BWSSB's interest in TG Halli gradually waned. TG Halli water today amounts to just a small fraction (1%) of BWSSB's supply. In the last few years, for the first time, sewage and industrial effluent inflows have been entering TG Halli reservoir from Bengaluru's expanding fringe.

Policy responses

The current situation is a fragmented set of policy responses that reflect divergent stakeholder interests and fragmented understanding of the hydrology. As TG Halli's importance for Bengaluru's water security has declined, the deterioration in the quantity and quality of water coming into TG Halli became less relevant to the citizens of Bengaluru. TG Halli is now only valuable because of its reservoir storage capacity, not for the water itself. Reflecting this, recent plans for TG Halli involve using it to store either treated wastewater or the planned diversions of water via inter-basin projects such as the Yettinahole project. Likewise, in recent years, a number of citizen's groups and social movements have emerged with the objective of 'rejuvenating the Arkavathy river'. These movements are driven by a range of underlying motivations including urban elite looking for recreational or spiritual spaces, and rural environmentalism driven by farmers concerned over disappearing water. Responding to these demands, the Cauvery Neeravari Nigam Ltd. (CNNL), a quasi-state-government agency, was given responsibility for rejuvenating the Arkavathy river. But in practical terms, they have focused on the wrong end of the problem—removal of vegetation and encroachments in the stream channels to remove 'obstructions' to a non-existent flow, and de-silting of tank beds to store more non-existent inflows.

Additionally, in response to widespread concerns over groundwater depletion, the Karnataka Groundwater Authority was created by an Act in 2011. The Authority was given the mandate to regulate groundwater in the state, but has yet to put in place any rules to regulate pumping. At present, the only action undertaken is a requirement for registration of all borewells in the state. However, to date, even these rules do not appear to be enforced.

Finally, in recent months, the BWSSB has completely stopped using water from TG Halli. In response to lawsuits, the High Court, in its environmental activism, has been focused on enforcing zoning within the TG Halli catchment, mainly to control pollution while also commissioning studies to 'rejuvenate' the river. However, the non-dependence on TG Halli, the fragmented jurisdictions, and the poor understanding of the hydrology means that nothing significant is really being done.

THE WAY FORWARD

Many of these changes occurring in the TG Halli catchment are difficult to regulate practically by public policy instruments, as they are driven by private decisions of lakhs of land owners. Moreover, a number of agencies are in charge of different interconnected components of the water resources in the region. These agencies each respond to their own mandates, and have different understandings of the system depending on their training and stakeholder interests.

Given this complex reality, what is the way forward? There are no simple answers. The science tells us that groundwater over-extraction, watershed interventions such as check dams, and indiscriminate land-cover change to eucalyptus are inevitably going to reduce downstream flows. But who gets to decide who has a greater right on the water—upstream farmers (who are growing vegetables for the city or flowers for export), or downstream Bengaluru (which already gets a lot of water from the Cauvery)? Even if Bengaluru gives up its claim to surface flows, what about small towns whose municipal borewells are

TG Halli catchment is dotted with dry dug wells like this one. (Photo: T. Zuhail)

drying up, or small farmers who cannot afford to drill to 300 m? What is needed is a public consultation (either under the aegis of a single watershed authority, or a joint meeting with all relevant agencies) that makes these trade-offs clear. Such a consultation must negotiate a vision for the TG Halli reservoir and catchment that is acceptable to all stakeholders. Then all agencies must execute rules that are consistent with the common vision.

Further reading

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