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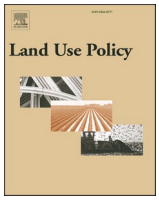

Integrating blue-green infrastructure in urban planning for climate adaptation: Lessons from Chennai and Kochi, India

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ABSTRACT

Nature-based solutions, such as reviving blue-green infrastructure (BGI), for climate adaptation in cities have been gaining global attention. In the case of India, the rapid urbanization since the end of the twentieth century has exacerbated the impact of climate change at significant environmental, social, and economic costs. Coastal cities in India commonly face climate change related hazards of flooding, rise in sea level, and urban heat islands. This article has assessed the usefulness of scientific information and community knowledge in planning, reviving, and maintaining BGI to make it a successful climate adaptation practice in coastal cities. The existing waterways and water bodies in India's coastal cities are a network linked to the green infrastructure that has been altered by sprawling urbanization. In response to Sustainable Development Goals 11 and 13, the cities of Kochi and Chennai have begun a process of recovering their BGI for greater resilience. This research has detected a shift in the social and administrative perception of BGI as a valuable resource for climate adaptation in recent times. Actions in backwaters and canals, promoted by Chennai and Kochi municipal corporations, present new steps toward mainstreaming adaptation of BGI into the local regulatory framework.

1. Introduction

Cities and human settlements, due to their exposure and vulnerability, have taken centerstage in the contemporary debate on the impacts of climate change and adaptation strategies that condition urban and regional planning (Martos et al., 2016; Göpfert et al., 2019). Globally, nature-based solutions have emerged as a key mechanism for climate change adaptation in urban areas (Frantzeskaki et al., 2019). Urban communities have realized the climate risks and, consequently, there has been increasing public support for nature-based solutions (Badura et al., 2021). Blue-green infrastructure (BGI) can be described as an interconnected network of natural and designed landscape components, including water bodies such as rivers, creeks, lakes, and green spaces like parks and marshlands (Ghofrani et al., 2017). BGI provides multiple functions such as water storage for irrigation and industry use, flood control, wildlife habitat, and recreation space that are identified as important nature-based solutions for climate adaptation in urban areas (Ghofrani et al., 2017; Govindarajulu, 2014).

In many cities of the Global North, the redevelopment of BGI has been identified as a key strategy for climate adaptation. For instance, Lisbon, which faces risks of flooding and the urban heat island effect, has integrated the ecological structure of the city into its Master Plan (PDM Lisboa, 2020). Copenhagen has developed flood-control projects in Sankt Jørgens Lake and the Sydhavnen Canal by identifying the direct impact of BGI on urban planning (Hvilshøj et al., 2016). In the United States, Fort Lauderdale, Florida, has identified Adaptation Action Areas as zones that are susceptible to flooding and defined the same in its Master Plan, promoting a green management of these areas (García, 2019; City of Fort Lauderdale, 2022, pp. 273–284). Programs to strengthen green infrastructure and mainstreaming the same into urban planning have been promoted by New York in recent years, with changes in ordinances for greater resilience (García et al., 2018; NYC, 2019).

In the cities of the Global South, which face rapid urbanization and increasing climate risks, climate adaptation and resilience measures have continued to lag behind. Furthermore, the integration of BGI as a nature-based solution for climate adaptation has still been lacking (Ghofrani et al., 2017; Khajooria and Kumar, 2017; Pauleit et al., 2021).

In India, average annual temperature has risen in several cities

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(Jaganathan and Andimuthu, 2013; Kothawale et al., 2016) due to climate change, leading to droughts, water scarcity, and urban heat islands (Veena et al., 2020). Floods associated with climate change in cities such as Mumbai, Chennai and Bengaluru have caused severe damage (Revi, 2008; Guhathakurta et al., 2011; Rafiq et al., 2016), especially during the monsoons, i.e., the months of June–September and October–December (Gupta, 2020). A rise in sea level has also impacted many coastal cities in India, such as Mumbai (Pramanik, 2017), Chennai (Ramachandran et al., 2017) and Kochi (Murali and Kumar, 2015). Growth in population and changes in land use, including the conversion of wetlands into residential, commercial, and industrial land use (Sadashivam and Tabassu, 2016; Avashia and Garg, 2020) have further exacerbated climate-related risks in Indian cities (Ranger et al., 2011; Gupta, 2020).

The 74th Constitutional Amendment Act (1992) of India was a milestone for urban development and governance in Indian cities. The amendment led to the creation of elected urban local bodies (ULBs) as part of a decentralized system for city planning and service provision, which paved the way for people's participation in urban governance (Batra, 2009; Sharma and Tomar, 2010). The ULBs are municipal corporations in large cities and municipality in small cities. Other urban institutions like the City Development Authority, and the Department of Town and Country Planning are also empowered under different legislations for urban development, planning, and governance in India.

However, these institutions were largely unable to properly respond to climate-related risks in Indian cities, mainly due to the lack of technical knowledge on climate risks and resilience planning (Karanth and Archer, 2014; Khosla and Bhardwaj, 2018). Moreover, urban governance remains weak in many cities as administrative powers are not transferred from the State to ULBs despite the constitutional amendment in 1992.

BGI used to be well protected, conserved, and managed in India's cities before and during the colonial period. However, the unplanned growth of Indian cities has reversed their existing resilience capacity to floods and water logging, as BGI has lost ground to urbanization (Mukherjee and Madapala, 2018). Earlier urban planning practices in India lacked guidelines to integrate land and water into Master Plans and missed out the spatial analysis and requirements of buffer blue-green areas against climate change impacts (Kumar et al., 2017; Ramaiah and Avtar, 2019). However, after 2014, with the increased exposure of cities to climate risks, new planning guidelines and national level missions have led a few Indian cities to integrate BGI into their urban development plans as a climate adaptation measure.

The revised guidelines on urban and regional planning issued by the Ministry of Urban Development in 2015 have made it mandatory to plan land use after considering BGI, ecosystem-based approaches, and integration of resilience measures within urban planning (GoI, 2015). Urban development programs like the Smart City Mission (GoI, 2015; NIUA, 2020) and the Atal Mission for Urban Rejuvenation and Transformation (AMRUT, 2015) also have strong provisions for the redevelopment of BGI. In addition to environmental regulations, it is significant for national governments to fund pilot schemes and restoration initiatives. AMRUT and the Smart City Mission (GoI, 2015; Mukherjee and Madapala, 2018) have already generated new interest and competition among cities to restore their BGI.

This article has analyzed the empirical evidence on the recent transitions made by two coastal cities, Kochi and Chennai, on reviving BGI and integrating it into their urban planning and redevelopment processes to build urban resilience. These two cities were affected by frequent urban floods and have developed new resilience initiatives focusing on BGI through their institutions. The main objective of this research has been to analyze the factors driving the shift in recovering BGI in these two cities for climate adaptation, and what it has meant for the development of regulatory changes aimed at greater urban resilience. This paper has also examined the role of community and municipal administration in the new initiatives to recover and restore BGI as adaptive measures against future climate risks. It has then drawn lessons for integrating BGI into urban planning for building urban resilience in other Indian and global coastal cities. Lessons from Indian case studies can become important knowledge addition on the subject for cities of the Global South (NCE, 2016). Moreover, Indian cities present an excellent opportunity to examine how BGI, as a nature-based solution, can help alleviate the climate risks in rapidly urbanizing cities.

2. Study cities

For this study, we selected two Indian coastal cities, Chennai and Kochi, which lie on India's east and west coasts, respectively, and have experienced rapid urbanization and increased climate risks. Chennai and Kochi were affected by severe floods in recent years, with the most severe ones being in 2015 and 2018, respectively. Further, both the cities have been vulnerable to extreme flooding events and rising sea levels. The review of Kochi's and Chennai's Master Plans and disaster management plans that were prepared before the flooding events showed that there was little to no integration of BGI as a climate adaptation measure (Govindarajulu, 2020). However, following the disastrous 2015 and 2018 floods in Chennai and Kochi, respectively, both cities have made progress in reviving and integrating BGI into their urban development.

To understand the effects of climate change in Chennai and Kochi, climate projections from published literatures for both cities are presented in Table 1. A notable increase in temperature is expected in both cities which will strengthen heat stress for the urban population. Rainfall is likely to decrease overall, but extreme storm events are expected more regularly. As for the rise in sea level, the projections are not precise, and vary between +20 cm and 1 m in height.

2.1. Chennai

Chennai is located on the east coast of India. The population of the urban agglomeration grew from 2.64 million in 1971 - 4.68 million in 2011 (Census, 2011). Its population is currently estimated to have exceeded 9.0 million (IIHS, 2018, p. 24) and will reach 14.0 million by 2030 according to the Census of India. Chennai has transformed from a commercial and manufacturing base to a growing information technology hub (Krishnamurthy and Desouza, 2015).

The economic growth of Chennai has contributed to urban agglomeration, spreading through the bordering municipalities, and growing from an earlier 176 sq. km. to 426 sq. km. in 2011 (IIHS, 2018). The built-up area increased by 20 % between 1997 and 2017, to reach 88 % of the entire surface area (IIHS, 2018). Several urban sectors were developed in the city's flood-prone areas leading to substantial declines of vegetation surfaces, open spaces, and water bodies (see Fig. 1).

Despite the progress made in recent years, Chennai lagged behind in urban infrastructure development and resilience planning. Its sewerage system and stormwater drainage capacity were much below the recommended norms set by the Ministry of Urban Affairs, Government of India (Gupta and Nair, 2011; Govindarajulu, 2020). Further, the shortage and lack of accessibility of affordable housing led to the

Table 1
Climate change projections by 2080: Chennai and Kochi (India).

City	Temperature		Sea Level Rise		Rainfall	
	Middle Range	High End	Middle Range	High End	Middle Range	Extreme Events
Chennai	+1.6°C to + 2.1°C	+4.1°C	+0.19 m.	+1.20 m.	-1 % to − 5 %	Yes
Kochi	+2°C to + 4.5°C	+4.6°C	+0.20 m.	+1.00 m.	-15 to − 20 %	Yes

Sources: CCC&AR and TNSCCC (2015); CMC (2019); State Government of Kerala (2014); Veena et al. (2020).

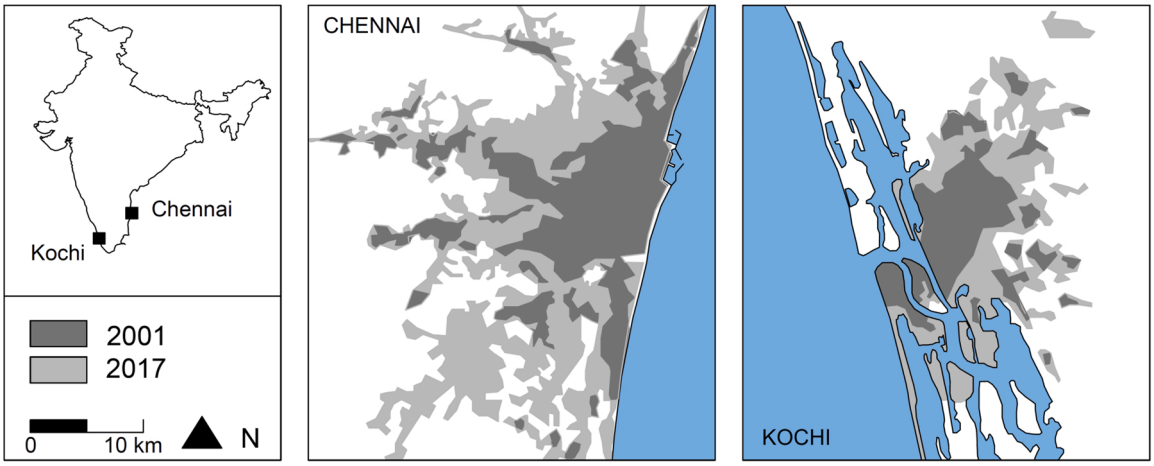

Fig. 1. Changes in urban growth, Chennai and Kochi 2001–2017. Compiled by authors based on IIHS (2018).

settlement of the urban poor along the city's high flood-risk areas like canals and river beds (Joerin et al., 2012, 2014) (see Fig. 2). As per the 2011 census, Chennai had fared poorly in household level civic services like drinking water supply and sewerage connections. Also, the per capita provision of urban green spaces of less than 1 sq. m. was much below the norms of 10–12 sq. m. recommended by the Government of India (Govindarajulu, 2014).

The BGI in Chennai began to be altered from 1876, when the Buckingham Canal was constructed and developed as a significant waterway. The canal was originally intended as a waterway transport that connected the backwater lakes and rivers across Chennai and beyond, and also served as an important storm water drainage for the city. The canal lost its waterway transport purpose around 1954 and large parts of the network became unusable with reduced drainage capacity (Gupta and Nair, 2011; Ramachandran et al., 2019). Adding to the city's woes, the rapid urbanization in the last two decades led to considerable loss of wetlands and changes in the city's drainage patterns including the drainage into Buckingham Canal (Srinivasan et al., 2013; Jameson and Baud, 2016).

2.2. Kochi

Kochi lies on the southwestern coast of India between the Malabar Coast and Vembanad Lake. The Kochi Municipal Corporation area is spread over 98 sq. km., with a population of 0.6 million (Census, 2011). The population in 2017 was estimated at 2.5 million (IIHS, 2018). During 1990–2000, urban expansion outgrew the boundaries of the city (Jayalakshmy and Mereena, 2016) (see Fig. 1). The developments spread through the arterial corridors, leaving small pockets of open spaces free of urbanization (ICLEI South Asia, 2020). Between 2001 and 2011, Kochi and its surrounding small towns witnessed a rapid population growth by over 30 % (ICLEI South Asia, 2020). Notably, Kochi is also a regional economic hub with several electronics/ information technology and related industries. Port activities also remain central to the region's economy. In fact, Kochi is one of the 12 major ports of India (GoI, 2019).

The urban pressure of central Kochi led to the occupancy of more than 90 % of the 78.31 sq. km. of terrestrial municipal surface (see Fig. 1). The total area of the backwaters under the jurisdiction of Kochi city is spread over 23.31 sq. km. Urban expansion has reduced this area, especially in the intraurban sectors, where inland backwaters, canals, marshes, and ponds currently occupy 7.25 % of the urban area (ICLEI South Asia, 2020). Like Chennai, Kochi filled up much of its available urban land with informal settlements that developed in its highly vulnerable areas (see Fig. 2).

Infrastructure development in Kochi was weak with a shortage of sewerage networks. The city had negligible storm drains, and only 5 % of the sewerage system was treated, while most of the storm water was allowed to flow into the existing canals and backwater networks (State Government of Kerala, 2010, 2014). Many of the intercity canals had reduced their water holding capacity due to encroachment, solid waste dumping, and siltation (Kumar et al., 2017). Low-lying areas, which cover large parts of the city, are highly vulnerable to floods, coastal erosion, and sea level rise (Sowmya et al., 2015). In 2018, Kochi faced its

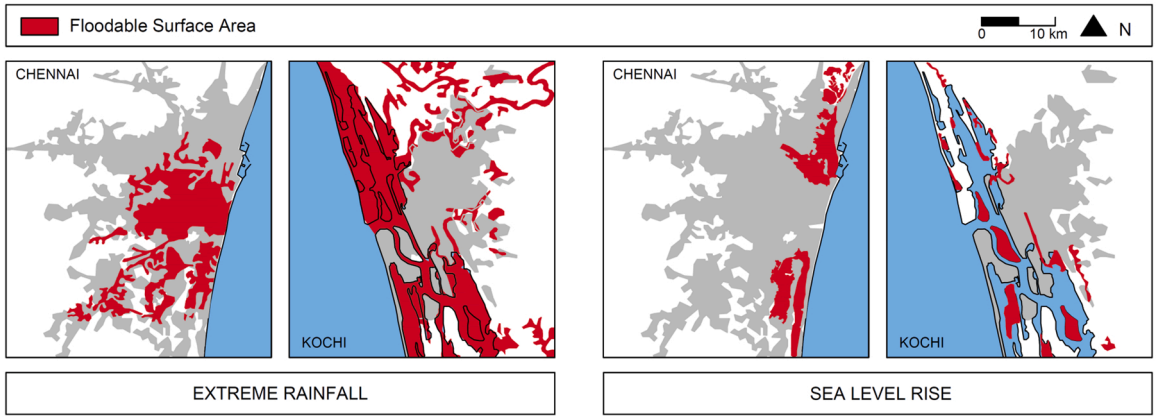

Fig. 2. Floodable zones due to rainfall and sea level rise (+ 1 m). Compiled by authors based on cartography elaborated by Care Earth Trust and Climate Central for Chennai; Murali and Kumar (2015); and Vishnu et al. (2019), for Kochi.

worst urban flood event, which led to severe economic losses with the Kochi Airport shutting down for two weeks (Madhukalya, 2018).

3. Methods

This research has been based on the analysis of the scientific literature and policy documents published by public institutions. The objective was to analyze the key factors that contributed to the shift in recognition and integration of BGI into the urban development and planning for climate resilience in Chennai and Kochi. The measures that these cities took up in response to the challenges they faced have been analyzed in this article to assess their advantages as climate-resilient actions. This article has examined the empirical evidence from the actions of the Chennai and Kochi ULBs as well as their interrelation for climate resilient urban development.

The key documentation for the analysis of Chennai included the Disaster Management Plan (2017), the Chennai Master Plan (2018), the Resilient Chennai Strategy (2019), and the Eyes on the Canal (2019). For Kochi, the analysis included the City Development Plan (2006, amended several years), the Development Plan for Kochi City Region, 2031 (2010), the Kerala State Action Plan on Climate Change (2014), the Local Biodiversity Strategy and Action Plan for Kochi Municipal Corporation (2020), and the EnteKochi initiative (2020).

Secondly, the primary information from scientific literature for the case studies included 12 peer-reviewed scientific articles for Chennai, and nine articles directly related to climate change, and adaptation policies and actions for Kochi. Relevant information was extracted from these papers to detect keys to the processes of change in the revaluation of BGI, relating them to the broader scientific literature on BGI and adaptation strategies, especially in the Global South. Other published secondary literature was reviewed and extracted, such as the state policy and planning documents and reports. Based on all the available information, the relationship between risk and resilience has been analyzed and discussed in this paper through BGI recovery projects and institutional transformation mechanisms towards resilient planning.

Two BGI recovery projects were selected for each case study—the Pallikaranai Marshland and Buckingham Canal in Chennai, and the Kadamakudy Wetlands and Mullassery Canal in Kochi. In both cases, we have examined local community participation and institutional actions in BGI recovery as a climate adaptation and resilience measure. We have done this by examining the project documents available in the respective city administration websites, as well as from published literature. We have used a discourse analysis approach to understand the contents of a policy document and examine how the interventions were initiated and implemented as well as to understand the role of local communities, scientific institutions, and municipal administration in those interventions. The discourse analysis approach has been widely used in studying urban policies and research (Jacobs, 2006). Such documentary review has allowed us to evaluate the role of BGI in climate change adaptation in Chennai and Kochi as well as the role of participatory approaches in integrating BGI into urban planning and development for climate adaptation. Finally, we have drawn key lessons from the case studies on integrating BGI into urban planning and development for climate adaptation.

A spatial analysis of both the cities, considering the various sources, complemented the quantitative data and qualitative assessments of the BGI, its evolution over time, and the most recent intervention proposals. Two risk maps were developed, based on the existing documentation (Figs. 1–3 for Chennai; and Figs. 1, 2 and 5 for Kochi). Flood maps that were previously obtained from Care Earth Trust and Climate Central for Chennai; Murali and Kumar (2015) and Vishnu et al. (2019), for Kochi, have been scanned and printed. The limits of the areas identified as flood areas have been digitized in CAD system, both due to extreme precipitation and sea level rise. The cartography has been superimposed on the same graph (see Fig. 2) for the flooded areas. From this information, we detected the most vulnerable areas and how they related to urbanized areas and BGI. The maps are for representative purposes only, to show the importance of the case study locations in the context of BGI and resilience. From the two case studies presented in Sections 4.1 and 4.2, we then identified the key factors contributing to the shift in resilience initiatives towards BGI, discussed in Sections 5.1, 5.2 and 5.3. Finally, we drew key lessons from the case studies on integrating BGI into urban planning and development for climate adaptation in the concluding section.

4. Results

4.1. Chennai: reviving a marshland

Our review of the secondary literature showed that Chennai city's administration and urban planning had grossly neglected the importance of BGI in climate adaptation. A post analysis of the 2015 floods by a government audit agency noted gaps in land use planning and development control regulations as well as weak institutional capacity of the municipal administration in flood mitigation and management (CAG, 2017). The 2015 floods in Chennai brought about a positive change in the mindset of municipal administrators and citizens alike in protecting BGI to avoid such disasters in future. In 2017, the ULB, the Chennai Municipal Corporation (CMC), revised its Disaster Management Plan for the city. With support from 100 Resilient Cities – The Rockefeller Foundation, a resilience plan—Resilient Chennai Strategy—was also prepared after the floods (CMC, 2019). By 2019, the CMC had identified over 52 water bodies including rivers, canals, marshlands, tanks, and lakes for restoration and rejuvenation (CMC, 2019). The restoration work is expected to help in flood mitigation, provide water supply to the city, and replenish groundwater recharge.

Although Chennai city had faced floods before, the impact of the 2015 floods was unprecedented (Devi et al., 2019). Also, the Velachery region in southern Chennai was severely affected. The storm water runoff from this region was expected to drain into the Pallikaranai Marshland, but its overflow led to Buckingham Canal through a 2.8 km natural drain of Okkiyam Maduvu (see Fig. 3), severely affecting the local residents (Ramachandran et al., 2019).

Restoration of the Pallikaranai Marshland (Fig. 3) was given high priority after the floods. The restoration of the marshland involved the removal of solid waste and stopping further waste dumping, widening, and desilting of Okkiyam Maduvu to improve its storm water holding capacity (Surya, 2016). The Pallikaranai Marshland conservation authority, an institutional arrangement to protect, conserve and revive the marshland, was set up in 2012. However, it was only after the 2015 floods that this institution and its activities achieved greater significance.

Scientific inputs in identifying the important areas for BGI recovery proved to be helpful to the city administration. The study by Ramachandran et al. (2019) had identified the Okkyam Maduvu as one of the bottleneck areas for flood waters. The authors considered its widening and desilting to be a priority. The Pallikaranai Marshland Conservation Authority had scientific information and technical support from Non-Governmental Organizations (NGO), such as Care Earth, to initiate restoration efforts (CMC, 2019).

Another model of change regarding the integration of BGI into urban planning is based on "technical assistance" by international agencies, such as the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. To tackle climate change impacts and enhance the city's adaptive capacity, GIZ, based on the project—Cities Fit for Climate Change—had developed an open ideas competition on reimagining Chennai's Buckingham Canal (see Fig. 3). This competition was part of the Eyes on the Canal Project, an initiative to promote the urban design collective and the participation of neighborhood communities. Eyes on the Canal is an initiative for participatory urban planning to make the Buckingham Canal a more resilient BGI.

The Buckingham Canal is a historical, artificial, 800-km-long

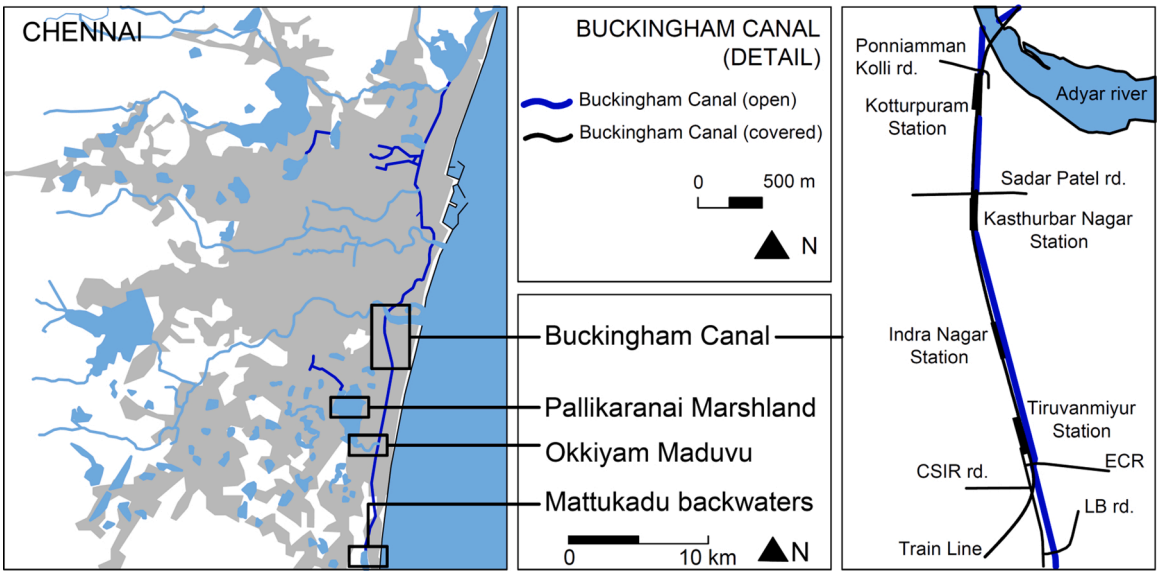

Fig. 3. Chennai's BGI and location of projects studied. Compiled by authors based on CMC cartography, GIZ (2019).

waterway that runs parallel to the Coromandel Coast. Designed primarily for transporting goods, the canal has suffered numerous encroachments that have severely compromised its width. The open ideas competition under the Eyes on the Canal Project for a selected 3.5-km stretch of the Buckingham Canal within Chennai pursued the goal of adding to and strengthening the current processes, approaches, and strategies of the municipal government, while highlighting the potential of the innovative ideas collected (GIZ, 2019). The proposals presented for a sector of the canal tried to recover the urban interstices to generate interconnections between the BGI, increasing the surface of open spaces with a firm commitment to soil permeability solutions.

The community participation in this competition was ensured by two local NGOs, Agam Sei and Urban Design Collective, which helped in addressing the local community, researching, collecting data, raising awareness (e.g., river walks), and documenting the competition (GIZ, 2019).

In this process, the Greater Chennai Corporation participated in the development of the initiative and validated the winning solutions that started from a stage of knowledge exchange with the local communities and extend throughout the analyzed sector of the canal. Linked to the Resilient Chennai Strategy (CMC, 2019), the winning entry among the 28 contestants, proposed integrating the social, economic, and ecological resilience into urban space design, thereby preparing the city for future shocks like floods (Fig. 4).

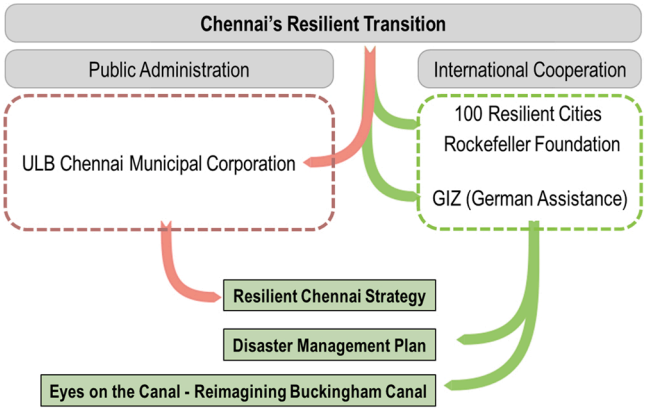

Fig. 4. Chennai's Resilient Transition according to projects and programs analyzed. Compiled by authors.

The strategy has had a strong implication on BGI and urban planning (GIZ, 2019). The participation of specialists in urban planning, taking into account the local knowledge, has allowed individuals and the local community to become aware of the problem of climate change and how BGI is a community resource for overcoming this challenge. The project, therefore, has increased local knowledge on climate and urban flood risks, which has resulted in a greater capacity for adaptation. On the other hand, being aimed at increasing the capacity of public stakeholders involved in urban planning, the initiative has opened new opportunities for local decision-makers to replicate it in other sectors of the city. For instance, 210 degraded urban water bodies are being restored (CMC, 2019). This has improved coordination between the different policy areas (urban and regional planning or ecosystem and water–sanitation management) and, thus, has provided for a new approach in the planning process towards a resilient vision of the city (GIZ, 2019).

The open ideas competition was planned as a pilot project for the recovery of BGI with multiple co-benefits on urban adaptation and social resilience. The next step will be an integration into the urban planning of the chosen solution. Regardless of whether the proposal is part of the Chennai Master Plan 2026, the increased awareness of the problem and the existence of this resource in the face of flooding are important advancements in Chennai's climate risk management strategy. The revised Master Plan 2026 for Chennai, according to the updates made in 2018, has marked out BGI of the Pallikaranai Marshes, Buckingham Canal, and a few other remaining wetlands as eco-sensitive areas that would be protected against future urbanization (CMDA, 2008 – amended in 2018). Undoubtedly, these experiences represent a new process towards Chennai's resilient transition.

4.2. *Kochi: collective steps toward resilience*

The earlier official planning document of Kochi showed gaps in its urban planning approach to fight climate change and the lack of a concrete definition of actions (KMC, 2006; State Government of Kerala, 2010). The blue infrastructure was considered as an element of natural conservation and a strategic mitigation resource with the use of water bodies for transportation. The urban planners of Kochi accept that for an adequate control of floods, the recovery of the canals must be taken into account. However, this is not considered from a broader perspective for the protection against the impacts of climate change. The risk assessment for the city of Kochi does not contemplate the rise in sea level and extreme rainfall events as a decisive aspect for urban planning (State

Government of Kerala, 2010, Vol. I, p. 239). Subsequently, this deficit was amended by the Kerala State Action Plan on Climate Change where it acknowledges the increased risk of sea level rise and urban flooding due to climate change (State Government of Kerala, 2014, p. 25).

In line with the Government of India's national planning focus on the recovery of wetlands (the National Lake Conservation Plan, National Wetlands Conservation Program and the National Plan for Conservation of Aquatic Eco-systems, 2013), the Hon'ble Supreme Court has ruled on having buffer zones and no-development zones for BGI protection (GoI, 2016). The coastal regulation zone (CRZ) is one of India's significant environmental regulations to protect BGI, particularly in coastal cities. The CRZ classifies the land area from the High Tide Line to 500 m. on the landward side along the seafront and 50 m., or the width of the creek, as a no-development zone (GoI, 2019). The revised notification of this legislation in 2019 made provisions for already identified, critically vulnerable coastal areas for increased protection and conservation involving the local communities. Following this notification, the urban planning institutions were required to comply and develop future "master plans" with due consideration to different development zones as laid out by this legislation.

Another initiative taken by the city of Kochi toward a resilient transition was the new solid waste management (SWM) model. Solid waste is a significant threat to BGI in most cities in India, which add to civic woes like encroachment and land use changes. In 2014, Kochi generated about 400 tons of solid waste per day (Dhanalakshmi, 2014). Before effective SWM in the city, much of the solid waste was dumped in water bodies and open spaces. The Kudumbashree initiative, a flagship poverty alleviation program of the State Government of Kerala for door-to-door garbage collection and separation in the city, led to phenomenal improvement in SWM in the city as well as in water bodies (Dhanalakshmi, 2014). Another example of community involvement in the protection and restoration of water bodies was by the local fishing community in the wetlands of Kadamakudy in Kochi (see Fig. 5), where the local communities came together to protect the wetlands for paddy and shrimp cultivation (Deepak, 2016).

The opportunities for resilient transformation that BGI offers are being integrated into Kochi's land use policies through collaborative plans and projects, where citizen participation is decisive. Based on the coordinated management between local communities, scientific institutions like the Cochin University of Science and Technology, the Department of Town and Country Planning, and external support from agencies such as ICLEI South Asia, or international cooperation institutions such as GIZ, Germany, the Kochi Municipal Corporation is developing a reconversion of BGI in its urban planning and development (Fig. 6).

Supported by ICLEI South Asia, Kochi is the first city in India with a scientifically informed and participatory Local Biodiversity Strategy and

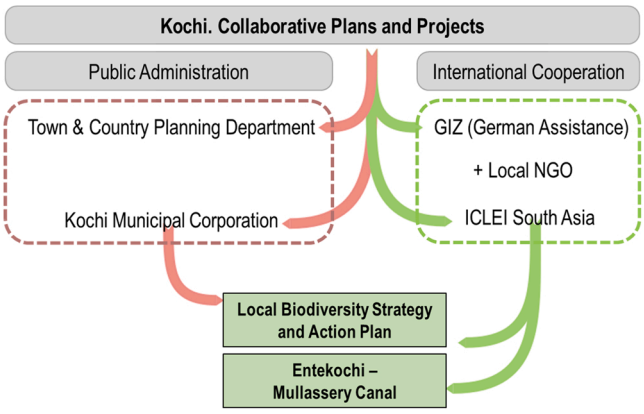

Fig. 6. Collaborative Plans and Projects in Kochi. Compiled by authors.

Action Plan (ICLEI South Asia, 2020) and will likely be Kerala's first 'sponge city', where BGI will be redeveloped to absorb and mitigate floods (Hussain, 2020). In this strategy, the perspective of climate change has been integrated with the Sustainable Development Goals (SDG) in an orderly planning of BGI for city service. Through a participatory planning approach, the key BGI has been graphically identified, providing a visual interpretation of the existing urban ecosystems. The main strategy is to protect not only the canals and backwaters from the urbanization process, but also the agricultural sectors such as the traditional Pokkali cultivation (rice and fish), a symbiosis of the BGI in coastal and peri-urban areas.

In the central sectors of the city, the initiative for an open design competition in the Mullasery Canal area (see Fig. 4), supported by Kochi Municipal Corporation and GIZ, revitalized neighboring communities through an urban laboratory process. Developing participatory surveys, the resident population was involved in the city's urban planning and redevelopment projects. EnteKochi is the institutional framework to develop the urban transformation of Mullassery Canal (GIZ, 2020). Undoubtedly, the initiative facilitated the participation of neighbors and recovered modes of community relations to increase social resilience. Here, "…water emerged as a unifying civic vision for the city in most of its neighborhoods and, thus, became the most obvious ingredient for thinking about the city collectively" (GIZ, 2020, p. 68). Problems such as solid waste disposal and growth of weeds like *Eichornia crassipes* affecting the water flow in Mullassery Canal were identified by the local communities. Moreover, local communities suggested that in terms of lost connectivity with the city's water bodies, more public spaces should be built along the waterfront, which are central to the identity of Kochi (GIZ, 2020, p. 25).

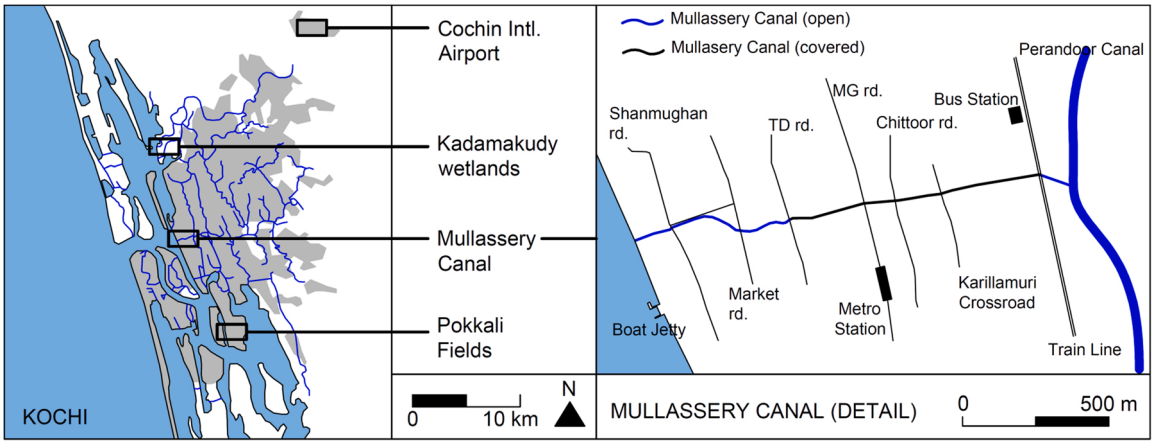

Fig. 5. Kochi's blue infrastructure and location of projects studied. Compiled by authors based on Aziz et al. (2018), and GIZ (2020).

5. Discussion

Both Chennai and Kochi presented a new approach toward integrating BGI into their urban planning and redevelopment for resilience building. Previous studies had shown how important it was to consider socioenvironmental justice when implementing nature-based solutions by using integrated governance approaches that consider the participation of diverse actors (Kabisch et al., 2016; Pauleit et al., 2021). The Chennai and Kochi case studies represent an involvement of the scientific community, consideration of socio-environmental needs, and a participatory approach. The EnteKochi and Mullassery Canal restoration work are exemplary cases for resilient transformation in urban India, where citizen participation, together with research and international cooperation, have transformed urban planning processes. The restoration of Pallikaranai Marshland in Chennai and the Mullassery Canal in Kochi are likely to mitigate future urban flood situations and advance climate adaptation, improving ecosystem services such as groundwater recharge and providing other opportunities like recreation (Ramachandran et al., 2019; Aziz et al., 2018; Bigith and Kumara, 2019).

In these two cities, better scientific information, community engagement, support from NGOs and international entities, and legal regulation changes at the national level have helped in renewing efforts toward climate adaptation and achieving SDG 13 and 11 on sustainable cities and communities. These adopted strategies are summarized in Table 2.

The Chennai and Kochi case studies on reviving BGI as a climate adaptation strategy offer important lessons for other cities of India and the Global South, which is discussed under the following pillars (see Fig. 7):

5.1. Enabling national framework

The first pillar is the link of a new national framework to the resilience initiatives in Chennai and Kochi. The projects in these two cities are consistent with the new national level policy framework that promotes the protection of blue infrastructure and the revaluation of ecosystem services.

In the specific case of Chennai, BGI became a strategic resource for urban administrators to mitigate floods and improve water availability in the city, which fluctuates between flood prone to water scarce (CMC, 2019). Although some resilience initiatives were taken in the past, municipal administrations and citizens have become more aware of the importance of BGI in building resilience after the floods suffered by the city. This initiative supports the SDG 13, Target 1 emphasizes the necessity of strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries (United Nations, 2015).

For such resilience initiatives at local level, as stated previously in scientific literature (Dodman and Mitlin, 2013; Nalau et al., 2015; Lehmann et al., 2015), strong national level legislations and related local level actions on climate adaptation is required, such as the strategies developed at Kochi based on national policy framework. The CRZ notification, 2019, and the Supreme Court judgement on the buffer zones for water bodies are important steps in this direction to prevent loss of water bodies from urbanization (GoI, 2019).

Integrating BGI into urban planning and development requires strong environmental regulations and institutional processes. Urban redevelopment projects in India like the AMRUT and Smart City Mission strongly focus on water conservation (GoI, 2015). The Chennai Smart City project targets improving urban green spaces and restoring water bodies (https://cscl.co.in/focus-areas/smart-environment) (Mukherjee and Madapala, 2018).

Table 2
Key planning strategies and projects for developing BGI in Chennai and Kochi.

Pillars	Projects developed in Chennai	Projects developed in Kochi
i. Link to national legal framework	Atal Mission for Urban Rejuvenation and Transformation (AMRUT, 2015), Coastal Zone Regulation (2016), Smart City Mission (2015)	
ii. Response to climate change	Resilient Chennai Strategy (2019)	Kerala State Action Plan on Climate Change (2014)
iii. Shift to a new urban sustainability model	Pallikaranai Marshland (2012–2020)	Local Biodiversity Strategy and Action Plan (2020)
iv. Community-based planning	Buckingham Canal projects (2019)	Mullassery Canal projects (2019)

5.2. The change of urban model towards a climate transition

The second pillar addresses the inescapable local demand for responses to the problem of climate change. Along with this public demand, advances in scientific knowledge demonstrate the existence of this phenomenon in Indian cities, and urban planning is obliged to use this information.

In Chennai, vulnerable hotspots for flood risks that were identified in parts of the city by modelling for extreme rainfall events under future climate change scenarios (Ramachandran et al., 2019) are valuable climate-related information for municipal administrators to focus on flood mitigation measures. Detailed hydrological planning is required to identify areas that are suitable for recharge wells and storm water drains, and appropriately develop the same. This information is basic for the development of climate-resilient planning, but critical to protect the wetlands from encroachment and to ensure catchment hydrology and flow. To protect and improve the large numbers of water bodies in the city, it is important to understand the catchment hydrology and create storm water drain networks that effectively drain the rainwater to these water bodies, thereby preventing water logging and flooding. These efforts in good practices could be emulated in Chennai, thereby reducing the groundwater demand for use in low rainfall years. Environmental planning and landscape ecological approaches can help in better integration of BGI in urban planning (Govindarajulu, 2014). The restoration of the Buckingham Canal and the Pallikaranai Marshland have exactly followed these approaches.

The third pillar is the change toward a new urban model based on sustainable principles, avoiding the loss of BGI from previous urban sprawl and their restoration. The cities of Chennai and Kochi have reversed the trend for urban expansion leading to the consumption of land and BGI. The enhancement of canals, lakes, and ponds favors a better adaptive response to climate change. The co-benefit of this approach to blue infrastructure can help in reducing transport greenhouse gas (GHG) emissions, as has been seen in the case of Kochi, with the strategy of mobility through the waterways (Aziz et al., 2018). Also, the latest generation equipment for the production of renewable energy, such as the recently installed Floating Solar Power Plant on the backwaters of the Cochin International Airport, can produce 452 KWh per day (Keralaumudi, 2021). Despite the opportunities that BGI offers for both mitigation and adaptation, however, a decisive step is still missing—the translation of these strategies into planning tools. Mainstreaming climate change adaptation into urban planning is a complex task that requires the commitment of urban administrators as well as policymakers (Sharma and Tomar, 2010). Both Chennai and Kochi show the difficulties in the integration process. However, this challenge should be perceived as a new opportunity to change the ways of urban planning in our cities.

5.3. Role of institutions, actors, and local communities

The fourth pillar is the shift in the mindset on the urban administrators and policy makers on inclusion of scientific knowledge and community engagement in climate adaptation measures. The examples of Chennai and Kochi highlight the robust institutional arrangements

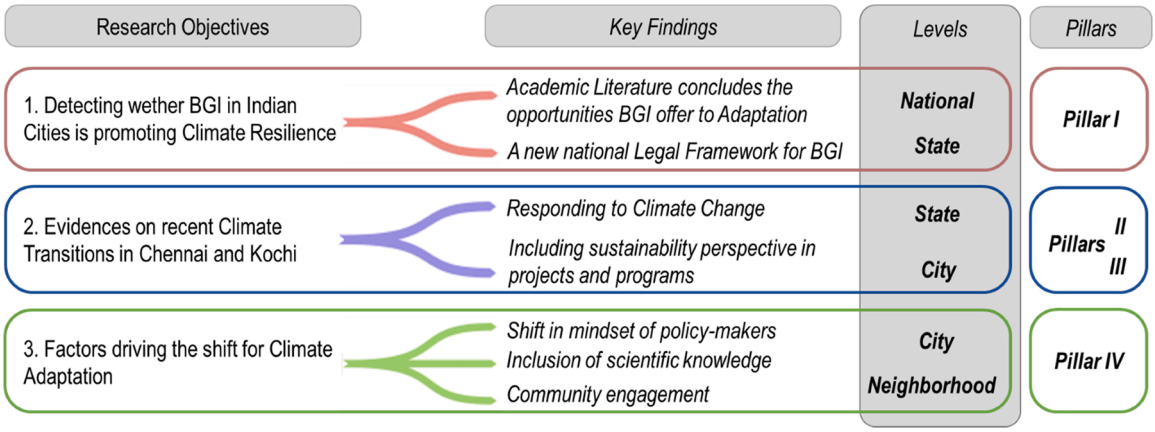

Fig. 7. Objectives and key findings structured by 4 pillars. Compiled by authors.

that are necessary for climate adaptation in Indian cities, such as strategy formulation and knowledge creation. They also highlight the downstream functions of coordination and implementation of city level climate action plans, such as the Resilient Chennai Strategy (CMC, 2019) or the Local Biodiversity Strategy and Action Plan for Kochi (ICLEI South Asia, 2020).

An aspect of interest in the development of the Mullassery and Buckingham Canal urban resilience projects has been the institutional collaboration between international entities such as the Rockefeller Foundation, ICLEI South Asia, or GIZ, local NGOs (Agam Sei or Urban Design Collective) and municipal and state public administration, in line with what has been defined by different authors, especially in the Global South (Chu et al., 2016). The positive synergies generated corroborate the importance of connecting political strategies and technical and scientific resources of international support institutions with the participation of local action groups.

The incorporation of scientific knowledge and climate science into urban planning enable planners to highlight the value of BGI. This is important to address the institutional challenges. In case of Chennai, the Conservation Authority of Pallikaranai Marshland is a significant institution for local communities, scientists, and municipal administrators to make collective and effective decisions on restoration efforts.

Community engagement has proven to be an essential aspect for the success of projects (ACCCRN, 2013), reinforced by citizen participation strategies as stated previously by authors such as Chu et al. (2016), and Taedong and Hughes (2017). With the participation of local communities, the projects rescale their results. For example, Kochi residents were invited to share their thoughts, stories and experiences from the Mullassery Canal neighborhood to improve the EnteKochi project (GIZ, 2020). The Eyes on the Canal project in Chennai was also conceived as a participatory planning exercise to re-imagine the once integral Buckingham Canal as part of the community (GIZ, 2019). Both the projects were conceived to increase the participation of stakeholders and neighboring communities.

Finally, we have detected that the new planning strategies include new actors in the process. On the one hand, public participation is incorporated from the early stages of the projects, with the valuable contribution of local community knowledge. This contribution allows taking into consideration cultural values and preservation of the heritage of the blue infrastructure and its relationship with the land uses that had been lost. On the other hand, organizations, such as international cooperation agencies, are also incorporated into the process, in coordination with municipal corporations, to establish the necessary guidelines for an inclusive and multi-stakeholder process, for guaranteeing a climate resilience perspective.

Both Chennai and Kochi are in an early stage of this transition to climate-resilient planning. Nevertheless, this process is only viable with the participation of the community in the development of actions, as can be seen from the Buckingham Canal and the Mullassery Canal collaborative proposals. This process brings multiple co-benefits and the adaptation interventions have the support of the community, wherein the problem is understood and an opportunity for change is detected in the proposals. In addition, the transformation actions to be integrated into urban planning are themselves based on the local culture, recovering the long tradition of using the canals and backwaters.

The results of this study demonstrated how engaging local communities, including the vulnerable urban poor and citizens as key stakeholders in building urban resilience would help in implementing the complementary measures in BGI management, like SWM or rainwater harvesting. Local communities show higher participation in the conservation and restoration of BGI if there are suitable economic benefits, as well as through increased awareness on environmental benefits as noted in the case of the Kadamakudy Wetland in Kochi and the Pallikaranai Marshland in Chennai.

6. Concluding remarks

Indian cities as well as those from other developing countries in the Global South must recognize the increasing climate change threats, such as extreme flood events or rising sea levels. There has been increased advocacy on promoting nature-based solutions for climate adaptation in coastal urban areas of India in the last decade. However, many cities in India face knowledge gaps and institutional barriers in understanding climate risks and responding to them through resilience measures, due to a lack of adequate funds for adaptation or human resources, as well as in identifying and acting on the opportunities for actions related to BGI, as previously reflected by Kabisch et al. (2016).

Redevelopment of BGI presents an opportunity as nature-based solution to adapt and mitigate climate risks while improving a city's social and environmental well-being. The cities of Chennai and Kochi were involved in the normative integration of adaptation, based on a multiplicity of actions and projects, and the recovery of BGI as a structural strategy for greater urban resilience against climate change. The support of international cooperation organizations to municipalities in the two case studies (Buckingham Canal in Chennai and Mullassery Canal in Kochi) represented a milestone in the process of a new regulatory integration. Nonetheless, climate adaptation in coastal cities in India would still require better climate information (such as future flood risks, sea level rise, knowledge on adaptation options) and the improvement of actors' capacity for resilience building in coastal cities.

Finally, the analysis of the case studies revealed the importance of local community knowledge and participation as well as scientific information for resilient transformation processes. In these initiatives, the communities participated collaboratively with the urban design teams,

which promoted an adequate insertion of the proposals into the urban fabric. There were gaps in land use planning, urban infrastructure, and the capacity of the municipal administration to mitigate disaster risk. However, this study identifies those adequate steps are still being taken to build a new framework of social, administrative, and structural resilience in both cities. A review of the planning tools with a climate resilient vision is necessary. For this, it is necessary to deepen the methods and expand the knowledge of new participatory formulas of the community and coordinate with the municipal technical manpower to facilitate the integration of adaptation in urban planning.

Data availability

Data will be made available on request.

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