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Sahar Abdel Moneim Attia,
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National Autonomous University of Mexico, Mexico
Aparajithan Narasimhan,
Madras Ecobuild Pvt Ltd., India

*CORRESPONDENCE
Christoph Woiwode
✉ woiwode@igcs-chennai.org

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Identifying entry points for adaptive governance in peri-urban Chennai (India): a multi-dimensional, multi-level, and multi-scalar approach

Christoph Woiwode[1,2]*, A. Ramachandran[1], Tarun Philip[1], D Rishika[1] and Sudhir Chella Rajan[1]

[1]Indo-German Centre for Sustainability, Indian Institute of Technology Madras, Chennai, India, [2]Leibniz Institute of Ecological Urban and Regional Development, Dresden, Germany

Governing transitions have assumed increasing significance in managing change with respect to climate change and rapid periurbanization. In this respect, evidence from sustainability transitions research in South Asia stipulates the need for institutional innovations that are suitable to the governance context, which is characterized by a fuzzy field of "speculative frontiers," and strong hierarchically structured mechanisms. This paper focuses on Chennai, India to ascertain the potentials of "adaptive governance" in this periurban region of the Global South. We approach this by (a) defining the periurban space from a bio-regional, socio-ecological systems perspective, (b) complementing it with a zonal classification considering disaster and climate change risks, and (c) presenting an adaptive governance framework. Based on analyzing existing governance structures, the paper discusses identified syndromes, synergistic potentials and activities for adaptive governance, especially highlighting water and agroecology-related pathways. Our integrated analytical approach is (a) multi-dimensional deploying the adaptive governance framework, (b) multi-level considering local, intermediate and state governance, and (c) multi-scalar applying macro, meso and micro scales. The implications underscore that transformative interventions, sooner or later, will have to challenge the system that produces such climate vulnerabilities. In spite of several barriers, there are noteworthy indications of adaptive governance practices discernible in numerous niche projects in the Chennai region that demonstrate diverse embryonic forms to build more strategic and conscientious approaches.

KEYWORDS

periurbanization, adaptive governance, sustainable transformation, climate change resilience, Chennai, India

1 Introduction

Chennai's growth story as an industrial hub and fourth-largest metropolitan agglomeration in India during the last few decades has led to significant urbanization, drastically altering a complex land- and waterscape (Homm and Bohle, 2012; Gajendran, 2016; Gandy, 2022) while simultaneously making it vulnerable to multiple climate risks, as evidenced recently by the floods in 2015 (Arabindoo, 2017; Bremner, 2020). This was followed by a period of acute water

scarcity in 2019, leaving the city to oscillate between water abundance and scarcity, a condition that is expected to get worse. For centuries, however, Chennai's hinterland ecology of natural and constructed water bodies has contributed to manage and mitigate these types of risks that were inherent to its climatic landscape (Das, 2009; Schütt et al., 2013; Gopalakrishnan, 2014). As the city expands and urbanizes into these hinterlands, our core question is: can the city develop adaptive pathways to address the twin challenges posed by rapid periurbanization and climate risk?

Next, to Manchester, the metropolitan region of Chennai is one of two selected in-depth case studies of the global Peri-Cene Project (Ravetz et al., 2022; Woiwode et al., 2022), which aims to explore the interactions between periurbanization and climate-environmental change, at local and global levels, and to co-design adaptive pathways toward periurban climate resilience. With this research aim, this paper concentrates on the Chennai case study to ascertain the potentials of "adaptive governance" in this periurban region of the Global South, critically engaging with scholarship related to "Asian" or "non-Western" theories of periurbanization (Wu and Keil, 2020; Gururani and Kennedy, 2021).

Governing transitions has assumed increasing significance in managing change with respect to the challenges of upscaling and multilevel governance (da Cruz et al., 2019; Köhler et al., 2019; Pierre, 2019). In this respect, evidence from sustainability transitions research in India stipulates the need for institutional innovations that are suitable to the Indian context (Chebrolu and Dutta, 2021) and applicable beyond an urban focus, which is characterized by a fuzzy field of "speculative frontiers" (Sood, 2021), and strong hierarchically structured, top-down governance mechanisms (Resilient Chennai and Okapi, 2019a,b) with fiscal decentralization remaining a "nascent reform" (Janaagraha, 2023). By applying the *multi-dimensional* "adaptive governance" framework that was developed during the Peri-Cene project, this paper seeks to contribute to the debates of formulating solution-oriented systemic interventions in transition governance (Chaffin et al., 2014) in the Global South. Such approach is embedded in an overall "synergistics" model of collaborative engagement (Ravetz, 2020) and experimentation (Fastenrath and Coenen, 2021). It is also linked to the notion of "adaptive development pathways," one of which identified in Chennai is envisioning an agroecological transformation of the metropolitan region (Volz and Woiwode, 2022).

The next section outlines in broad strokes the methodology of the project, followed by sections of classifying the periurban region of Chennai and related climate change risks and projections. A fourth part then introduces the proposed adaptive governance framework. Based on this groundwork, key features of governance in Chennai are presented, followed by the identification of entry points for adaptive governance and a mapping of related, illustrative adaptive pathways.

2 Methodology

The foremost goal of the Peri-Cene project is a global assessment of the periurban and its climate change risks and adaptation challenges. For this purpose, the research teams carried out various focused literature reviews related to periurbanization, governance and particularly climate change risks of the selected local case studies. Two in-depth case studies focus on the "Chennai region" (India) and the "Manchester region" (UK, Carter et al., 2022). Each characterized by a different history, development pressures, socio-economic trends and climate risks. Our methodologies are both *mixed*, using heterodox narratives combined with an analysis of supposed change ("system syndromes") and desirable alternatives ("pathways mapping") by applying the synergistics approach by Ravetz (2020). This approach is rooted in futures studies (Inayatullah, 2008) and considers scenarios of thematic, transformative, adaptive pathways including adaptive governance.

Methodologically, the Chennai region case study approaches these objectives in the periurban space by identifying three scales—macro (bioregional), meso (landscape), and micro (neighborhood) where these themes of periurbanization and climate change entangle, creating both challenges and opportunities. For two of these spatial scales (macro, meso) a bioregional approach was chosen as they are delineated along geo-hydrological boundaries of water basins, which are of defining nature for the human-ecology relationship of Chennai (McGinnis, 1999; Potulski, 2012). Maps were generated for the tailor-designed Peri-Cene Spatial Analysis Tool (P-CAT)[1] drawing on existing global and local datasets such as the Global Human Settlement Layer (GHSL), the OECD Functional Urban Area classification, and the World Resources Institute's Global Forest Watch. The P-CAT provides for visualized, interactive features of geospatial data for each of the 21 partner cities of the Peri-Cene project, with ground-truthed results of the two selected case studies. It comprises three complimentary sections: 1. City visualizers that include population distributions, built-up areas and degree of urbanization; 2. City surveys: an interactive engagement tool that allows stakeholders and citizens to contribute to discussions about periurbanization by adding geospatial data to the database, using the city surveys for the city of their interest; and 3. Analyses in multiple formats using spatial and non-spatial data presented in an exemplary manner in storymaps for Manchester and Chennai.[2] For Chennai, these maps embedded with the storymap, serve to show impacts of its growth and the fallout at three sites that are representative of each scale. This *multi-scale* perspective plays a role to tease out how various actors and stakeholders interact with each other and how they work within different *multi-level* governance arrangements at each scale. Further, this approach of visualizing these dynamic changes was complemented by field research and stakeholder interaction.

Additionally, a comprehensive "Policy Lab"[3] was conducted online with researchers at 18 periurban sites globally. This space contributed to (a) the diagnosis and mapping of problems (syndromes), and (b) the design of responses and "adaptive pathways." Due to the pandemic all activities were moved online, which proved to be a challenge for creative thinking, but also an opportunity for a wider consultation. It also included structured interviews with a "20 questions" template for each city, small group meetings, and an international series of online workshops.

Accordingly, the first project phase focused on mapping and spatial analysis, followed by the design of adaptive pathways through

1 For further details visit https://Peri-Cene.net/p-cat-tool/

2 For the Chennai story map visit https://storymaps.arcgis.com/stories/839e3c209e064a4a934169e6b6cc3dda

3 For details on the process and method visit https://Peri-Cene.net/policy-lab/

these policy labs. In the context of Chennai, these steps and topics are subsequently covered in this paper:

1. identification and classification of the periurban in Chennai with view to climate change risks (sections 3 and 4);
2. structures and institutions of governance in Chennai (sections 5 and 6);
3. analysis and diagnosis of governance in Chennai deploying the adaptive governance framework (sections 7 and 8);
4. results and moving toward transformative interventions: entry points for adaptive governance and connection to adaptive pathways (section 9).

3 What and where is the Chennai periurban?

Peri-urbanization can be seen as a political process of being and becoming over time and space (Leaf, 2016). In spite of the rapidly growing literature on the periurban, it remains a fuzzy concept characterized by manifold attributes such as "periurban interface" (Adell, 1999; Allen, 2003; McGregor et al., 2006), the periphery (Gururani and Kennedy, 2021), a "transition zone" (Rakodi, 1998), a "hybrid zone" mixing rural and urban or, similarly, an "in-between" city space (German "Zwischenstadt," Sieverts, 1997), and yet, the periurban is still distinct from the city - separated by either agricultural land or open spaces (Oliveau, 2005). But, as McGee (1991) argued with the concept of desakota especially in the Asian context, it is the urbanization of rural areas apart from the big cities and metropolises that brings about a morphologically distinctive spatial category. As a result of continuous and increasing periurbanization, "The metropolis as a new urban condition" and the related peculiarities of the periurban (Arabindoo, 2009) have become viewed as a distinct phenomenon in its own right, sometimes referred to as planetary urbanization (Schmid et al., 2018). However, it is not merely a static condition but rather "a process in which rural areas located on the outskirts of established cities become more urban in character, in physical, economic, and social terms, often in piecemeal fashion" (Webster, 2002). Typically, the spatiality and localization of the periurban is vague and varies depending on the specificity of the actual case or focus of interest, it may be indeed between cities reshaping rural areas and settlements into "rurban," or on their edges, it may as well be a sort of continuum from the rural to the urban fringe, or a fragmented patchwork of peripheral development nodes across a region, as noted by Gururani and Kennedy (2021).

This perspective aligns well with the notion of periurbanization in the Peri-Cene project, which is a play with the "new era" called Anthropocene that describes the global, anthropogenic phenomenon of urbanization of the "rural." Literature on periurbanization in India is growing constantly, covering a range of topics from governance (Dupont, 2007) and spatial development planning (Arif and Gupta, 2020), social and political context (Arabindoo, 2009), geographic implications (Oliveau, 2005; Singh and Narain, 2020), economics (World Bank, 2009), periurban dynamics and changes (Ravetz et al., 2013; Follmann et al., 2022; Varkey, 2023) to infrastructure provision, water and the environment (Shaw, 2005; Narain and Roth, 2022). In the context of the global south, and in particular in India, "Land development in peripheral urban areas necessarily has to negotiate with the colonial and prereform structure of land tenure" (Wu and Keil, 2020, p. 949). As these latter authors stress, investigating and conceptualizing periurbanization in the global south requires being "sensitive to the history and local context" (Wu and Keil, 2020, p. 949). In this regard, Follman (2022) recent, comprehensive review of the conceptual debates on periurbanization with a focus on the global south provides a more nuanced and differentiated perspective by acknowledging the diversity of periurban phenomena and processes. In order to conceptually distinguish periurbanization in the global south, Follmann et al. (2022) reframes periurbanization as an umbrella term to variously identify "bypass urbanism," "plotting urbanism," "agrarian urbanism," "extended urbanization," or "peripheral urbanization."

One conception of the periurban is to employ ecological boundaries instead of administrative ones that are man-made and rendered porous through multiple processes such as urbanization. Based on previous research in the Chennai region that highlights the interdependence of human settlements, livelihoods and water resources (Sudha et al., 2013; Harishankar and Vedamuthu, 2019; Nithila Devi et al., 2020), a bioregional approach to identifying the regional limits was chosen. Consequently, the Chennai region is defined based on the watershed area of four river-basins. For methodological-analytical reasons, this approach resulted in the identification of three scales (a) macro/bioregional scale, (b) meso/landscape scale, and (c) micro/community/neighborhood scale, where the themes of urbanization and climate change converge and entangle, creating both challenges and opportunities. Essentially, these scales play a role in teasing out how various actors and stakeholders interact with each other and how they work within different governance arrangements at each scale. Furthermore, we distinguish four functional zones within this bioregion but outside the core city which is delineated by the administrative boundaries of the Greater Chennai Corporation (Figure 1):

1. Zone 1: IT corridor stretching southward along the coast and immediate hinterland (East Coast Road and Old Mahabalipuram Road);
2. Zone 2: Ennore region in the north with its ports, large scale infrastructures like power stations and industrial estates;
3. Zone 3: Industrial corridor toward west/southwest along the Bangalore highway, Oragadam and the Great Southern Trunk (GST) Road;
4. Zone 4: Hinterland encompassing a large watershed region overlapping three states (Tamil Nadu, Karnataka, Andhra Pradesh).

The Peri-Cene has used global mapping systems and local consultations to address the question where the periurban is located. Sahana et al. (2023, p. 2) argue for a "pluralistic" framework for the demarcation of the periurban, because "The spatial identification and demarcation of peri-urban areas is difficult due to the complex and diverse nature of rural–urban linkages along city boundaries, and, so far, there is no clear definition that is universally applicable for the delineation of peri-urban areas." The transitory dimension is especially complex in a dynamically urbanizing context such as the Chennai region characterized by several satellite towns, extended suburbs, urban greenspaces, water bodies and semi-rural hinterland with its rapidly changing population and evolving built environment indicators.

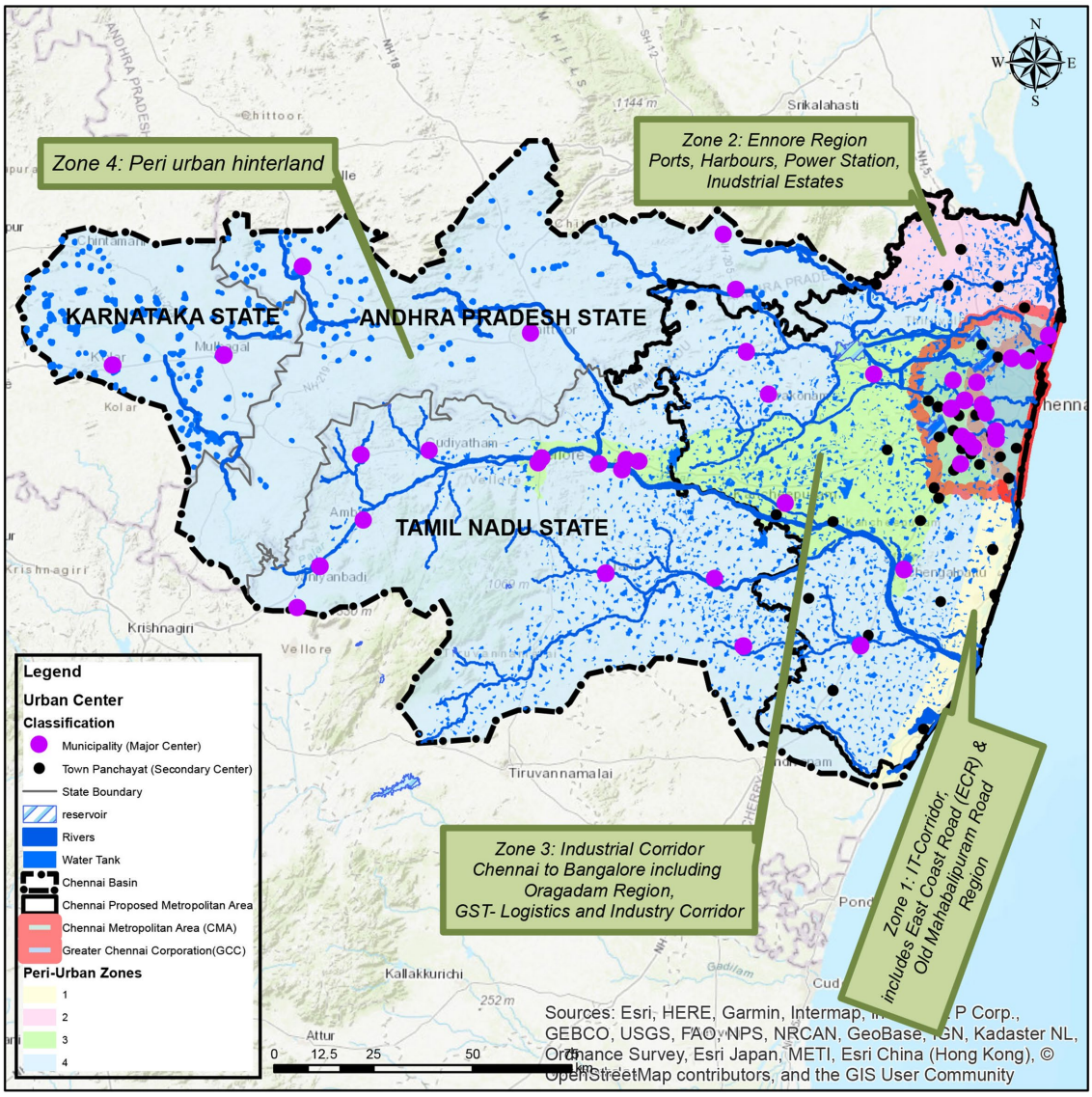

FIGURE 1
Chennai periurban region (© Periurban Initiative, Pericene Project).

Overall, a relatively simple definition of the periurban may be based primarily on population data. The data analysis for Chennai resulted in a detailed framework that includes five different periurban types (Table 1), calculated for the whole 200 × 200 sq.km:

a. Urban greenspace: open land/forest/other near within urban areas
b. Urban fringe: lower density suburban/extended settlements
c. Periurban hinterland: smaller satellites and lower density settlements outside urban areas
d. Urban edge: higher density suburban/extended settlements within urban areas
e. Periurban settlement: large satellites and higher density settlements outside urban areas

The calculation includes Greater Chennai, the extended metropolitan area, and hinterlands of north and west of Chennai. According to these data, the lower and higher density periurban, which together make up approx. 3.5% of the total population but 40% of the land area, combined an extraordinary population growth rate of 140% between 1990 and 2015, whereas the urban/suburban with more than 90% population and 50% land area saw a population increase of slightly more than 50%. In summary, while the most dynamic demographic change is taking place in the lower and higher density periurban, the largest absolute population increase is still occurring in the urban/suburban areas of Chennai.

4 The nexus of periurbanization and climate change risks in the Chennai metropolitan region

Economically, Chennai city is one among the fastest growing cities in the world according to Forbes (Kotkin, 2012). The Chennai metropolitan region is one among the largest urban spaces in the

TABLE 1 Vital statistics summary of periurban classification (© Periurban Initiative, Pericene Project).

Peri-urban classes	Peri-urban typology	Population/km	Total land area 2015	Population 2015 (in % to the total)	25 yr change (%, base year 1990)	Annual % change compound
Open land and peri-rural	"Urban greenspace"	< 50 p/km	9.40%	0.18	126.40%	3.32%
Lower density peri-urban	"Urban fringe" or "peri-urban hinterland"	<125 p/km2	17.00%	0.88	141.00%	3.58%
Higher density peri-urban	"Urban edge" or "peri-urban settlement"	<300 p/km2	22.10%	2.65	141.40%	3.59%
Urban and suburban	"Urban"	urban >300 p/km2	51.50%	96. Kgf 29	52.30%	1.70%
Total		Total area	100%	100%	54.40%	1.75%

TABLE 2 Climate projections for Chennai region.

Climate variable	2020 (2010–2040)	2050 (2035–2065)	2080 (2065–2095)
Maximum temperature (°C)	1.0	2.0	3.1
Minimum temperature (°C)	1.1	2.2	3.2
Annual rainfall (Percent change- %)	(2–7)	(1–4)	(4–9)

Source: Tamil Nadu State Action Plan for Climate Change (2017) and Jeganathan et al. (2021).

world (Demographia World Urban Areas, 2021) and at the same time highly vulnerable to climate change. Driven by population growth and rapid land use change, the city region is expected to grow twice in its size by 2026 compared to 2011 census data (Aithal and Ramachandra, 2016). The Chennai region predominantly receives its rain from the North Eastern Monsoon Rainfall (NEMR) (Rajeevan et al., 2012). The NEMR plays an important role in prediction of rainfall over regions in Tamil Nadu including Chennai, since NEMR is greatly influenced by large scale circulation in the pacific sea (Wang et al., 2018).

Topographically, Chennai is located on the highly exposed southeast coast of India on relatively low and flat coastal land. Three major rivers, the Adyar, Cooum, and Kosasthalaiyar, frequently inundate following even short periods of rain. The Climate Change Vulnerability Index of 2021 ranks Chennai the highest among large Indian cities in terms of exposure to climate change-related threats (Verisk Maplekroft, 2021). Another study shows that Chennai is ranked the most socioeconomically vulnerable to climate change among the metropolitan cities in India (Malakar and Mishra, 2017). The risk of flooding in Chennai is expected to worsen with climate change. Higher temperatures and more frequent droughts are expected to exacerbate water scarcity in the city.[4]

In the past decades, the city has experienced floods and drought due to climate change, and the recurrence has only increased in recent times. The future projections of climate conditions in the region are predicted to be on the rising trend, making the city region more vulnerable to risks of extreme events like floods and drought (Table 2; Jeganathan et al., 2021). Almost all extreme weather events in Chennai—flooding, droughts, cyclones—oscillate around water (Table 3). Chennai city reports recurrent flooding for the years 2006, 2007, 2008, 2010, 2015, and 2021 due to single day extreme rainfall (Guhathakurta et al., 2011; Jeganathan et al., 2021). The coastal area of about 27.79 sq.km is classified as highly vulnerable for erosion due to seven coastal factors, which includes sea level rise as one among them (Jeganathan et al., 2021), with the most severe scenario of sea level rise being projected of ~78 cm by 2,100 (Ramachandran et al., 2017).

TABLE 3 Frequency of climate events in Chennai.

Events	1985–2000	2000–2020
Floods	3	8
Cyclone		7
Droughts		7
Heat wave	4	6
Tsunami		1

Source: Chennai Resilience Centre (2019).

A review of papers on past occurrences of extreme climate events in the Chennai region revealed sparsely available information in such regards. Most of the studies are centered on the 2015 Chennai flood event, while other studies attempt to understand climate anomalies during the November–December month of 2015 (National Remote Sensing Centre, 2016; Arabindoo, 2017; Ramasamy et al., 2018).

4 More climate risk can be drawn from Tamil Nadu State Action Plan for Climate Change: Chapter 3, https://www.environment.tn.gov.in/Document/tnsapcc/Chapter%203.pdf and Chapter 4, https://www.environment.tn.gov.in/Document/tnsapcc/Chapter%204.pdf of TNSAPCC 2.0.

TABLE 4 Effects of climate change on Chennai's periurban region (© periurban initiative, Pericene Project).

Local conditions within the periurban	Periurban as part of the whole city-region system
- Flooding and inundation of low-lying areas, especially new low-income housing agglomerations (partly a result of encroachments on water bodies) - Drought periods, with effects on ecosystems, landscape types and local farming. Agricultural lands being converted for non-agricultural purposes; especially toward speculative real-estate and water-supply economy. - Over-extraction of ground water coupled with sea-level rise causing salt water intrusion into coastal aquifers. - Extreme heat, which affects vulnerable social groups, in particular the elderly and outdoor workers. - In the coastal and estuary periurban areas of the various river basins (along the coast), sea level rise, coastal erosion and saline incursion is a growing problem.	- Water management in the periurban has a direct effect on the flood risk and exposure of downstream urban areas; - Landscape management in the periurban has an indirect effect on water: e.g., where upland land-use and ownership creates problems of storage & run-off; - Conventional farming practices in the periurban create further problems of run-off, chemical pollution, soil erosion, clearance of natural areas etc. - The urban heat island effect may be alleviated by outward movement to the periurban, with increase in urban greenspace and decrease in density - Housing development in the periurban is a direct effect of urban pressure, and the need for natural capital and greenspace: much new development is disruptive of landscape and water systems, increasing the flood risk downstream.

Nevertheless, a study by De et al. (2005) that reviewed extreme climate events in the country for the past century, reveals an increasing number of extreme events throughout the decades. In Tamil Nadu specifically, the number of heat waves and drought are observed to be increasing considerably and becoming more recurrent in nature. Although, Tamil Nadu experiences more dry days compared to the past (Dash and Mamgain, 2011; Rajkumar et al., 2021), the number of 1 day extreme precipitation events has been observed to have increased (Indian Meteorological Department). Similarly, in the case of cyclonic events, there has been an increasing number of cyclonic storms observed during the pre-monsoon and post monsoon seasons (Mishra, 2014). The local warming of the Bay of Bengal indicates much larger influence than rising global temperatures in triggering extreme climate events in Chennai city (Krishnamurthy et al., 2018).

Chennai city is known to be highly vulnerable to climate change (Tamil Nadu State Action Plan for Climate Change, 2017), predominantly as the coastal regions are classified as highly vulnerable zones. The state of the city's vulnerability is influenced by various factors. Firstly, its inherent topography results in less free runoff flow, secondly due to external conditions partly by climate change like surface temperature and rainfall, but mostly by human induced factors such as degradation of water bodies, improper solid waste system, under capacity drainage systems (Gupta and Nair, 2011). In the past few decades, Chennai has grown physically (Gupta and Nair, 2011), but the city also grew eight times in population between 1901 and 2001 due to the large influx of migrant population from Tamil Nadu and other parts of the country. This has also led to an increasing number of slum formation at the banks of water bodies and flood plain zones (Diwakar, 2021). Floods were some of the major disasters that took place in the city in the past years due to heavy rains influenced by the warming and ultimately depression at the Bay of Bengal. Given the tremendous growth and lack of space in the city, even the smallest of floods create considerable damage. Although the trends of rainfall in Chennai are not showing significant changes throughout the century, the recurrent occurrence of single day extreme floods in the city comes down to following factors (Gupta and Nair, 2011; Krishnamurthy et al., 2018):

1. Drainage channels that are being blocked due to heavy encroachments.
2. Inadequacy of storm water drainage system and lack of proper maintenance of the drainage system.
3. Increasing land use changes open spaces to impervious surfaces.
4. Lack of coordination between institutional agencies involved.

Chennai region is predicted to experience more recurrent droughts in the future as the projection for rainfall is on a decreasing trend (Shankar et al., 2020). Preceded by failed monsoons in the years 2017 and 2018, the year 2019 was the driest for Chennai with a rainfall recorded around 10 cm (Mishra et al., 2021). The four reservoirs of Chennai city - Red Hills, Cholavaram, Poondi, and Chembarabakkam, which provide potable water were heavily depleted leading to the declaration of "Day Zero" (The Economic Times, 2021). An analysis (Gupta and Nair, 2011; Praveen et al., 2016) on occurrence of drought events in South India reveals the influence of global climate on the North-Eastern Monsoon during October to December, which was deficit hence leading to dry weather conditions. The risk of drought is exacerbated with other factors summarized below:

1. Increasing demand for water with an increasing population.
2. Lack of ground water recharge mechanisms.
3. Encroachment and construction on water bodies deteriorating the integrity of water bodies.
4. Decreased water holding capacity of water bodies.

In consequence, the effects of climate change on Chennai's periurban region are twofold: firstly, in terms of the local conditions within the periurban areas, and secondly, the need to view the periurban as part of a whole city-region system (Table 4).

5 Conceptualizing an adaptive governance framework

Three research questions focus on problems, solutions, and pathways: What are the main challenges to realizing adaptive governance in periurban areas? What are the principles of effective "adaptive governance" in periurban areas? Which kinds of pathways could lead toward adaptive governance?

Adaptive governance has become a term for addressing and dealing with wicked problems such as climate change and other global (poly-)crises of socio-ecological-economic nature that render our future uncertain (Chaffin et al., 2014; Munaretto et al., 2014; Castán Broto, 2019). It appears to be particularly suited for recognizing and acknowledging the intertwined complexities of socio-ecological systems (Folke et al., 2005; Karpouzoglou et al.,

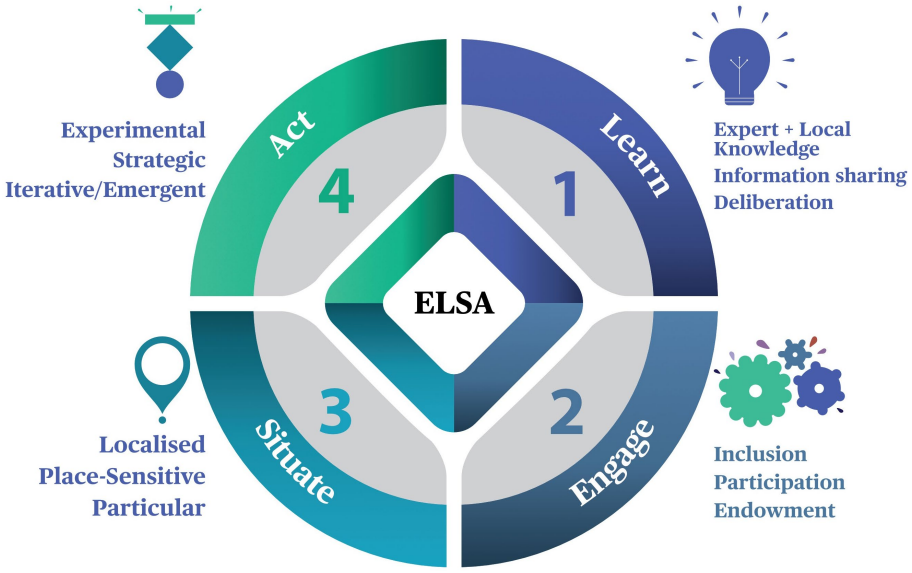

FIGURE 2
The ELSA framework of adaptive governance for climate change adaptation (copyright Peri-Cene Project; Winter and Karvonen, 2022).

2016) including highly dynamic urban environments (Birkmann et al., 2010, 2014) while taking into consideration power relationships in formal and informal institutions (Cleaver and Whaley, 2018). Especially institutional change may be seen as crucial for successful adaptive governance as "Institutional innovation … refers to intentional changes in collective choice institutions that allow cities to be more adaptive and better prepared under uncertain and evolving climate change futures. Practically, this could include changes in policy and legal frameworks that structure decision-making, changes in policy instruments for implementation, changes in organizations to meet new objectives, and changes in coordination arrangements between different actors" (Patterson and Huitema, 2019, p. 375). Following from this, adaptive governance can be defined as "decision-making systems comprising formal and informal institutions and social networks that are able to adapt in the face of uncertainty" (Boyd and Juhola, 2015, p. 1235, cited in Winter and Karvonen, 2022).

Adaptive governance may include various combinations of formal statutory government, market-based measures, collaboration, and informal actions. It is often seeking synergies across these combinations, systems, and levels. According to Ravetz (2020), adaptive governance is closely related to three modes of urban and regional governance. Mode 1 is a functional approach that involves command and control government, representing a traditional approach to governing that involves a strong central government with policies, regulations, and bureaucratic procedures. In contrast, Mode 2 is an evolutionary approach that is informed by market-based competition and an embrace of innovation. There is a conscious effort by stakeholders to go beyond traditional modes of governance (Mode 1) and provide fresh ways of organizing society. However, Mode 2 continues to rely on existing societal structures related to economics, politics, and culture, whereas Mode 3 can be characterized as "co-evolutionary" emphasizing the importance of collaborative partnerships to co-produce decisions and actions. This mode of governance varies significantly from the previous two because of its emphasis on democratic inclusion and distributed agency of involved stakeholders.

Based on a review of literature on empirical studies of flood governance in periurban areas which underscores "a need to develop new modes of governance to address the inadequacy of structural measures, social and economic inequalities, and the uneven geographies of climate change" (Winter and Karvonen, 2022), our colleagues developed the ELSA framework of adaptive governance to clarify four key principles and to provide a general tool to assess the adaptive governance characteristics in a particular place (Figure 2). Moreover, this framework is complemented by five cross-cutting key dimensions characterizing adaptive governance as collaborative, knowledge-based, contextual, emergent, and transformative.

Accordingly, the purpose of the framework is not to offer a definitive, finalized structure for adaptive governance but rather to synthesize the findings of recent research into a simple and useful analytic tool. How these key principles of Engaging, Learning, Situating, and Acting play out in different contexts will continue to inform the emergence of new modes of governance that can engage with climate adaptation. For the specific context of the Chennai case study, we apply a perspective of adaptive governance that is (a) *multi-dimensional* by deploying this adaptive governance framework, (b) *multi-level* considering local, intermediate and state governance levels, and (c) *multi-scalar* applying the Peri-Cene approach of the bio-regional (macro), landscape (medium) and community/neighborhood (local) scales (Figure 3).

In this context, adaptive pathways are viewed as the overarching "room of maneuver" within which adaptive governance practices operate. Ideally, adaptive governance approaches and pathways go hand-in-hand as they complement each other.

6 Key features of governance in Chennai

Literature on governance in Chennai is scant (Ellis, 2012; Roumeau et al., 2015; Jameson and Baud, 2016; Roy and Ayyangar, 2022; Saharan et al., 2022), with a focus on periurban conditions almost absent (Janakarajan et al., 2007; Singh, 2020). A recent in-depth study

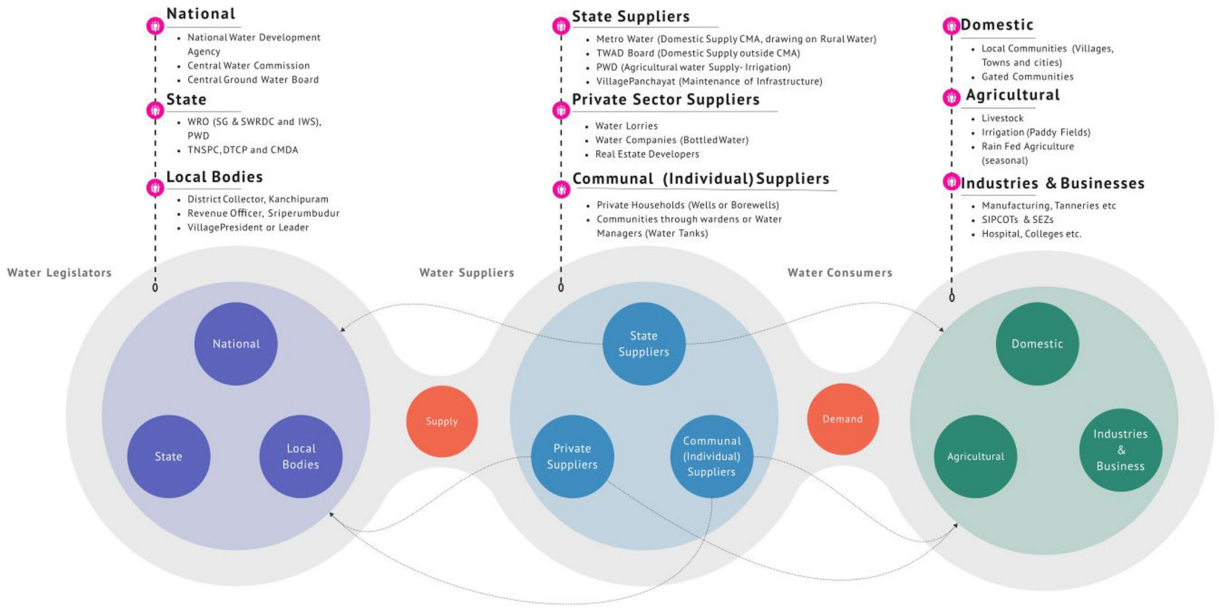

FIGURE 3
Actors in periurban water governance of Chennai (source: John, 2015, p. 29).

(Resilient Chennai and Okapi, 2019a,b) reveals the current state and challenges of metropolitan governance in Chennai, characterizing it as:

a. polycentric,
b. multi-level (local, state, and national level),
c. multi-type (with nested, overlapping and fragmented jurisdictions),
d. multi-sectoral (various public and private organization, civil society and others), and
e. multi-functional (with units performing specific functions).

From a diagnostic point of view, the plethora of government agencies and jurisdictions including parastatals poses a conundrum of inefficiency and often uncoordinated decision-making, frequently resulting in exacerbating or even generating additional disaster and climate risks. Notable is the existence of the strong administrative, decentralized yet not devolved structure of the state with roots in the British, top-down, colonial government (e.g., districts, taluks, appointed officials), versus the elected, democratic system of multi-level, constitutionally devolved role of rural (Panchayats) and urban local bodies (Town Panchayats, Municipal Corporations). Focusing on the administrative set up, various overlapping boundaries are characteristic of the situation such as Chennai Metropolitan Area (CMA) which represents at the same time the Chennai Metropolitan Development Area (CMDA). The districts, as an element of the decentralized state administration, cut across the boundary of the Greater Chennai Corporation—the local urban body with an elected assembly but smaller than CMA—while at the same time reach further into the hinterland thus encompassing the urban fringe and wider periurban region. In addition to these various levels of administration, a multitude of planning and infrastructure related agencies are mandated to operate across these levels *outside* the mandates of rural and urban local bodies. The latter are rather one among many players than fully fledged self-governing local bodies, sitting under continuous control by the state government.

BOX 1 Case study—government structures in water management, Sriperumbudur

Sriperumbudur is one of the 385 Taluks within Tamil Nadu and comes under the Kancheepuram District. Within the Sriperumbudur Taluk there are 100 village panchayats, two panchayat unions and three town panchayats (Adelina et al., 2015). Those panchayats used to form the soul foundation of Indian society, as they represent the traditional community-based governance tool. These self-governing bodies have been eroded over the past 50 years and replaced by formal governance structure with little power (Palanithurai and Ragupathy, 2008). The formal structures comprise an administrative body with a democratically elected panchayat president. The panchayat governing body utilizes a warden system, which are partly found to be based on the traditional water management system (Palanithurai and Ragupathy, 2008), whereby individuals are elected to represent the residents in their locality and report issues to the local government. Therefore, peri-urban regions are constituted of a three-tier governance system: the village panchayat, the panchayat union and the district panchayat. Sriperumbudur Taluk is thus divided into the Sriperumbudur and the Kandrathur block. Furthermore, Sriperumbudur Taluk falls partly under the jurisdiction of the CMDA and partly under the jurisdiction of the DTCP. Consequently, the supply of water is also split between the CMWSSB, supplying the CMDA area and the TWAD Board taking care of the rest of the Taluk. Furthermore, there are many other agents that are active… (Figure 4 in this paper).

Due to its significance, the water sector is a critical case in point to understand the administrative complexities, multitude of stakeholders and governance conditions in periurban Chennai, as the example of Sriperumbudur demonstrates (Box 1; Figure 4). Our research found that

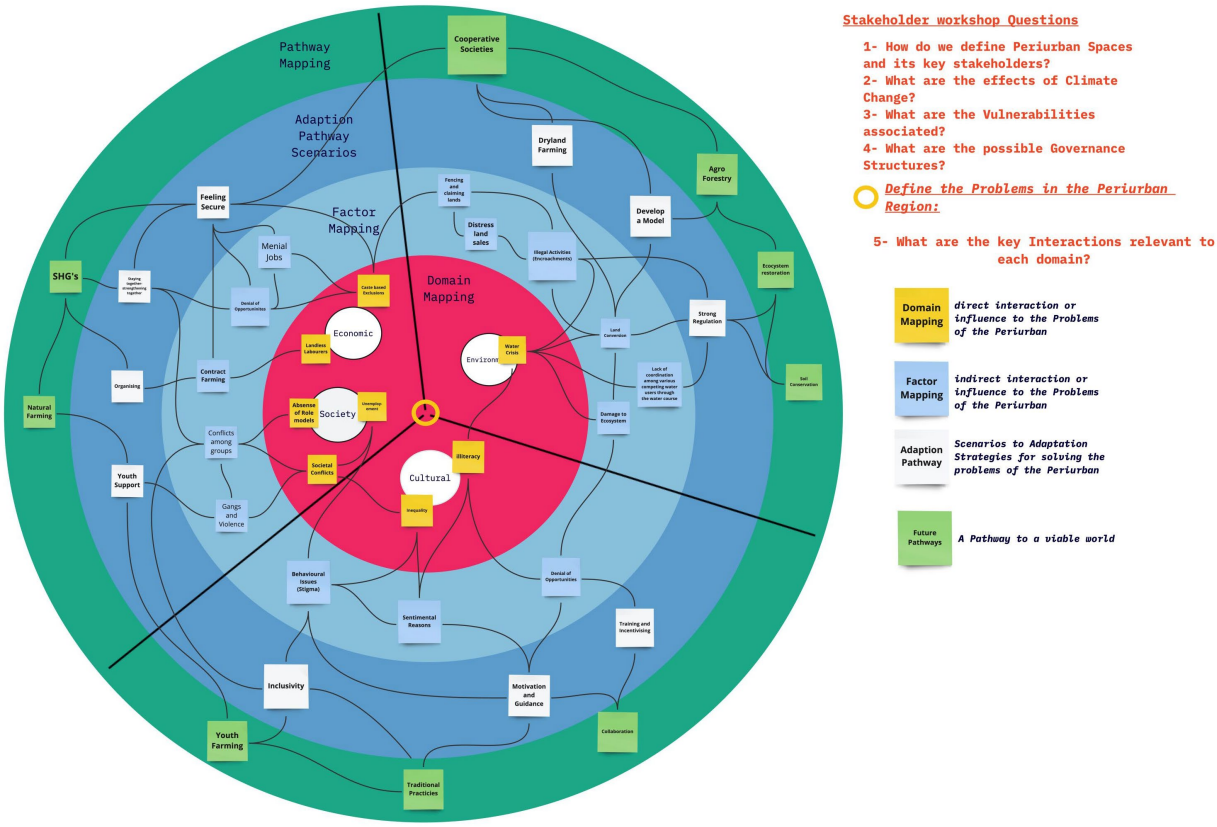

FIGURE 4
Illustration of the online Policy Lab Workshops—Chennai. Four "tables" that represent working groups during the online sessions. Peri-Cene Policy Lab workshops were conducted on the challenge of peri-urbanization and climate change around the world. These workshops aimed to create innovative "adaptive pathways" for urban/climate transformation, in each of the partner city-regions, in this case Chennai. The workshops explored future scenarios: spatial/synergy mapping, climate and peri-urban governance pathways, with the help of the Pathways Toolkit (source: Authors).

"Despite the seemingly clear division of tasks, there are many overlaps and conflicts between department's obligations and tasks. The insufficient coordination between governing bodies and hence the unclear mandates lead to incoherent and non-holistic policy measures" (John, 2015, p. 29).

Typically, ex-post analysis of each weather related disaster that affected Chennai has always critically raised concerns of the governance situation, reflecting the fact that governance structures and mechanisms are inextricably interwoven with the political ecology of the production of urban water and landscapes (Roumeau et al., 2015; Roy and Ayyangar, 2022). Lack of coordination, working in silos, multiple agencies with overlapping activities and an obscure bureaucracy dominated by rigid systems combined with minimal civic engagement are but a few of many such weaknesses that crop up, thus exposing the criticality of the state of governance. Adding to this are various other governance syndromes such as political fragmentation, widespread elite capture, and unauthorized construction and encroachments. Therefore, even though growing climate awareness is discernible (see the recent Chennai Climate Action Plan),[5] rigorous and committed implementation of policies is largely absent or sluggish.

7 Identification and characterization of entry points for adaptive governance

Rather than merely concentrating on the problems and obstacles of existing governance configurations, we focus on utilizing advantages of periurban dynamics and the potentials of transformative innovation in governance structures such as "reframing urban sustainability," "renegotiating governance arrangements," or "reconfiguring socio-technical-ecological interactions" (Marshall and Dolley, 2019). We introduce the term entry points in a similar way to "windows of opportunities," a term used in sustainability research for enabling the emergence and realistic implementation of innovative niche activities (Geels, 2010; Frantzeskaki et al., 2017). While related, entry points are distinct from Meadow's leverage points, which are identified as "places in a system where relatively minor interventions can lead to relatively major changes in certain outcomes" (Meadows, 1999 in Fischer and Riechers, 2019, p. 3). In our understanding, entry points indicate thematic or institutional areas with potential or initial activities for adaptive governance interventions; these areas themselves may be systems within which shallow and deep leverage points for transformative change may be identified (Abson et al., 2016). We characterize these two dimensions of entry points for adaptive

5 Only a draft document is currently available at https://chennaicorporation.gov.in/gcc/pdf/CCAP_GCC_CSCL_ENGLISH.pdf

innovation for analytical rather than practical reasons. In reality though, they are related and often interdependent:

1. *Thematic entry points*: e.g. (traditional) water management; peri/urban agroecology; eco-tourism as adaptive pathways;
2. *Institutional entry points*: windows of opportunity and niche innovations in formal and informal practices and institutional structures (such as organizational set up, relationships of agents/stakeholders, legal framework).

There are a number of recent examples of governance impulses in Chennai that were induced either through policies or calamities that occurred:

1. *Smart cities mission*: lauded as participatory, even though primarily a low level, weak type of participation close to tokenism (public feedback process via online mode, stakeholder consultations);
2. *Climate Change Action Plan Chennai 2022*: criticism about TN government's insensitivity to local constituencies (e.g., was initially not published in local language Tamil), only online feedback possible, and only for a 2 week time window (Roul, 2022);
3. *73rd/74th CAA* (Constitutional Amendment Act), 1992, to devolve functional and fiscal self-governance to rural and urban local bodies: not fully implemented in Tamil Nadu and across India (Gandhi and Pethe, 2017);
4. *Post-tsunami 2004 response*: "classic" disaster relief response through relocation of vulnerable communities (esp. fishing communities); World Bank funded; set up of an early warning system;
5. *Post-flood 2015 response*: mostly technical-engineering solutions as immediate response (still ongoing works on storm water drainages, desilting, water body conservation); early warning system; relocation and resettlements of slum and squatter settlements; only in the aftermath the National Disaster Management Policy of 2005 was implemented at state level that had been neglected until then;
6. *Recent change in 2022*: approval given by Government of Tamil Nadu to enlarge the CMDA boundary five times from 1,189 to 5,904 sq.km, adding another 1,200 periurban villages to the city's planning region and administrative upgrading of towns to municipal corporations (The Hindu Bureau, 2022).

In all these instances, institutional changes either happened (a) in a prescribed manner (incorporating or changing statutory status of local rural/urban bodies as for the enlargement of the planning region), (b) by establishing entirely new institutions such as a State Disaster Management Authority (as per national law), or (c) in a conventional manner such as the establishment of the Special Purpose Vehicle for the implementation of the Chennai Smart City projects. Bold experimentation to facilitate innovative procedures, mutual learning and co-creative knowledge production through participatory, more equal participation of stakeholders remains largely absent. Clearly, the undercurrent of planning and implementation processes is still adhering to an instrumental, result and output focused bureaucratic style than a process-orientated multi-stakeholder approach. In contrast, the area with the potentially widest scope for institutional reform, the 73rd/74th CAA, has received only partial support from state governments since its inception in 1992.

In spite of this, we argue that periurban areas within the Chennai region are also providers of climate change adaptation functions. As outlined earlier, these will become particularly significant in the coming decades as the climate continues to change and extreme weather events are expected to become more frequent and intense. A notable example relates to opportunities of building on traditional water tank management measures for the implementation of the conservation and maintenance of water bodies (Mosse, 1999). As research shows, these have seen significant changes from locally decentralized to state level, more centralized infrastructures and governance over the course of a century (Haufe, 2017; Harishankar and Vedamuthu, 2019). Other adaptation functions include the creation of food sovereign spaces to support local ecology conservation around water-bodies in a changing climate that simultaneously provide livelihood opportunities to the landless local populations while ensuring their nutritional security. Strategies are needed to encourage and progress these opportunities.

Working to conserve and enhance the water management functionality of landscapes in the periurban hinterlands of the Chennai watershed can reduce flood risk in downstream urban areas and mitigate drought upstream, while also delivering benefits locally. However, this raises significant governance challenges that remain unaddressed or at best in proposal stage at the Chennai Metro Flood Management Committee (Roul, 2021). Appropriate governance frameworks are needed, encompassing the wide range of sectors and stakeholder groups interested in the future of these areas. Current governance frameworks are fragmented both, spatially and sector-wise, and work in silos. Moreover, the role of non-governmental agencies is inadequate due to limited communication and knowledge sharing between government agencies. As Roy and Ayyangar (2022, p. 200) in their study note: "This accounts for a governance scenario that is not conducive to collaborative action, wherein the visions of different stakeholder groups can collectively drive policymaking and implementation." However, emerging good practices can also be found. Thus, we encountered informal partnerships which exist with a mandate and role within more extensive institutional arrangements like independent third sector civil society, formal organizations that play an active role in informal partnerships (e.g., Meenavar Sangam/fishermen collectives; Water-Users Associations) (Rajan and Woiwode, 2023). These are promising good practices that increase participation and decision making opportunities at the local level, closer to the people concerned. At another level, there are formal governance partnerships like the Chennai River Water Restoration Trust, which bring together different levels and units of government. Thus, the thematic entry point water management, has partly become an opportunity for participation due to its annually rising criticality.

8 Chennai: adaptive pathways at multiple scales

Taking clues from these instances and our analytical research findings on the situated conditions of periurbanization and the climate change risks identified for Chennai, we mapped potentials and requirements of adaptive governance and related adaptive future pathways (Figure 4). The presented charts are results from the online Policy Lab sessions which were held with researchers, representatives of civil society and government authorities. The workshop in the Chennai region employed a multi-scale approach, examining

adaptation pathways at various levels, including the community scale, neighborhood scale, and basin scale. This approach aimed to understand how these pathways transitioned across different scales, facilitated by methods like actor mapping, domain mapping, and factor mapping. By analyzing the actors, domains, and critical factors at each scale, the workshop sought to identify opportunities for intervention and adaptive governance strategies. This comprehensive, multi-scale approach allowed for a more holistic understanding of the intricate dynamics and challenges related to climate change adaptation in the region. The participants emphasized the importance of federating local units and establishing a coordinated framework for various initiatives and activities within the region. For example, the proposed "Mutthukadu Wetlands Authority" at landscape level would be based on a statewide structure with sub-units operating at the district level. These district-level units would be capable of working closely with local communities, private entities, and government agencies to manage the region's wetlands effectively and ensure the sustainable use of resources while minimizing potential conflicts.

Complementary to the adaptive governance approach is the notion of adaptive development pathways. In our perspective, adaptive governance practices sort of facilitate the implementation of adaptive pathways as a flexible, adjustable "instrument"; while at the same time adaptive governance is in itself an adaptive development pathway. It is therefore both, means and end, similar to concepts such as participation and empowerment. In this sense, governance of social-ecological-technological systems (SETS) acknowledges dependencies across time and space as well as being responsive, or even ideally anticipative, to shocks and stressors. In virtue of these characteristics, adaptive governance enables and coordinates transformation processes across spatial and temporal scales (Krueger et al., 2022).

We use the term "pathway" rather than "route/road-map," because goals are fuzzy due to wicked problems like climate change and hence routes are uncertain. A pathway here is based on synergies between two or more domains (social, technical, economic etc.), which can bypass or bridge present-day gaps and barriers. For transformation from "problems" or "syndromes" to "responses" and synergies (generally wise or wiser systems), we look for "synergistic pathways from smart to wise." These are ways of learning and thinking and creating, which use collective intelligence to connect present problems with future opportunities. These processes of connection are designed with pathway mappings, with the help of cartoons and diagrams (Ravetz, 2020).

Adaptive pathways applicable to Chennai were derived from the mapping of existing systems and diagnostic problem analysis during the online Policy Lab workshops (Supplementary Figure S1) with research teams from all participating institutions in the Peri-Cene project and 18 additional periurban city regions. These analytics are summarized for Chennai around the four core interfaces: the periurban, climate, society, and governance (Figure 5). They are spelled out at two levels, firstly, a strategic meta-level with four themes of 1. periurban development syndromes (sprawl, extraction, waste), 2. socio-climatic syndromes (controversy, division), 3. socio-economic syndromes (inequality, exclusion), and 4. governance syndromes (defunded, captured, fragmented). Secondly, at a more topically specific level, syndromes and impacts describe specific issues such as divisive inequalities due to private residential enclaves, impact on land and ecosystems, or market governance open to corruption and elite capture, among others (Figure 5, top).

Flipped around, positive potential synergies and pathways were constructed, again at a more strategic meta-level as well a topic-specific level of thematic synergies and pathways. At the strategic level, the four identified pathways are 1. synergistic periurban development and market transformation, 2. synergistic socio-climatic consensus and capacity, 3. synergistic periurban economic, social development and resilience, and 4. synergistic governance and institutional development. Within the topic-specific synergies and pathways, water, flood and drought related pathways are the most crucial with high priority. Finally, the syndromes and mirrored pathways levels are also always interdependent as they are intrinsically intertwined; however, these interdependencies need to be closely investigated and understood from a socio-ecological systems perspective in order to design interventions that go beyond the cause-effect logic and to leverage on co-benefits and at systems level.

A detailed multi-scalar system mapping study[6] of ongoing interventions complements and underpins the systems and pathways mapping (Supplementary Figure S2). At the bio-regional scale, numerous projects and initiatives focus on climate change adaptation, disaster risk reduction, development, infrastructure, and various sectors. These projects encompass various facets of urban development and environmental resilience. When shifting to the landscape level, a transect study conducted along two distinct transects aimed to comprehend the interactions between people and their environment, as well as risk profiles, in a region undergoing periurbanization and grappling with the impacts of climate change and water-related disasters.

The diagram (Supplementary Figure S2) employs color coding to represent the three scales of analysis:

- Macro scale: Here, the focus is on *policies and programs*. The diagram categorizes programs as national, state-level, and city-level development initiatives, particularly in sectors such as agriculture, irrigation, and ecosystem.
- Meso scale: This scale delves into *various projects and their connections*. It also maps stakeholders within the context of two specific transects, Uttandi/Semencheri urban villages and Siruseri SIPCOT (IT SEZ).
- Micro scale: At this scale, the diagram zeroes in on *local stakeholders*, with the villages of Karikattukuppam, Kovalam, Muttukadu as specific examples.

For illustrative purpose we now outline some such specific pathways that were identified based on the multi-scalar notion of intervention.

8.1 Social eco-innovation and micro-governance pathway

At the neighborhood scale, use of a community gardening initiative to develop social capital among disenchanted youth groups and marginalized communities by providing a supplementary source of income and potentially rebuild and rekindle a lost sense of community and arrest social unrest within the community. This is

6 The study involved secondary research on Policy documents, informal interviews with various stakeholders, including local residents.

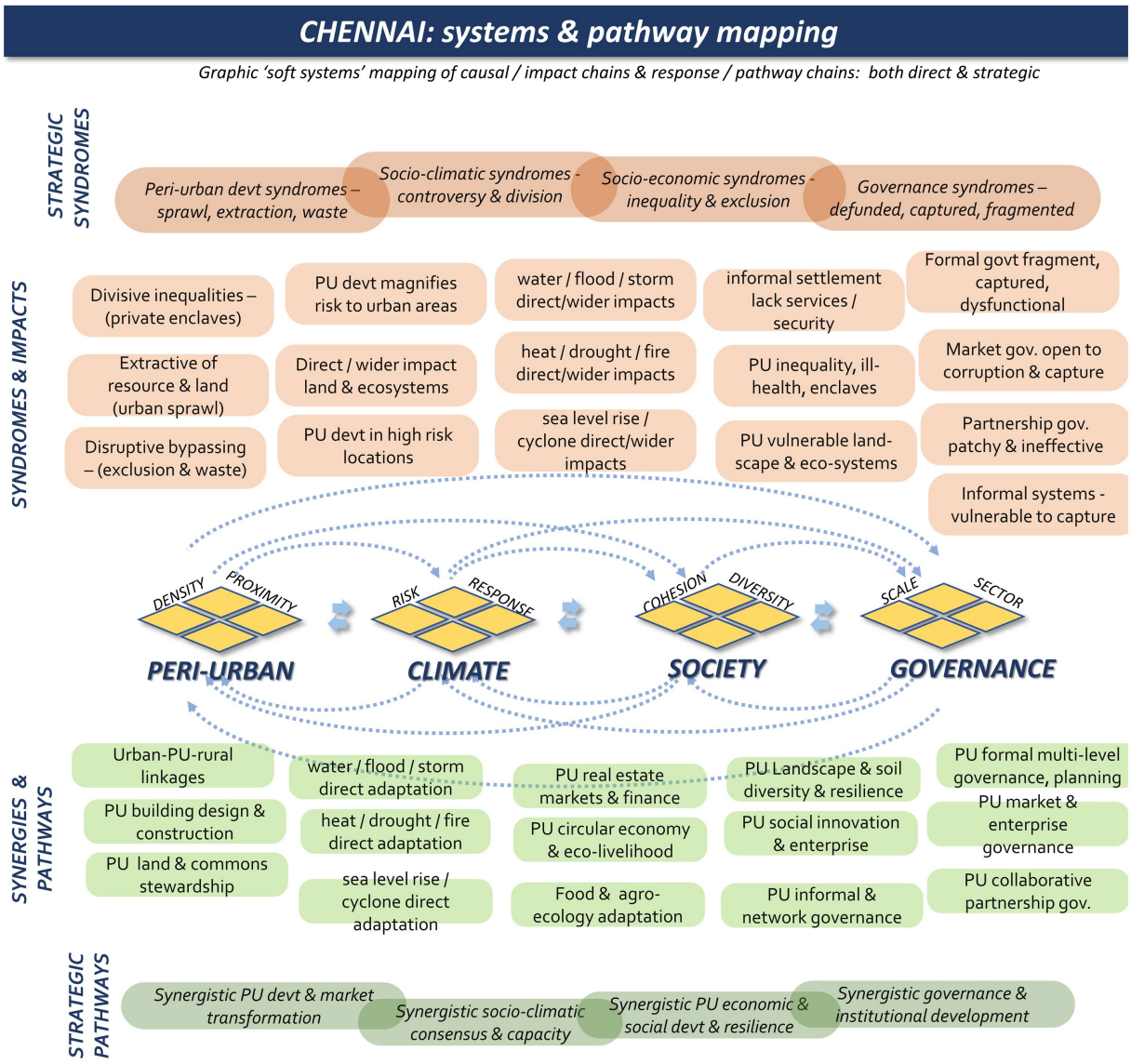

FIGURE 5
Systems and pathways mapping, Chennai (© Periurban Initiative, Pericene Project, design: Ravetz et al., 2022).

already demonstrated in the village of Katchipattu near Sriperumbudur, in the industrial corridor (Woiwode et al., 2024).[7]

8.2 Eco-tourism pathway

At the periurban landscape scale on the southern periurban fringe of Chennai in the Muthukadu-Kovalam sub-basin, an earlier project "Water as Leverage" shows possibilities to intervene in a region that will continue to urbanize rapidly. Future policies could use design tools to incorporate nature-based designs of "blue-green" and "sponge-city" concepts to avoid further social and ecological fragmentation and raise the potential for resilience at such a scale, while at the same time generate economic opportunities through an eco-tourism approach in an attractive ecological environment.

8.3 Agroecology pathway

At the bio-regional scale, an agenda for food sovereign spaces in "poramboke" lands ("commons" land attached to water bodies) has significant potential for building climate resilience in the urban and periurban geographies by involving local communities. This is also about greening the city's waterscapes with food-forests. It would mean

7 IGCS is currently implementing two CSR funded action projects in this periurban village, one with a focus on social community transformation (https://periurban.in/nook_chennai.html; https://periurban.in/index.html), the other on kitchen gardens and environmental conservation (Indian Institute of Technology Madras, 2023).

re-imagining current food supply chains, shortening them, involving local, marginalized communities, alternative socio-economic models such as FPOs (farmer producer organizations) that will over time ensure food sovereignty but importantly also safeguard ecological assets, foremost of which the water bodies and ground water, and thereby reduce flood risk in the city on account of an increased water holding capacity. Agroecological approaches and transition to sustainable or non-conventional farming and food systems including peri/urban farming and horticulture have gained momentum in Chennai (Bopp, 2020; Volz and Woiwode, 2022) and other parts of India (Garud and Rao, 2017; Zasada et al., 2019).

9 Discussion and conclusion

The multifaceted challenges faced by the communities necessitate holistic development approaches. There is a need to advocate for comprehensive policies that encompass environmental conservation, infrastructure development, disaster preparedness, and economic growth. The engagement of government and external organizations is essential to help these communities adapt to the evolving challenges they face and improve their overall well-being. Yet, as other cases such as Ghaziabad near Delhi in India illustrate, "periurban waterscapes do not fit into existing urban or rural planning models because these same models largely fail to recognize the periurban interface as a distinct form of territorial development" (Mehta and Karpouzoglu, 2015, p. 159). In that case, the periurban-climate agenda is subsumed in a larger and more uncontrollable dynamically shifting picture of power, conflict, turbulence and disruption. This shows up in practical cases, for instance, the Chennai adaptation agenda translates into practice with the clearing of informal settlements from the banks of the rivers and water bodies arguably for the management of flood defense. However, in a rather blunt and conventional way these residents are moved to periurban "resettlement colonies" (Coelho et al., 2020; IRCDUC and HLRN, 2021), cut off from jobs and services and communities while at the same time adding to the disruption of water and ecosystems in the hinterland which contributes to such flooding.

Eventually, the potential for water management measures to sit as one of the pivotal elements of a broader flood-drought risk management response in the Chennai basin has risen up the agenda. Managing and restoring these traditional water-bodies encompasses a wide range of interventions: from restoring degraded reserve-forests upstream in the catchment areas to clearing the drainage channels, desilting the tanks, removing invasive species in the water-spread area, removing unauthorized constructions especially along the soft-edge of water bodies, strengthening the bunds and associated infrastructure, addressing point and nonpoint pollution risks and preserving the natural ecology of the associated wetlands.

This paper focused on the identification of possible entry points for generating an adaptive governance approach for sustainable, climate change responsive development pathways for periurban Chennai. Against this background, we discussed periurbanization within the specific context of Chennai by defining the periurban space from a bio-regional, socio-ecological systems perspective that comprises the watershed basin of the four major rivers which are vital for the survival and economy of the metro-region. This perspective is complemented by a zonal classification characterizing various sub-regional areas within this periurban space, and considering the impact and consequences of disaster as well as climate change risks. We then presented an adaptive governance framework that was developed in the international collaboration research project. Based on these foundational sections, the existing governance structures of Chennai were discussed, followed by presenting the findings with respect to identified syndromes, synergistic potentials and activities for adaptive governance and the concomitant notion of adaptive development pathways. This integrated analytical and diagnostic approach we conceptualize as (a) *multi-dimensional*: the adaptive governance framework comprising several normative features; (b) *multi-level*: considering local, intermediate and state governance levels; and (c) *multi-scalar*: bio-regional macro, landscape medium, community/neighborhood local scale.

Pathways to sustainable development are often discussed at the global scale but emphasizing regional variations on account of socio-cultural and historic contexts (Westley et al., 2011; Bennett et al., 2021). Characteristics of pathways underscore that there is no "one-size-fits-all" logic but rather multiple pathways, and what is needed is a pluralistic approach due to different prioritization of values that result in different realizations of pathways and outcomes. Bennett et al. (2021, p. 173) contend, "the history of societal transitions suggests that the most important effects are unknowable and will have to be made sense of and navigated as they arise." It is for this reason that adaptive governance as a process is pivotal for urban transformation to sustainability. Periurban regions provide a separate scale, and for Chennai, we have applied a diversified set of several spatial scales. This is particularly important and a significant contribution of this case study, since most of the literature on sustainability transitions and transformation focuses on the urban scale. Consequently, we developed scenario visions for several constituent pathways at these scales and with different thematic focus whose potential interactions and outcomes can only be sketched out due to the unknowns of future events, because of the complexities of socio-ecological-technical systems in (peri)urban contexts (Andersson et al., 2021; Krueger et al., 2022). However, a synergistic perspective of such interactions and interdependencies as presented here potentially benefits the development toward sustainable transformation, for promoting a periurban agroecology pathway and a water management pathway may leverage existing opportunities as witnessed in other parts of the world (Pérez-Belmont et al., 2021). Essentially, a pathways perspective permits what Frantzeskaki et al. (2017) refer to as deeper transformations, the fundamental, structural systemic realignments within urban contexts, but which require the ability to generate and adopt "urban transformative capacity" (Wolfram et al., 2019).

Therefore, as a key challenge in Chennai remains the transition from a predominantly top-down, strongly hierarchical, government-led and dominated type of governance to a more experimentally guided, co-creative and co-productive type of collaborative governance, which allows for climate change adaptation within a longer-term perspective of transformative future development pathways:

> "The city probably needs to explore an innovative, "adaptive governance" model. Adaptive governance, as a new model of cooperative or collaborative governance, is not confined to only climate change adaptation…. It is a multi-tier and multi-layer

> cooperative and/or collaborative model beyond the strict control of techno-bureaucratic-consultant model. It is neither a fixed top-down nor a bottom-up approach. It is flexible as well as reflective, innovative and strategic. At best, the adaptive governance motto may include elements of co-imagine, co-initiate, co-design, co-learn, co-implement and co-evaluate all the 3 Ps (projects, programs, and policies) related to the city and beyond" (Roul, 2021).

In spite of this assessment, our research in Chennai acknowledges the challenges and constraints of the highly dynamic situation of periurban and socio-economic, spatial change at multiple scales, levels and of multiple dimensions, across various policy areas with a high pressure on policy makers and stakeholders of practice. While a number of barriers, bottlenecks and constraints of adaptive governance exist, there are also noteworthy indications of adaptive governance practices that demonstrate diverse potentials for enhancing this trend in a more strategic and conscientious manner. The implications of our research and ongoing dynamic changes, hence, underscore that sooner or later the Peri-Cene "adaptive pathways" and recommendations, will have to challenge in some way the existing system which has produced such problems, and enables them to continue and reproduce.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

CW: Writing – original draft, Writing – review & editing, Conceptualization. AR: Formal analysis, Investigation, Software, Visualization, Writing – review & editing. TP: Formal analysis, Investigation, Project administration, Software, Visualization, Writing – review & editing. DR: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. SR: Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2024.1368240/full#supplementary-material

SUPPLEMENTARY FIGURE S1
Peri-Cene Policy Lab—illustration of online discussion tables.

SUPPLEMENTARY FIGURE S2
System mapping study (© Periurban Initiative, Pericene Project).

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