

RESEARCH ARTICLE

# Making water flow in Bengaluru: planning for the resilience of water supply in a semi-arid city

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**Abstract:** The south Indian city of Bengaluru (formerly Bangalore) has a long history of human occupation. Today as one of the fastest growing cities in the world, Bengaluru is unusual in the fact that it is an old city, located at a distance from perennial sources of fresh water. While in the precolonial past, it depended upon an interconnected system of rainwater harvesting via lakes and wells, today it relies on water that is pumped from a river at a distance of over 100 km.

This paper traces the evolution of Bengaluru's water supply infrastructure from the precolonial past into the present day. We posit that the shift of the city's dependence on water from local to distant sources, with the advent of technology and the introduction of centralized piped water, has weakened local residents' and policy makers' awareness of the importance of conservation of local ecosystems. The resulting degradation and conversion of the city's water bodies has reduced the resilience of Bengaluru to flooding and drought, especially affecting the poorest and most vulnerable of its residents. The disruption of the links between water and other forms of commons, including grazing lands, fishing areas and wooded groves, has further fragmented the once-organic connection between the city and its ecosystems, with widespread construction on wetlands leading to flooding and water scarcity in different seasons. In an era of increasing climate change, cities in semi-arid environments such as Bengaluru will be hit by problems of water scarcity. We stress the need to develop an integrated perspective that considers the importance of local ecosystems as commons for increased urban resilience.

**Keywords:** lakes, wells, resilience, urban infrastructure

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## 1 Introduction

Urbanization is taking place at increasingly rapid rates of progression, leading to largescale transformations in land use and land cover across the world<sup>[1]</sup>. The rapid growth of cities has led to a host of environmental challenges, of which water scarcity is one of the most apparent and widespread<sup>[2]</sup>.

Challenges of water availability and access are especially pronounced in the context of developing countries such as India, given the high population density and inequity in access to resources<sup>[3]</sup>. Cities in India today face frequent challenges of droughts leading to frequent conditions of water scarcity<sup>[4]</sup>. Water therefore becomes a highly contested resource, creating massive conflicts and disputes both locally as well as regionally over its management and appropriation<sup>[5]</sup>. An example of one such

conflict is the ongoing Cauvery Water Dispute between the south Indian states of Karnataka and Tamil Nadu over the waters of the river Cauvery<sup>[5]</sup>. In such cases, while states and bureaucracies are engaged in legal battles over water, the most affected are marginalized communities for whom water represents lives and livelihoods<sup>[6]</sup>. At the same time, with increased focus on meeting the demands of their rapidly increasing demographics, cities have over time forgotten traditional methods of water storage, harvesting, and recharge<sup>[7]</sup>. Many traditional water storage and harvesting structures across the country thus have been dismantled, built over, or degraded. Examples include the massive, ornate stepwells (*baolis*) scattered throughout north and central India, the tanks dotting the south, and open wells across the country<sup>[7]</sup>. They are unable to perform their role in enhancing the water security of the landscape of which they were once an integral part<sup>[7]</sup>. Fur-

thermore, the social capital of communities once centred on water harvesting systems and other forms of associated commons such as grazing lands and wooded groves has been disrupted, affecting the lifestyles of communities dependent upon them<sup>[8]</sup>.

This paper is focused on the city of Bengaluru (formerly Bangalore), in the south Indian state of Karnataka. Known famously as the Garden City of India, and internationally known for its Information Technology industry, Bengaluru is located in a semi-arid region, distant from large rivers, and faces frequent challenges of acute water shortage<sup>[9]</sup>. Yet, it has also been a city with a long history of settlement<sup>[10,11]</sup>. How did the city survive and grow in a water-scarce landscape, and what lessons can we learn from its past that may be relevant for its resilience today? Through a narrative of changes in the history of water supply in Bengaluru from its precolonial past to the present day, we examine these questions.

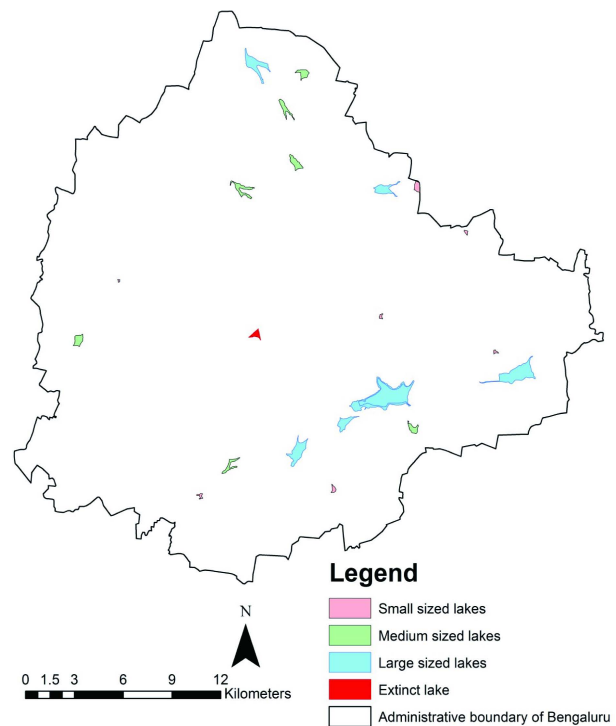
## 2 Methods

We conducted detailed analysis of archival records and historical maps from the Karnataka State Archives in Bengaluru, the Divisional Archives in Mysuru, the Mythic Society of India in Bengaluru, and the British Library in London. We also conducted field research on the current uses of commons, with semi-structured interviews of commons users to understand recent changes in access and usage.

Drawing on old maps, we examined changes in lakes in the older parts of Bengaluru from the late 19th century to current times. The “Map of Bangalore Cantonment and its Environs for the Year 1884–1885” was referenced from the Mythic Society of India, Bengaluru. The “Bangalore Guide Map for the year 1935–1936”, published by the Survey of India in 1935, was obtained from the Indian Institute of World Culture, Bengaluru. 1 : 25,000 scale topographic maps dating to the 1970s were obtained from the Survey of India’s Bengaluru Office. All maps were scanned, georeferenced to Google Earth images, and then digitised to look at changes in the number and extent of lakes.

Field research was conducted around 21 lakes around the city, some of which are no longer extant over three years, *i.e.*, from 2012 to 2015. The lakes were chosen using a process of stratified sampling across gradients of size. They were distributed across the city and ranged from those located within its core to those situated in its peripheral peri-urban zones. [Figure 1](#) shows the location of each of these study sites as located within the current administrative boundaries of the city. At each lake, we recorded the social and ecological uses through a combination of field observations, archival literature, and interviews with resource users. The archival material

we used for the study was obtained from the holdings of the Karnataka State Archives in Bengaluru, the Divisional Archives in Mysuru, and the British Library in London. The material analysed covered the period between the late 18th century (about 1799 CE onwards) and the year 1935. These files consisted of government records of use, regulation, and conflicts surrounding water bodies within the city.



**Figure 1.** Map showing the study sites within administrative boundary of Bengaluru.

They also detailed various schemes – proposed and implemented – to provide water for Bengaluru. Additional historical information was obtained by consulting secondary sources of information in the form of old school magazines and records of speeches made by former ministers of the colonial city.

The former were obtained through internet-based searches, while the latter from the collections of the Mythic Society, Bengaluru. We also conducted oral history interviews with communities living around each lake to understand changes they perceived in their relations with the water bodies over time. A description of each of these 21 lakes is provided in [Table 1](#).

A total of 129 such interviews were conducted around the study sites to arrive at the results we present here. As the focus of our study was the history of use and change around water bodies, we conducted interviews with elderly members of communities living around the lake selected through a process of snowball sampling where one

**Table 1.** Characteristics of study area.

Name of lake	Area (Acres)	Size*	Degree of urbanity	Level of pollution	Governance of lake	Managing Authority**
Pillappanakatte	3.48	S	Low	High	Public	Unknown
Thubarahalli lake	8.46	S	Medium	Medium	Public	BDA
Bhattarahalli lake	8.91	S	Medium	Medium	Public	BDA
Kelaginakere lake	10.01	S	Low	Medium	Leased	BBMP
Doddakallasandra lake	13.30	S	Low	Medium	Public	BDA
Nyaayanayakanahalli	18.82	S	Low	High	Public	BDA
Rampura lake	42.24	S	Medium	High	Public	BDA
Sawl <i>kere</i>	50.35	M	High	Low	Public	BBMP
Sarakki lake	52.84	M	High	High	Public	BDA
Kogilu lake	60.05	M	Low	Low	Public	BBMP
Jakkur lake	61.87	M	Medium	Low	Public	BDA
Mallathalli lake	67.56	M	Low	Medium	Public	BDA
Rachenahalli lake	76.43	M	Medium	Medium	Public	BDA
Hebbal lake	89.09	M	High	Medium	Private	LDA
Madivala lake	99.40	L	High	Medium	Public	FD
Kalkere lake	117.22	L	Medium	High	Public	BBMP
Agara lake	193.70	L	High	Medium	Private	LDA
Yelahanka lake	196.66	L	High	Medium	Public	BBMP
Varthur lake	376.57	L	High	High	Public	BDA
Bellandur lake	829.02	L	High	High	Public	BDA
Sampangi lake	NA***	NA	High	NA	Converted into built space	Department of Youth Services and Sports, Karnataka

\*S = Small sized lakes; M = Medium sized lakes; and L = Large sized lakes

\*LDA = Lake Development Authority; BDA = Bangalore Development Authority; BBMP = Bruhat Bengaluru Mahanagara Palike; and FD = Forest Department

\*\* NA = Not applicable as lake has been converted into a built space

interviewee would direct us to the next. During these interviews, we asked the interviewees what they remembered of the inception and use of the lakes, changes perceived in the quality and utility of the resource as well as perceived causes for these changes. We also examined how communities perceived themselves as having been affected by landscape transformations around each lake. At each study site, our interviews were supplemented with field observations made through field visits conducted over two seasons (pre-monsoon and post-monsoon). Adopting this mixed-methods approach, we were able to trace out the various provisioning and cultural dependencies communities have formed around lakes in the city of Bengaluru.

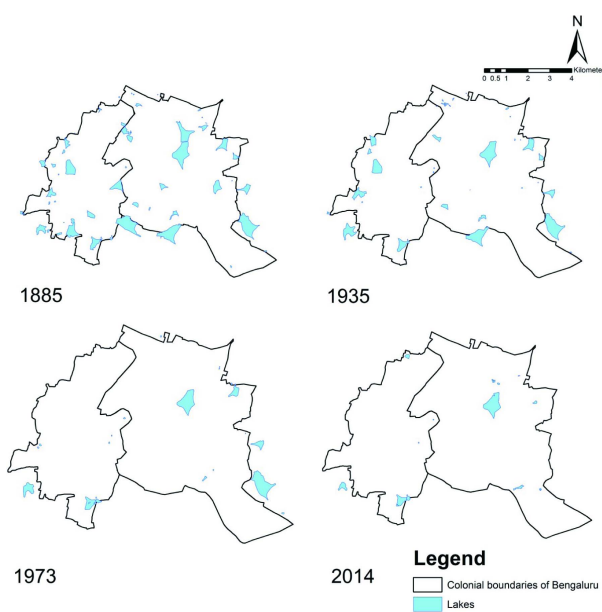
### 3 Results

Figure 2 shows the changes in the distribution of traditional water bodies (lakes) within the area covered by the older parts of Bengaluru city (colonial Bengaluru) between the years 1885 and 2014. It shows that the number

of lakes has drastically reduced in the intervening years.

Epigraphic inscriptions discovered around the city reveal that the landscape surrounding present day Bengaluru was ruled from about the 6th Century AD by a succession of dynasties including the Gangas, Cholas, Pallavas, Hoysalas and the Vijayanagaras<sup>[11]</sup>. These dynasties placed great economic, spiritual, and cultural importance on exploiting the undulating terrain to harvest rainwater from seasonal rivulets and streams in the form of networked cascading reservoirs – tanks or lakes – to capture and provide rainwater to local communities<sup>[12]</sup>.

Great importance was attached to their management and upkeep, with inscriptions listing a number of curses aimed at discouraging potential violators<sup>[10]</sup>. Lakes were connected in networks along topographic gradients, with water flowing from upstream lakes to those located downstream at lower elevations, via storm water channels (locally known as *kaluves*)<sup>[12]</sup>. A semiarid landscape covered by thorny scrub was thus transformed into a fertile irrigated landscape with paddy fields, fruit, and flowering orchards, large herds of cattle, and thriving village



**Figure 2.** Changes in the distribution of lakes within the colonial boundaries of Bengaluru between the years 1885 and 2014.

settlements, by the design of interconnected rainwater harvesting systems.

The market town of Bengaluru was founded in 1536 AD by a local chieftain Kempe Gowda<sup>[10]</sup>. Kempe Gowda and his successors are credited with the construction of a number of new lakes across the city, some of which still survive to the present day. To supplement the water in lakes, a number of smaller tanks – *kalyanis* – and massive open wells were constructed, which connected to the shallow ground water table recharged by the lakes on the surface<sup>[10]</sup>. These water bodies were managed as commons and community life revolved around them<sup>[8]</sup>.

Each lake was connected to one or more local areas that jointly undertook the responsibility of its maintenance and upkeep. Rules governed the access, appropriation, and management of these resources bearing in mind the various dependencies associated with the water body as well as the number of dependents<sup>[12]</sup>. Both archival as well as oral histories have shown that water from the lake was used for various purposes – irrigation, brick making, laundering, fishing, domestic needs, and drinking. Grass and green leafy vegetables growing on the banks of the lake were harvested for use as fodder and food respectively<sup>[8]</sup>. Our interviewees recall that certain plants, chief among which was called the *Onagane soppu* (*Alternanthera sessilis*) were particularly harvested as a nutritional supplement in times of drought. They also recalled that the banks of the lake provided a space for livestock grazing and the dung so left behind was collected both for fuel and manure. In the case of the Hebbal lake particularly, interviewees remembered the intense competition with which

local women would reach the lake in order to collect cow dung. Some of the collected resource was used to meet subsistence needs, while the rest contributed to increasing the income generated by the family. Irrigation too was regulated around the lake by means of manual sluice gates operated by specific members of the community (the *neer-ganti* or the village waterman) who also monitored levels of water in the lake<sup>[12,13]</sup>.

Lakes were further associated with a number of other commons integral to the lifestyles of village communities. Wooded groves or *gundathopes* planted with fruit trees were situated in close proximity to lakes and they provided shade and shelter both to nomadic tribes as well as the livestock herders of the village associated with the water body<sup>[3,8,14]</sup>. Water is held sacred in many communities and therefore cemeteries or burial grounds for both humans and livestock were situated close to lakes. Our field studies have documented the continued presence of some or all of these structures in the immediate vicinity of the extant lakes we have studied. *Gomalas* or grazing commons were also part of the commons associated with water bodies<sup>[13]</sup>. The strong ties communities built around their water resources were further reflected in the cultural traditions that revolved around water bodies, many of which continue into the present day<sup>[3,15]</sup>. These traditions included various forms of worship of female deities associated with water bodies<sup>[3]</sup>, rituals related to flooding and overflow cycles of the water body such as the *Gange Pooje* (a tradition where numerous oil lamps were lit and set afloat on the lake during its first overflow of the year)<sup>[16]</sup>, and festivals such as the Karaga<sup>[15]</sup>.

In 1799 AD, after the defeat of the ruler Tipu Sultan, the city of Bengaluru passed into the hands of the British<sup>[10,17]</sup>. At this point in time, lakes and wells still formed the primary source of water for the population, and agriculture was one of the primary occupations<sup>[18]</sup>. Thus, narratives of the time describe how advancing armies were deterred or slowed down by the presence of vast flooded marshlands and paddy fields in their path<sup>[15]</sup>. The British regiments established the Cantonment in 1807 AD, to the east of the then existing city limits. From 1831, the British established direct rule over Bengaluru until 1881, when they signed an agreement of Rendition with the Wodeyar rulers of the Mysore State<sup>[16]</sup>. The city was then divided into two zones – the British governed Cantonment and the native city or the *Pete*, managed under the jurisdiction of the Mysore state.

Lakes and open wells continued to meet the water needs of this increased population, with the Cantonment and *Pete* sharing resources from certain lakes dotting the cityscape<sup>[18]</sup>. Yet, it was also around this time that sewerage systems of the city directed their contents into some of the city lakes (which were not used for the supply of water), heralding an era where lakes began to be contaminated in different forms<sup>[19]</sup>. In 1830 AD, with a view to

improving the water supply of the city, various lakes began to see restoration attempts to rectify damages caused due to prolonged conditions of war<sup>[20]</sup>. Between 1873 and 1882, new tanks such as the Millers tanks and the Sankey tank were constructed to augment existing water supply following conditions of drought and famine in the preceding years<sup>[21]</sup>. The Mysore Gazetteer of 1897 records an impressive number of 2,388 government tanks, 16,725 wells and 254 canals present within the District of Bangalore<sup>[18]</sup>. Yet, this supply of water was insufficient for the city, which experienced a number of successive years of drought towards the late 1880s. The city started looking beyond its local boundaries to meet its water needs. The year 1895 AD saw the introduction of piped water from the Hesarghatta reservoir (artificially created by damming the river Arkavathi), about 13 miles to the northwest of the city<sup>[18,20]</sup>. Three additional lakes – the Kakol, Byate and the Yellemallappachetty – were further created in the outskirts of the city<sup>[3]</sup>.

The introduction of piped water to the city from a distant reservoir heralded a new era in how lakes within the city began to be perceived and used. Lakes now (keeping with the dominant colonial ethic of recreation and aesthetics) began to be seen as picturesque spaces for recreation, exercise, and nature appreciation<sup>[16]</sup>. Uses of the water body that were perceived to spoil the beauty of the landscape were prohibited. Examples include the extraction of mud from the lake for purposes of brick making and the excavation of wells around the water body<sup>[22]</sup>. In the case of Sampangi Lake, for instance, our interviewees remembered that uses such as grazing cattle on the banks of the lake, washing clothes and collecting fodder grass began to be regulated by uniformed guards stationed around the water body<sup>[16]</sup>.

Our research into the social ecological history of the Sampangi Lake has revealed that the deepening of the lake to provide additional water to agriculturists began to be seen as a potential threat to the low-lying bungalows and establishments that had sprung up around it by the year 1904 AD<sup>[16]</sup>. While such activities sparked protests among the farmers and horticulturists<sup>[16]</sup>, they also saw people gradually distancing themselves from both the maintenance of the water body as well as their dependencies on it. Interviewees recalled that migration of resource-dependent communities became widespread, and such areas began to be repurposed in creating newer settlements either to house the landless poor or the urban middle classes<sup>[16]</sup>. The lake began to become more polluted with the constant inflow of sewage. Its seasonality was lost and it became a perennial pool of sewage, whose only value now lay in fishing and extraction of fodder. Consequently, cultural traditions associated with the water body too began to dwindle, with many water-based traditions becoming mere memories. Significant portions of the lake were drained and used in many ways such as

for compensatory efforts, or for use as polo grounds<sup>[16]</sup>. Lakes, in general, also began to be perceived as breeding spaces for mosquitoes<sup>[23]</sup>. While these changes were occurring, the most affected individuals included those whose livelihoods depended upon the water body such as the farmer, the fisherman, and the pastoralist<sup>[16]</sup>. These people were deprived of a formerly important resource, further enhancing their ongoing disconnect from lakes. Interviewees around the Sampangi lake recalled that many horticulturists migrated away from the resource, leaving behind space for newer settlers to occupy. These new settlements however did not share the same utilitarian or cultural connect with the water body as their predecessors, further influencing the decline of the social-ecological system.

The years 1925 and 1926 saw the failure of two consecutive monsoons, plunging the city into conditions of severe drought<sup>[22]</sup>. This necessitated augmenting the existing water infrastructure, resulting in the construction of the Thippegonanahalli reservoir in the outskirts of the city<sup>[17]</sup>. Lakes and wells within the city fell into further disuse with many water bodies drying and in some cases (such as the Sampangi) being used as playgrounds or as spaces to conduct cattle fairs, and carnivals<sup>[16,24]</sup>. In other parts of the state, lakes began to be seen as spaces within which to develop public amenities such as stadiums and bus terminals – a trend which began to be repeated within Bengaluru as well<sup>[22]</sup>. Existing lakes were either converted into residential and resettlement sites, or public amenities such as sports stadiums, forever destroying the deeply ecological character of these resources.

This trend of converting water bodies into built spaces continued well after India gained independence in 1947. Lakes were either seen as aesthetic adornments to the landscapes or as barren spaces suited to meeting the housing needs of a growing city<sup>[25]</sup>. Water supply continued to be sourced from the Thippegonanahalli and Hesarghatta reservoirs until about the year 1969<sup>[26]</sup>. With the formation of the Bangalore Water Supply and Sewerage Board (BWSSB) in 1964 and the inception of the Cauvery Water Supply Scheme in the year 1969 (currently ongoing in several stages), Bengaluru shifted its entire water dependency upon the river Cauvery, located at a distance of over 100 km from the city, at a lower elevation<sup>[26]</sup>. A number of lakes were further drained as part of efforts aimed at malaria eradication, and converted into malls, bus stands, and stadiums<sup>[27–29]</sup>. In some of these places today, there exists a collective memory of the lake having been part of the landscape (examples include the Sampangi Lake, and the Koramangala Lake). However, in others, we found it immensely challenging to find interviewees who recalled the presence of the water body, or remember its name (examples include field interviews conducted around Neelastandra and Byappanahalli regions of Bengaluru).

By about 1985, local residents, particularly in and

around the heart of the city (Bellandur, Varthur and Agara lakes, to name a few) recall that their lakes had become nothing more than sewerage collection units. They had become extremely polluted not just with the entry of sewage into their depths but also industrial and chemically laden agricultural runoff (such as around the Yelahanka Lake). Lakes no longer met the drinking water needs of communities dependent upon them, except in some cases (such as Kalkere Lake) where wandering pastoralists consume the heavily polluted water even today. Domestic uses such as bathing and washing vessels also ceased around most of these lakes<sup>[30]</sup>. Pastoralism, brick making, and commercial laundering of clothes are examples of traditional livelihoods that have persisted into the present day, albeit in small pockets of the urban landscape. Connectivity between lakes was lost due to encroachments and building over of the channels that connected various lakes. In addition, the seasonality of lakes was lost because of the perennial inflow of sewage into the lakes. Both these activities led to the stagnation and further pollution of the once flowing water in these lakes. In such places, older residents are able to point out specific locations where former channels leading into and out of the lakes used to flow, as well as those of the village groves and grazing commons. In the case of the Bhattarahalli Lake, residents have even resorted to using legal instruments to reclaim some of their urban commons, though with little success.

Uses of lakes that were dependent upon the seasonality of lakes too halted. Rapid urbanization that took place around most lakes within the urban and periurban landscapes of the city further reduced agricultural dependency upon lakes<sup>[30]</sup>. The polluted status of lakes, especially from about 2000 to mid-2014 has discouraged fishing around some of these lakes. Interviews we conducted around some of these lakes (Rampura Lake, Bellandur Lake, and Pillappanakatte) reveal a sense of loss within former fishing communities when they spot fishes (some of them weighing over 7 kilograms) swimming within the murky depths, but are unable to harvest them to supplement their regular incomes.

Around this point in time, responsibility for the maintenance and upkeep of lakes rested entirely upon the state. Furthermore, around the early 2000s, certain lakes within the study area underwent differing processes of enclosure such as leasing out for maintenance (Kelaginakere), creation of public parks with paid entry (Madivala Lake) and Public Private Partnerships (PPPs) (Hebbal and Agara lakes). Such undertakings have reduced the more utilitarian and spiritual dependencies built around the water bodies. At the same time, they actively encourage middle-class and bourgeois notions of aesthetics and recreation, unwittingly excluding a significant population of ecosystem users from the resource. Another way in which resource dependents have been alienated are the restrictions on timing, patrolling by home guards and active discour-

agement of traditional activities introduced after state led or community led rejuvenation in many lakes. Interviewees recall that these changes imposed restrictions upon traditional users in the form of gated entry, fences, and levy of entry charges and the boom of middle to upper middle class real estate around them. Along with these restrictions, development of the enclosed lakes has proceeded with strong emphasis on building the aesthetic and recreational value of the water body.

These dominant perceptions favouring aesthetics and recreational value for water bodies have inherently distanced traditional livelihoods such as brick making and pastoralism, which were seen to be against that ethic. Villagers around each of these lakes reported a strong disconnect from the water body, so much so that formerly integral cultural practices around the water body were also discontinued. In addition, people hesitate to go near the lake or its perimeter, while expressing a feeling of being powerless to effect any change. Also, in the case of certain lakes, informal, unmanned entry points are used by some traditional users to derive certain provisioning ecosystem services (such as fodder grass), though with a high risk of eviction from the premises.

This trend of distancing long-term village residents from their lakes has continued into the present day. While leasing out of lakes and PPPs has been discontinued mostly due to citizen led protests against these practices<sup>[31]</sup>, newer forms of enclosure continue to omit traditional users from accessing benefits from these water bodies. Due to the high levels of pollution, many lakes in the study area (examples include Rampura, Bellandur, and Varthur lakes) were covered by froth from detergents used by city residents. In these lakes, pastoralism and the collection of fodder grass from lakes has been adversely impacted.

In the last decade, great attention has been paid to the condition of lakes within the city, especially with focus on their aesthetic potential. Further, at the level of legislations too, action has been taken to clear lakes of encroachments and unauthorized construction around water bodies. Keeping with this larger climate of attention to water bodies, the city has seen the rise of many localized lake protection groups comprising of middle to upper middle class urban residents living around lakes. At the other end of the spectrum are state led rejuvenation efforts which seek to divert sewage away from lakes, and develop them into aesthetically appealing lung spaces for the city. Through interactions between these two groups, certain lakes (such as Kogilu, Sawlkere, and Rachenahalli lakes) have been earmarked for rejuvenation and subsequent maintenance. Building upon the ethic of enclosure, these lakes too have had treatments ranging from draining polluted water, dredging, and diversion of sewage. They have also been landscaped to include parks and jogging tracks, while being fenced and patrolled by home guards.

Restrictions are strictly imposed with respect to access into the water body except in the case of tender based fishing activities. Traditional occupations such as commercial laundering and grazing cattle are prohibited especially within the fenced perimeter of the lake. However, in some lakes, respondents are permitted to enter the lake (within the restrictions imposed on timing) and harvest fodder grass.

Our studies indicate that lakes closer to the urban centres have already distanced their traditional communities for the most part, while those in peri-urban regions are progressing steadily towards doing so. Increasing real estate around lakes, coupled with further losses in connectivity, and the gating of lakes has further widened the gap between communities and the formerly important resource.

## 4 Discussion

This paper demonstrates changes in the waterscape of the city of Bengaluru, both at the level of providing water to a city as well as the strong interpersonal relationships that people build with a source of water. It shows how as the city grew and expanded, it looked to ever-distant sources of water. In doing so, the connection to local sources of water was disrupted. Consequently, the perception and use of water bodies as local commons, on which people depended for subsistence, livelihoods, worship and recreation was altered. Lakes became considered as areas to be preserved for biodiversity, aesthetics, and recreation<sup>[3]</sup>. They have consequently evolved and transformed into their contemporary identities concomitant with changes in how they became used and imagined. Through the introduction and establishment of centralized piped water supply systems and the rapid pace of urbanization and migrations both into and out of the city, these spaces have come to be perceived through different lenses than what they were originally meant to be.

While lakes then began to be seen in these terms, benefiting only certain sections of the society (for whom aesthetics and recreation assumed great significance), it also affected the lives of the urban marginalized whose livelihoods depended upon the water body. This created a distancing of such communities from the resource, leading to neglect in its use and subsequent maintenance. Their vulnerability to development and urbanization increased, while at the same time reducing the city's capacity to deal with potential conditions of drought and flooding during extreme weather events.

## 5 Conclusion

While this study focuses on lakes in the city of Bengaluru, insights provided by this study are relevant to other urban ecosystem resources in cities across the globe, when the

local link between maintenance and use is disrupted. In documenting the complexity of this change and its implications for the present day, this study also underscores the importance of understanding the historical changes in the use of and governance of urban commons. It is clear that there is continued prioritization of certain forms of ecosystem uses from historical times into present day planning and policy mechanisms. Therefore, it becomes imperative that present day mechanisms of ecosystem governance should necessarily be guided by knowledge of how exclusionary regimes have operated in the past and how events of long ago have shaped and moulded the landscape of the present<sup>[16]</sup>.

The appropriation of and exclusion from urban commons highlighted in this study is supported by examples from other cities of India as well<sup>[32-35]</sup>. We argue that, given the diverse threats to continued and equitable distribution benefits from the urban commons, there needs to be increased policy attention to dealing with contemporary management regimes that exacerbate exclusion. Democratic governance of urban commons has to be socially just, inclusive, and must take close cognizance of the diverse uses and values among all residents of the city.

On a broader level, lakes and associated water bodies (wells, stepwells and smaller *kalyanis* or tanks) have been integral to maintaining the water security of the city for centuries. Today, the city relies upon water sourced from distant rivers and reservoirs to meet its needs, while a potential local source of water has become polluted, dried up or been removed due to the pressures of urbanization<sup>[3]</sup>. At the same time, some studies have forecasted that the city is likely to run out of water in the coming decades<sup>[36]</sup>. Given these grim prospects, we need to better understand the processes of change and the factors we need to consider in order to reverse the process<sup>[3]</sup>. A city's innate resilience lies in its ability to absorb changes without losing its integrity in form or function<sup>[37]</sup>. It depends upon the capacity of the system to retain, adapt, and strengthen its inherent strengths, while at the same time providing an opportunity for reorganization and memory<sup>[38,39]</sup>. The availability of water is an important element integral to enhancing the resilience of any cityscape. Bengaluru, with its extreme dependence on water from the distant Cauvery, is ill prepared to deal with adverse changes in water availability because of excessive use, and depletion in availability. Yet, as our research has shown, traditional water bodies such as lakes continue to remain dynamic spaces that are integral to supporting a wide variety of lives and livelihoods. Making Bengaluru resilient to water risks will require preserving both the ecological and social importance of the resource. Encouraging the diverse and inclusive utilitarian uses of such resources (thereby creating value for the resource), will help encourage the retention of value associated with the remainder of the city's lakes, wells, and wetland systems along with other

distant sources of water. The current trend of unintentionally alienating communities from formerly integral resources places into question the feasibility of community led stewardship of these resources – an important step towards enhancing ecosystem resilience. In other words, fostering local collective participation towards sustaining and protecting both ecological and social values of a resource can go a long way in enhancing the resilience of the system<sup>[38]</sup>. While the city has witnessed numerous movements towards collective management of its water bodies (particularly its lakes)<sup>[40]</sup>, these efforts have mostly been spearheaded by the middle and upper classes of the society, for whom the lake ecosystem represents mostly an aesthetic and recreational resource. Including marginalized communities for whom water bodies represent more utilitarian benefits thus poses a potential challenge and has received limited success (barring a few examples such as Kaikondrahalli and Jakkur lakes)<sup>[41,42]</sup>. In this context, adaptive management<sup>[43]</sup> of urban commons that involves incorporating local knowledge into policy and planning, and fostering collaborations between citizens and administrators has contributed to resilience building in other cities of the global South<sup>[44,45]</sup>. The decentralised governance structure for Indian cities has the potential to foster adaptive management, but this is not happening at present to the extent required.

On one hand, restoring the former waterscape of the city of Bengaluru to provide a means to supplement its water resources remains unlikely owing to challenges in the form of rising populations, geographical spread, and massive changes in land use. On the other hand, it is imperative that surviving water bodies be focused upon in terms of ecosystem rejuvenation and promoting inclusivity in its access and appropriation. Such measures can only be feasible if the physical and cultural dependencies formed around the resource are thoroughly researched and understood. To do so would require historically and contextually sound understanding of the landscape coupled with massive effort in reconceptualising the space as being more inclusive and equitable. This requires long-term engagement with local residents around lakes, working with a diverse array of stakeholders from different sections of society with differing conceptions of, and dependencies on lakes, to understand how they envision the future development and restoration of these lakes, and towards what goals. Such a collective envisioning would be the first step in a process of reclaiming collective rights to the city<sup>[46]</sup>, and redefining lakes as urban commons thus enabling stewarding efforts to sustain these lake landscapes over the long term. This in parallel can support ecosystem functions such as groundwater recharge thereby enhancing water security and eventual resilience of the cityscape.

## Author Contributions

HU, SM and HN conceived and designed the research, analysed the archival datasets and wrote the paper; HU conducted the field work and prepared the maps.

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