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Comparative analysis of local adaptation processes in the future across peri-urban India to support transformations to sustainability

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ABSTRACT

Peri-urban transformations in emerging economies like India demand scientific attention given their impact on global environmental change processes. Some studies examine past or ongoing peri-urban adaptation processes, but insight into future adaptation needs and aspirations of peri-urban communities is lacking. Also, it is unknown how the high degree of informality that characterizes peri-urban areas, interacts with formal institutions to shape or enable more sustainable adaptation pathways. This study addresses these scientific gaps, using an existing typology of adaptation processes to investigate plausible future adaptation pathways in three peri-urban villages in India, near Pune, Hyderabad, and Kolkata cities. On-site field research followed by a Delphi-study were used to develop normative adaptation pathways for livelihood and household water use with local actors. The pathways represent development trajectories and adaptation strategies over the next 15 years in the livelihood and household water sectors. Pathways data was thereafter analyzed and compared in terms of drivers of vulnerability and opportunity, adaptation processes, and formal and informal institutions. Our ex-ante study identifies general and context specific drivers of vulnerability and opportunity shaping different peri-urban transformations. Results reveal similarities in future drivers, whose impact on peri-urban livelihoods and household water is context dependent. This comparative analysis contributes a deeper understanding of future adaptation needs by highlighting patterns in locally preferred adaptation processes for different drivers and water-use sectors. This normative understanding reveals preferences of local communities who are otherwise marginalized from decision-making arenas. A combination of adaptation processes will be needed to respond to the various drivers, only some of which are achievable through informal institutions. Formal government intervention will be essential for stimulating innovation, intensification, and revitalization forms of adaptation. Institutional adjustments will be key to shaping local agency and future adaptive capacity away from a business-as-usual trajectory.

1. Introduction

Peri-urban areas, situated close to growing cities, form the transition zone where urban influences gradually become visible in changing land uses, influx of population, and changing economic activities (Allen,

2003; Narain et al., 2013). Butsch and Heinkel (2020) define them as spaces of flows and exchange at the intersection of rural and urban, creating a mosaic of land use, diverse stakeholders and interests, and weak governance. While their urban proximity attracts migrants and opens up opportunities for new kinds of livelihoods, they are

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simultaneously sites of opportunities and sites of poverty and marginalization (Thorn et al., 2015). Local communities who reside in these areas use adaptation as way of dealing with these threats and opportunities during this transformation. Here, adaptation refers to the responses of households and other social groups to changes (Smit et al., 2000). Despite growing interest in peri-urban adaptation research (e.g. Anum et al., 2022; Padgham et al., 2015; Ricci, 2012; Thorn et al., 2015), our understanding of peri-urban adaptation processes in the future remains limited.

In India, peri-urban transformations affect traditional water-dependent livelihoods, e.g. agriculture, aquaculture etc. (Butsch and Heinkel, 2020) and household water supply for drinking and domestic purposes (Gomes, 2019; Narain et al., 2013; Roth et al., 2019; Sen et al., 2019). In both sectors, competition over increasingly scarce water resources is rising. The emergence of new economic activities such as polluting factories with high water use for manufacturing and untreated wastewater outputs threatens surrounding traditional livelihood activities (Butsch et al., 2021; Gomes, 2019). Water demand also increases due to growing populations and increasing per capita consumption (Sen et al., 2019). The pressure on peri-urban water is aggravated by nearby “thirsty cities” (Garrick et al., 2019) that draws water from peri-urban surroundings and degrades resources by using peri-urban areas as a sink for wastes. These changing waterscapes creates water insecurity, especially for economically disadvantaged peri-urban residents (Butsch et al., 2021). Many families are forced to diversify livelihoods and find alternate household water sources less affected by water insecurity through informal means (e.g. water tankers or packaged water providers) or privately fund their own water infrastructure.

The flux that results from peri-urbanization demands adaptive capacity at the local level. During such transformations, adaptations have been locally observed, however, strategies are oftentimes reactive or short-sighted leading to maladaptation. Winter and Karvonen (2022) for examine observed this in their study of flood responses in 26 peri-urban contexts including India. Moreover, existing adaptation strategies may prove ineffective against future threats. It is unclear how peri-urban areas will develop in the future and the type of adaptive capacity that will be needed. Therefore, our study seeks to better understand future drivers of development and community-level adaptation.

Peri-urbanization in India is taking place in a very specific institutional environment, defined here as formal and informal rules. The country’s overall urbanization is relatively low – 35% in 2020 - according to official statistics (UN DESA, 2018). Yet, others argue that by applying more common definitions of “urban”, India’s urban population share may, in reality, stand at 55% or even 63% (Aijaz, 2017: 8). Specific for India’s urbanization is that it largely occurs in smaller settlements, a process labelled “subaltern urbanization” (Denis and Zerah, 2017) or “agrarian urbanism” (Ren, 2021). This is related to keeping smaller towns under decentralized rural self-governance (locally referred to as *panchayati raj*). These fast-growing towns are administered like villages by a *gram* panchayat that lacks the administrative power to effectively govern growth. Thus, many peri-urban activities lie between rural and urban jurisdictions, resulting in a complex institutional interface (Narain and Nischal, 2007). Understanding these institutional settings will shed light on local adaptive capacity.

Formulating adaptation research in this context requires explicit consideration of some key characteristics. First, their dynamic nature is reflected in peri-urban changes and a heterogenous social composition, partially because of the increasing demand for land and water resources and/or environmental degradation (Díaz-Caravantes, 2012; Gomes and Hermans, 2018; McGregor et al., 2012). It is important to understand the drivers of change occurring in the wider peri-urban context and how these impact water-security in peri-urban communities. Second, existing institutions – defined here as formal and informal rules - that exist to regulate development and resource use are ineffective or are confronted with drivers beyond local administrative boundaries. Moreover, there is a disconnect between peri-urban areas and policymaking circles as their

geography makes them removed from rural and urban decision-centers, hindering inclusive forms of resource governance during transformations. Third, their transitional nature usually leads to the assumption that they are urban spaces to be, which hinders their scholarly examination (Simon, 2008) and also limits the imaginations of local actors of possible futures, thus hindering their development as spaces in their own right (Bartels et al., 2018; Butsch et al., 2021). When studying future peri-urban transformations, it is valuable to consider the perspectives of local communities and how they see themselves adapting to drivers of change under different development trajectories.

Examining community-level adaptation in the future is needed to support more sustainable peri-urban development. It entails taking into account what local communities envision when it comes to sustainable development but also how they cope and manage uncertainty through adaptation. Given the uncertainty of future peri-urban transformations, understanding what adaptation processes are readily available and the kind of adaptations requiring additional support will make communities better prepared for this. Furthermore, examining the institutional settings of future adaptations can reveal the institutional adjustments needed to improve local adaptive capacity. This understanding helps create more effective institutions to enable adaptation and allow peri-urban communities to better navigate future threats and opportunities in a more sustainable way.

However, peri-urbanization is extremely context dependent. Transformations are likely to vary from one peri-urban region to another given the differences in physical, socio-political or institutional settings. Studying this in a variety of peri-urban regions gives us an opportunity to identify more general patterns of adaptation in the future. Therefore a comparative study of peri-urban areas across India is used to generate theoretical conclusions about adaptation processes during future peri-urban transformations.

This paper addresses the following research question: How will peri-urban communities in India adapt to future threats and opportunities and what institutional adjustments are needed to support this?

To study this, we apply a normative adaptation pathways approach (Gomes et al., 2023) to collect data about peri-urban futures across three regions in India. These pathways describe adaptation strategies in the business as usual, ideal, and alternative scenarios within two key water use sectors – livelihoods and household water. The provide the main inputs for the comparative analysis of adaptation strategies using the typology of adaptation processes (Thornton and Manasfi, 2010). Future drivers are analyzed in terms of opportunities and vulnerabilities for local livelihoods and household water uses. Institutions associated with different pathway are categorized as formal or informal and is used to further compare and analyze local adaptive capacity.

This paper is structured as follows. Section 2 explains the relevant characteristics about peri-urban areas and ways to empirically study adaptation along with our hypotheses about peri-urban adaptation. Section 3 describes the methods used to develop future pathways in peri-urban India and thereafter, systematically compare and analyze them. Section 4 presents the comparative results of future drivers, adaptation processes, and institutions. A discussion of these results and study limitations is in section 5 followed by final conclusions in section 6.

2. Literature review for the examination of future peri-urban adaptation

2.1. Key characteristics of peri-urban areas relevant for studying adaptation

Peri-urban is a spatial category that is linked to the current urban transformations of the Global South. This peri-urban interface (Rakodi, 1999; see also: Allen, 2003; Simon, 2008) is a zone in transition with distinct characteristics, which cannot be found in the same way in the Global North. Peri-urban areas are typically situated close to urban centers (Iaquinta and Drescher, 2000) and characterized by their unique

mix of rural and urban features and interaction patterns across the rural–urban divide (Brook et al., 2001). They include a mosaic-type of mixed land-uses, a multiplicity of stakeholders and often also a multiplicity of institutions and governance arrangements (Butsch and Heinzel, 2020; Narain and Nischal, 2007).

The unique characteristics of peri-urban areas, introduced above, are important to take into consideration when studying adaptation in this context. Here adaptive capacity, refers to the human ability to adjust to negative disturbances or exploit opportunities that arise as a result of transformation processes in a system (Gallopín, 2006). An important feature of peri-urban areas relates to their temporal and heterogeneous nature. Peri-urban areas are dynamic and rapidly evolving. Growing urban footprints in cities of low and middle income countries place pressure on surrounding peri-urban areas. These peri-urban transformations start much before “urbanization” takes place, gradually becoming visible in changing land use, population, and economic activities. Over time, peri-urban features shift from those of a more rural nature to an urban one. For example, in India, dynamic peri-urban transformations are evident from the changing activities and resource use. Traditional livelihoods (e.g. fishing, farming or animal husbandry) are increasingly replaced by real-estate development, industries, service jobs in the city, commercial water vending businesses et cetera (Butsch et al., 2021). As a result, the composition of peri-urban communities is extremely heterogeneous. Therefore, peri-urban transformations are not likely to be experienced in the same way and requires different kinds of adaptation across actor groups who experience them.

Peri-urban communities are often marginalized as a result of being neither close to their rural nor urban decision centers. As a result, local needs and interests are not well integrated into government policies or programs and thus remain poorly addressed. For example, Thorn et al. (2015) observed this in peri-urban Nairobi where residents were not found to benefit from planned measures to reduce risk despite their existence at multiple governance levels. Moreover, this marginalization requires peri-urban communities to explore informal avenues for addressing local problems (Gomes, 2019; Randhawa and Marshall, 2014; Vij et al., 2019). Individual or household level adaptation strategies to peri-urban risks are dependent on access to different types of capital (e.g. social, natural, financial, human and physical) as well as social demographics (Thorn et al., 2015). For example, Anum et al. (2022) discovered that low access to agricultural insurance for small-holder farmers in peri-urban Ghana influenced adaptation to climate change, together with age, education and social networks. A closer examination on the role of capital or assets in livelihood strategies in peri-urban Accra is facilitated with the help of a modified sustainable livelihoods framework by Oduro et al. (2015). However, this framework does not make any connections to the institutional context. The role of institutions (both formal and informal) in enabling and constraining local level adaptation needs to be better understood, particularly in the future.

Peri-urban areas have unique institutional settings and challenges. In parallel to the above mentioned changes, resource needs grow and new institutional arrangements emerge. Typically, institutional arrangements are arranged along rural and urban boundaries. As these areas are neither distinctly rural or urban (Beilin et al., 2013), institutions become less effective in coping with its unique challenges. This has consequences for local governance concerning issues like climate change, water supply, agricultural activities etc. (Eakin et al., 2010a; Gomes and Hermans, 2018; Padgham et al., 2015). Rural and urban administrative boundaries shift during peri-urban transformations, leading to institutional dynamics (Marshall and Dolley, 2019). In such a heterogeneous context, formal and informal institutions are even more necessary to manage diverging interest and needs. Studies like Thorn et al. (2015) explain the significance of institutions in their study of peri-urban slums in Nairobi. Padgham et al. (2015) studied urban and peri-urban agriculture in cities across Asia and Africa. They used the adapted urban resilience framework of Tyler and Moench (2012) centered around the

interplay between systems, agents, and institutions. In peri-urban areas of Mexico, institutional voids are found to impact adaptive capacity to flood risk (Eakin et al., 2010a). This underscores that in peri-urban areas the role of institutional seems critical in mediating and shaping adaptation trajectories.

2.2. Adaptation pathways for dynamic peri-urban systems

Adaptation processes, whether incremental or transformative, are often conceptualized as part of a dynamic pathway. These pathways are typically used to explore long-term decision-making under uncertainty (Haasnoot et al., 2013). They represent a series of actions sequenced over time towards a variety of future scenarios. Each pathway is shaped by specific drivers of change. Adaptation is captured in the ability to shift between pathways as system conditions evolve. The literature outlines the common elements found in all adaptation pathways approaches and includes: current situation or baseline, future scenarios and the drivers that shape them, the pathways - each consisting of a sequence actions from the baseline to the futures -, and concepts relating to the shifts between pathways namely transfer stations and its associated signals, triggers, decision nodes and endpoints (Bhave et al., 2018; Bosomworth et al., 2018; Bosomworth and Gaillard, 2019; Butler et al., 2016a; Coulter, 2019; Haasnoot et al., 2013).

Adaptation pathways have been applied in several contexts as means of participative adaptive governance (see for example Barnett et al., 2014; Bosomworth et al., 2015; Haasnoot et al., 2013). Maru et al. (2014) used adaptation pathways to explore future pathways in vulnerable communities, disconnected from decision-making centers, a feature shared by many peri-urban communities. More recently, these approaches were developed and applied by the authors in peri-urban contexts (Gomes et al., 2023; Luft et al., 2022). The Delphi-based methodology described in (Gomes et al., 2023) offers the added advantage of incorporating normative perspectives about these futures and furthermore, incorporates the institutional and multi-actor elements within these pathways.

2.3. Comparing drivers, types of adaptation processes, and institutions across peri-urban areas

Future pathways in peri-urban villages are to a large extent externally driven, by drivers and changes at higher governance levels, regional economic trends, and urban development patterns. Peri-urban areas often face a multiplicity of drivers as a result of the growing urban footprint as well as emerging climate risks (Padgham et al., 2015). These drivers result in vulnerabilities like for example resource over-exploitation, poverty traps due to livelihood insecurity or rising costs of living, environmental degradation etc. However, not all drivers of change are sources of vulnerability (Gallopín, 2006), some can also bring opportunities for societal actors. Hence, adaptation does not solely pertain to reducing adverse effects but also includes taking advantage of emerging opportunities (Gallopín, 2006; Maru et al., 2014; Thorn et al., 2015). For example, peri-urban transformations can also create opportunities in terms of new job markets, improved water supply, public services etc.

These external drivers shape local responses and processes, which can be understood as local communities’ adaptation strategies. Communities who reside in these areas face constant pressure to cope or adapt with their changing circumstances over time. A peri-urban study by Thorn et al. (2015) is helpful for understanding autonomous adaptation by peri-urban actors to change in the absence of external support. They applied a typology of eight adaptation processes developed by Thornton and Manasfi (2010) (Table 1) in peri-urban contexts – and this same typology has been applied in other relevant studies on adaptation at the community level and in combination with pathways approaches (Roy et al., 2018; Thornton et al., 2019). This typology potentially allows for a deeper analysis of future adaptation strategies by peri-urban

Table 1
Typology of adaptation processes (Thornton and Manasfi, 2010).

| Adaptation process | Description |
|--------------------|---|
| Mobility | Seasonal movement or permanent migration to avoid risk or in search of better circumstances |
| Exchange | Flow of material and symbolic goods and services between people |
| Rationing | Controlling the circulation or consumption of limited or critical resources among members of a group |
| Pooling | Sharing or linking of assets (wealth, labor, knowledge) across social groups |
| Diversification | Increasing the variety of household and livelihood strategies, specialization, etc. to meet or enhance daily water needs and income |
| Intensification | Increasing the availability of resources by boosting theory yield within a certain space or time |
| Innovation | New, unplanned method of technique that arises to address a certain need |
| Revitalization | Organized reconfiguration of ideology and practices to reduce stress and create a more satisfying culture |

communities under different drivers and development scenarios.

Local agency, and hence adaptation processes, are co-defined by access to resources, which are determined by the overarching institutional arrangements. While formal institutions may not adequately curtail to local needs, peri-urban actors may use informal means to adapt. A better understanding of local impediments and potential ways of overcoming them is recommended in order to build resilience in such contexts (Padgham et al., 2015). Formal and informal institutional settings are likely to enable and constrain local agency to pursue particular kinds of adaptation to future drivers of change.

In summary, the literature on peri-urban adaptations, suggests that, although peri-urban areas across India would face similar drivers, the impacts they will have for peri-urban communities in terms of vulnerabilities and opportunities will vary between contexts, as will the adaptation mechanisms used to deal with them. Conceptualizing adaptation processes with a pathways approach, helps to identify and study certain favored and less favored adaptation processes by peri-urban communities in the future. When it comes to studying adaptation processes, institutional arrangements are an important co-determinant of agency and different formal and informal institutional arrangements across peri-urban contexts will translate into certain forms of adaptation. We may hypothesize, based on the eight types of adaptation processes identified by (Thornton and Manasfi, 2010) that in the absence of locally supportive formal institutions, communities will invest in those adaptation processes that are perhaps accessible through informal means. Furthermore, certain adaptation processes will only become accessible with institutional interventions and improvements to local agency. We expect that government support and formal institutional change are needed to activate diversification, intensification, innovation or revitalization forms of adaptation.

3. Methods

This comparative approach to study local-level adaptations to future peri-urban transformations was applied in 3 peri-urban regions across India as part of the 'H₂O-Transformations to Sustainability' research project. Selection of the three study regions was undertaken in early 2019 using the following selection criteria: they (i) had to be governed by *gram panchayats* or *nagar panchayats* (an institutional construct used to govern zones in transition, observed only in the Hyderabad context), or very recently brought under urban governance (*i.e municipal*); (ii) together they reflect a variation of physical-geographical factors; (iii) show transformations in income sources, population changes and land use/economic activities; (iv) constraints to locally considered solution strategies; (v) recent institutional change; (vi) existence of local platforms for learning and knowledge sharing; (vii) stakeholder willingness

to change the status quo; (viii) evidence of changes in household water sources or water use; (ix) threats to the primary household water sources; and (x) water outflows for uses beyond the village's household water needs.

The three peri-urban regions selected for this comparative study are Paud village (near Pune), and Anajpur village (near Hyderabad) and Hadia village (near Kolkata) (Fig. 1). They represent the variety of peri-urban areas in India in terms of hydrology, climatic conditions, institutions, and stage of peri-urbanization. As each village is also situated in a different Indian state, they are governed by different sets of institutions and are culturally different in terms of language, religion, caste etc. Paud village with 4000 inhabitants is situated 30 km west of Pune city (9 million people) in the rain shadow region of the Western *ghats* in Maharashtra state (Office of the Registrar General and Census Commissioner, India, 2011). Administratively, the core village area falls under the jurisdiction of the gram panchayat, the rest within the Pune Metropolitan Region Development Authority. Recent changes in the village includes the construction of a new residential township. Next, Anajpur village, is located at the periphery of Hyderabad city (7 million people) in the Indian peninsular region of Telangana state with a hard rock granitic aquifer. Its close proximity to two major transport routes (Outer Ring Road and National Highway 95), allows for easy commuting to the city. Administratively, it is part of Hayatnagar *mandal* (a sub-district unit or block) in the Rangareddy district. The Sanghi industrial complex and nearby Ramoji film studios strongly impacts the village's development. Finally, Hadia is located in the East Kolkata wetlands in the Ganges delta area of India. It lies outside the eastern border of Kolkata city (14 million people) and administratively falls under Bamanghata gram panchayat. Hadia is a group of hamlets with a mixed population of nearly 8000 that includes two tribal communities (Directorate of Census Operations West Bengal, 2011). Development activities here are controlled given the wetland's RAMSAR status since 2002. Its close proximity to Kolkata and a large leather complex nearby led to improved road connectivity and in-migration.

Data collection for this study was as follows. Field visits to Paud, Anajpur, and Hadia villages were held in March 2019, November 2019 and January - February 2020 by three of the authors with translations from local field assistants. During these visits, key informant interviews, transect walks, focus group discussions, and observational studies were conducted. In total 46, 47, and 35 interviews were conducted with residents and government representatives in Paud, Anajpur and Hadia respectively. Local interviewees included residents engaged in different livelihood sectors (typically male household members) and household water collection (typically female household members). Government interviewees represented key departments, agencies or ministries from the local to the state level concerned with water management, village administration, key livelihoods, environmental management, urban planning etc. Interviewees were identified from earlier field visits or through snowball sampling techniques. Further, a total of 7 transect walks were conducted with a community members and 8 focus groups discussions were held with community or local government representatives across the three villages. The researchers also made participatory observations during visits with local fishermen and farmers in each villages. This data was then used to prepare the baseline situation for each village from which adaptation pathways were subsequently developed.

Thereafter, between 14 and 20 local actors (representing the village and local government) from each peri-urban context were invited to form a panel to participate in focused discussions about the future through an iterative Delphi-led pathways building methodology described in (Gomes et al., 2023) between December 2020 and October 2021. This was implemented in parallel across the three peri-urban contexts. Panel members individually shared their opinions about future development trajectories in their respective village and provided the inputs needed to construct adaptation pathways for that context. The pathways building focused on three kinds of development trajectories

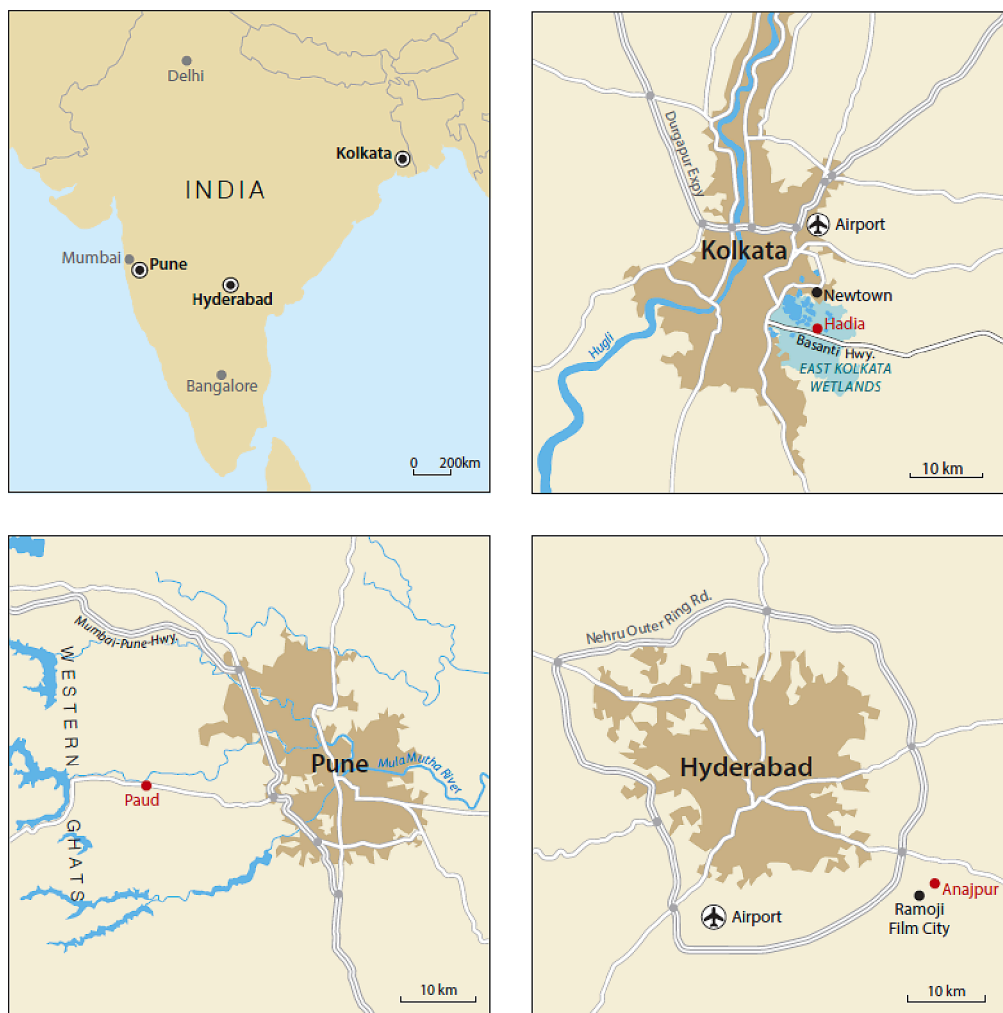


Fig. 1. Map of the three urban agglomerations studied – overview and location of the villages within the agglomerations. Map layout: authors, Cartography: Martin Gref, Data base: google maps images.

related to a business as usual, a preferred, and an alternate future scenario. These discussions were conducted remotely due to the Covid-19 pandemic and were structured using a Delphi study conducted via telephone based questionnaires in the local language by local enumerators. After each round, individual responses were synthesized by the researchers and presented back to the panel members in the subsequent round together with a follow-up set of questions. Over three Delphi rounds, adaptation pathways for managing livelihoods and household water (both drinking and domestic purposes) for the next 15 years were co-designed for each peri-urban context. A final workshop was also conducted with 19 of the 20 panel members from Hadia in October 2021 in a hybrid format to reflect on the pathways developed for Hadia. These pathways represent the data that is used for the comparative analysis presented in this study. For a detailed description of this methodology please refer to (Gomes et al., 2023).

The narratives accompanying these pathways diagrams were qualitatively coded and analyzed in Excel. The following information was extracted from these texts: (i) the main drivers shaping peri-urban transformations between 2020 and 2035 in the business as usual, preferred, and alternative future scenarios. The drivers were further analyzed as sources of opportunities or vulnerability. (ii) The adaptation strategies from the different pathways that will be used in each peri-urban context. These adaptation strategies consisted of different actions that were categorized using the adaptation processes typology of Thornton and Manasfi (2010). (iii) The institutional arrangements mentioned for each pathway were categorized as formal or informal.

Informal institutions reflect local agency whereas formal institutions refer to higher-level government assistance or policy change in facilitating adaptation. The analysis was performed separately for each context by one of the researchers and later cross-checked by the others. Using these results, comparisons were made across the pathways, the 2 water use sectors (livelihood and household water), and 3 peri-urban contexts. Simple calculations were used to identify the dominant drivers of vulnerability vs opportunity, adaptation processes in different pathways or sectors, and institutions associated with different types of adaptation processes.

4. Comparative results of future adaptation pathways across peri-urban India

In this section, we present the drivers (Table 2), adaptation strategies, and institutional arrangements in the business as usual, preferred and alternate development pathways for our three villages. Comparative results across the three peri-urban contexts are presented separately for each water use sector: household water and livelihoods in Tables 3 and 4 respectively. Detailed descriptions and schematic representations of the adaptation pathways developed for Paud, Anajpur, and Hadia villages can be found in the supplementary materials. In this section, we only include those details from these pathways that are relevant for our comparative analysis.

Table 2
Overview of future drivers and impacts across peri-urban villages.

| Future drivers | Effect on peri-urban areas | Affected Livelihoods (L) & Household water (H) pathways | | |
|---------------------------------|--|---|-----------|-----------|
| | | Business as usual | Preferred | Alternate |
| Paud | | | | |
| Village development | <u>Opportunity</u> • Infrastructure improvement • Transparent government actions | - | L & H | L & H |
| Changing water management | <u>Vulnerability</u> • Restricted water access for traditional livelihoods • Pollution of household water sources | L&H | L & H | |
| Urbanization | <u>Opportunity</u> • Improved water management | - | L & H | L |
| | <u>Vulnerability</u> • Uncontrolled urban expansion • Increasing household water demand | - | L & H | - |
| | <u>Opportunity</u> • Improved infrastructure | - | - | L |
| Land use changes | <u>Vulnerability</u> • Forced selling of land | L | - | - |
| | <u>Opportunity</u> • Protective land use development | - | L & H | - |
| Anajpur | | | | |
| Supportive state govt. policies | <u>Opportunity</u> • Village remains under rural administration | - | L & H | L & H |
| Urbanization | <u>Vulnerability</u> • Pollution of livelihood and household water sources • Increasing land prices • Loss of agricultural productivity • Inter-generational livelihood uncertainty • Increasing household water demand Distant urban water governance • Poor piped infrastructure maintenance | L & H | L & H | - |
| Local power networks | <u>Opportunity</u> • Greater political influence | - | L & H | H |
| Climate change | <u>Vulnerability</u> • Rainfall variability | L & H | L | - |
| Hadia | | | | |
| Village development | <u>Opportunity</u> • Access to government aid • Funding for livelihoods • Access to piped water infrastructure projects | - | L & H | L |
| Wetland management | <u>Vulnerability</u> • Unplanned wetland development | L | L & H | - |
| | <u>Opportunity</u> • Protected wetland environment • Unregulated industrial growth from unplanned dev. • Rise in packaged water plants from unplanned dev. | - | H | L & H |
| Urbanization | <u>Vulnerability</u> • Inter-generational livelihood uncertainty • Wastewater pollution | L | L & H | - |
| Climate change | <u>Vulnerability</u> • Rainfall variability | L | L | - |

4.1. Drivers of future peri-urban development

A variety of external drivers are expected to shape peri-urban development in Paud, Anajpur, and Hadia over the next 15 years. The directions they take determines their impacts on future livelihoods and household water needs. Table 2 summarizes the drivers across peri-urban contexts, the effect in each peri-urban context in terms of opportunities or vulnerabilities, and their local level impact on water-use sectors.

Comparing the drivers shows similarities in the stimulus behind peri-urbanization across peri-urban India: Urbanization is predominantly perceived as a future threat in both water use sectors across the three peri-urban contexts. The 3 sites further show a high variation regarding other kinds of expected drivers. This variation emerges from the specific contexts. Climate change is a driver mainly in Anajpur and Hadia. We can speculate that the geography of Paud in the rain shadow region of the Western ghats makes it less vulnerable or that the water pollution

and competition threats from nearby factories and the Ramoji film studio is considered a larger threat. Moreover, both urbanization and climate change are essentially considered drivers of vulnerability across peri-urban villages.

Another type of driver relates to natural resource management. The nature of this driver and the direction it take determines whether they reflect vulnerabilities or opportunities for peri-urban livelihoods and household water. In Paud and Anajpur, this driver refers to the management of land and water management; and in Hadia ecosystem management given the unique situatedness of this village in the East Kolkata wetlands. In Hadia especially, planned wetland development is very important given its protected Ramsar status and the question of how far existing wetland management rules are enforced is key. Controlled development and wetland protection will promote sustainable transformations, while unplanned wetland development will have negative consequences. Whereas, in Paud, management of land and water resources will be decisive. Especially the access to water bodies

Table 3
Overview of future adaptation processes & institutions in the household water sector across peri-urban villages.

| Pathway | Drivers: Vulnerability (V), Opportunity (O) | Household water adaptation strategy | Adaptation process | Institutions: Formal (F), Informal (I) |
|-------------------|---|--|--|---|
| Paud | | | | |
| Business as usual | | Diversified water sources: piped water via taps, treated river water & groundwater via borewells | Diversification | |
| | (V) Power outages in piped supply | Reduce tap water reliance & replace with more use of existing sources: groundwater, treated river water | Exchange & Diversification | |
| Preferred | (O) Village development, Improved land & water management | Replace diversified water sources with more reliable piped water supply Conserve piped water use and reduce water taxes | Exchange & Intensification Rationing & Revitalization | (F) Govt. funds & constructs bigger storage tanks (F) Govt. installs water meters & runs water conservation campaigns (I) Households monitor their water use through water meters |
| | (V) Urbanization & Poor water management | Reduce piped water reliance & more use of existing sources: groundwater, treated river water | Exchange & diversification | |
| Alternate | (O)Village development | Secure 24/7 piped water access by paying higher electricity charges Complement piped water with improved alternatives: tanker water, stored river water | Intensification Diversification, Pooling, Innovation | (F) Financial support for electricity costs & storage tanks (I) Construct storage tanks to store water & purchase water from tankers |
| Anajpur | | | | |
| Business as usual | | Diversified water sources: tap water (local cheruvu & state water supply project), packaged water | Diversification | |
| | (V) Urbanization, climate change | Reduce piped water reliance & replace with more packaged water | Diversification, Exchange | (I) Purchase from local packaged water plants |
| Preferred | (O) Supportive government policies, local networks | Replace diversified sources with improved state drinking water scheme | Exchange & Intensification | (F) Demand-driven water supply schemes, efforts to improve govt. accountability, mobilize development funds & MB infrastructure improvement projects (I) Increase accountability through local monitoring of infrastructure implementation (F) Panchayat builds awareness on water conservation (I) Households collectively reduce water wastage |
| | (V) Urbanization | Efficient water use through conservation & demand management Reduce reliance on piped water supply | Rationing & Revitalization Rationing | |
| Alternate | (O) Supportive government policies, local networks | Replace piped supply with diversified, improved alternatives: privately funded borewells, improved packaged water | Exchange, Diversification, Pooling | (F) Govt. schemes for installing groundwater recharge pits, better regulation of polluting industries & packaged water plants (processes & water quality) |
| Hadia | | | | |
| Business as usual | | Diversified water sources in the interim: packaged water, groundwater | Diversification | (I) Village appeals to local government for piped project completion |
| Preferred | (O) Village development, protected wetland environment | Replace diversified water sources with piped water supply via taps Conserve piped water use | Exchange, Intensification Rationing & Revitalization | (F) Government continues funding & installing piped supply project, Creates rules for piped water project (installation, quality, supply & storage) (F) Govt. rules that encourage water saving (I) Households collectively reduce water wastage |
| | (V) Climate change, Unplanned wetland development, Urbanization | Replace piped supply with existing diversified water sources: packaged water, groundwater | Exchange, Diversification | |
| Alternate | (V) Climate change, Unplanned wetland development, Urbanization | Replace piped water with improved, diversified alternatives: privately funded borewells, improved packaged water | Exchange, Diversification, Pooling, Innovation | (F) Govt. applies rules for regulating borewell installations (I) More packaged water plants set up, existing plants well maintained, Local rules for regulating groundwater sharing via handpumps |
| | | Replace piped water use with new alternatives: rainwater harvesting | Exchange, Innovation | (F) Govt. pilots rainwater harvesting technology |

and the real estate market will decide the viability of traditional livelihoods.

Governance related drivers (village development, supportive government policies, and local power networks) are expected to positively influence peri-urban development in the future. In Paud, village development refers to better local infrastructure (e.g. water and drainage networks) which is currently lacking whereas in Hadia, this driver refers to availability of government funds to develop traditional livelihoods (e.g. aquaculture, farming), alternate livelihoods (e.g. dairy farming) or piped water supply projects. In Anajpur, it means ensuring village centric policies to retain the village under rural administration.

Governance reforms are also expected to have a strong impact on sustainable village development in some villages. For Paud, more government transparency is considered a positive driver. Meanwhile, Anajpur requires improved political influence (e.g. state level) through strategic power relations to secure higher-level support for local water supply schemes and traditional livelihoods. This is due to the impact of powerful external actors, encroaching on the village and climate variability given that it is located in one of India's driest regions.

Table 4
Overview of future adaptation processes & institutions in the livelihood sector across peri-urban villages.

| Pathway | Drivers: Vulnerability (V), Opportunity (O) | Livelihood adaptation strategy | Adaptation process | Institutions: Formal (F), Informal (I) |
|-------------------|--|--|--|--|
| Paud | | | | |
| Business as usual | | Continue farming & fishing with reduced resources | Rationing | |
| | (V) Land use changes, Changing water management | Reduce farming & fishing activities & complement with other livelihoods (e.g. car wash) | Rationing, Diversification | |
| Preferred | (O) Village development, Land use change, Changing water management | Increase yields from fishing & farming with improved access to water, soil, livelihood inputs & markets Upscale agriculture with dairy farming | Intensification, Innovation Diversification, Revitalization | (F) Govt. allocates water resources & reduces soil and water pollution; govt. provides financing for inputs, & develops local markets/ economy |
| | (V) Urbanization, changing water management | Reduce farming and fishing activities | Rationing | |
| Alternate | (O) Urbanization, changing water management, village development | Replace fishing or farming by setting up small local business | Exchange & Revitalization | (F) Access to affordable, better housing and education. Govt. provides financial support for water transportation /storage. |
| Anajpur | | | | |
| Business as usual | (V) Urbanization, climate change | Continue in agriculture with growing uncertainty Reduce farming and fishing activities due to resource uncertainty Migrate to city for work & supplement income with home rental Replace traditional livelihood with work in local industries | Rationing Rationing Mobility, Exchange Exchange, Revitalization | (F) Govt. brings village under municipal administration (I) Households actively seek peri-urban renters (I) Local industries create job opportunities for village residents |
| Preferred | (O) Supportive government policies, Local networks | Intensify traditional livelihoods with improves access to livelihood inputs, new technology or techniques & market access | Intensification, Innovation | (F) Policy support for low-interest loans for livelihood inputs& keeping village under rural administration. Further Govt. strengthens cooperatives in village to improve market access (I) Households join cooperatives for market access & adopt new/ upgraded technologies |
| | (V) Urbanization, climate change | Reduce farming and fishing activities due to resource uncertainty | Rationing | |
| Alternate | (O) Supportive government policies | Secure funds to start small local business to replace traditional livelihoods Adapt business practices to new market conditions | Exchange, Revitalization Innovation | (F) Govt. provides loans/subsidies for small local businesses (I) Households self-mobilize finances or applies for subsidies. (F) Govt. builds market awareness and business skills of the community (I) Households improve business strategy through market research |
| Hadia | | | | |
| Business as usual | (V) Urbanization, unplanned wetland development, climate change | Continue traditional fishing (aquaculture) in less productive way Fishing cooperatives develop tourism to supplement fishing incomes | Rationing Pooling, Diversification, Revitalization | (F) Govt. subsidies for tourism dev. For cooperatives (I) Collective action by cooperative members to develop tourism activities |
| Preferred | (O) Village development, protected wetland environment | Intensify and secure traditional livelihoods through financial or technological support, improved wastewater management (access, treatment) & wetland management | Innovation, Intensification, Revitalization | (F) Planned aquaculture development by govt.: financial subsidies, new technologies, guaranteed minimum price, improved wastewater management & treatment plant, enforces wetland mgmt. rules (I) Collective action to reduce litter in the local wetland area |
| | (V) Urbanization, unplanned wetland development, climate change | Reduce traditional fishing (aquaculture) | Rationing | |
| Alternate | (O) Unplanned wetland development (O) Protected wetland environment | Replace traditional fishing (aquaculture) with more accessible factory jobs) Replace traditional fishing (aquaculture) with small local businesses or farming livelihoods | Exchange, Revitalization Exchange, Revitalization | (I) Local industries emerge in village & create job opportunities for village residents (F) Govt. support (e.g. financial aid) to start new business ventures or Govt. develops local agriculture sector |

4.2. Future adaptation strategies in Paud, Anajpur, and Hadia

Comparing adaptation pathways across the three contexts (Tables 3 and 4) reveals a strong desire and willingness to sustain traditional livelihoods, (typically fishing and farming) either by upgrading existing practices or by switching to different ones. Achieving household water security in the future is the main objective for these three peri-urban

villages. This is not surprising as some form of water insecurity already exists or is becoming an increasing concern for the villages. However, the adaptation processes used to achieve these livelihood and household water objectives vary from one context to another. Comparative results indicates a dominant or preferred type of adaptation processes for each village: diversification (n = 6) and rationing (n = 4) will be predominantly used in Paud; exchange (n = 6) and rationing (n = 5)

in Anajpur and exchange ($n = 6$) and revitalization ($n = 5$) in Hadia. Below, we present specific results for different pathways and drivers.

4.2.1. Adaptation strategies and processes in different types of pathways

Comparing adaptation processes across different pathways, indicates that for the business as usual scenario, diversification and exchange will likely serve as the dominant forms of adapting future livelihood. The one exception being revitalization through fishing cooperatives in Hadia given that such a cooperative structure already exists. For livelihoods, all three villages develop a relatively conservative vision with a preference for incremental changes in existing livelihoods, mainly resulting in better income opportunities for the same type of work either through expanding to new markets – intensification – with support from technical innovations and other sector improvements. This is also reflected in the adaptation processes for this pathway. Intensification followed by rationing in the longer term is the dominant strategy across the three contexts. This is further accompanied by innovation and/or revitalization processes. Further differences regarding the preferred development can be observed through the concrete adaptation strategies in this pathway across the three villages, which are context specific. For e.g., financial support and wastewater management will be essential in Hadia whereas for Paud and Anajpur improved access to (urban) markets is also necessary. If traditional livelihoods cannot be sustained in the future, people will be forced to enter new job markets (e.g. factory, labourer jobs) or explore entrepreneurial opportunities (e.g. small businesses) or live from money they receive from selling land or renting houses. This is confirmed by the use of exchange and revitalization processes across alternate pathways to help shift to new livelihood opportunities. Some actors plan a gradual shift from a traditional livelihood to non-agricultural livelihoods, others will continue agriculture or fishing as a side-business. This strategy reflects the fact that traditional livelihoods are by many seen more as a way of living than as means of income generation.

Meanwhile, rationing and diversification are the dominant household water strategies across the different pathways. Diversification forms the dominant adaptation process for managing household water needs in the business as usual and alternate pathways. The preferred pathways for household water reveals adaptation through exchange as most dominant ($n = 5$) as improved piped water supply replaces the current diversified water sources. For achieving the preferred household water supply, intensification and rationing forms of adaptation are most commonly seen. The difference lies in the timing of each adaptation – in the short term, the focus is on closing the supply gap through intensification through piped water supply while rationing will be the result of long-term water conservation measures. Regarding alternate household water strategies, peri-urban communities are more passive and reactive to changing circumstances. It varies across the villages depending on the type of alternative water sources available. Adaptation processes is also varied, largely relying upon diversification strategies once again and in some cases improvements through pooling of finances, innovation in rainwater harvesting or storage facilities etc.

4.2.2. Adaptation responses for different drivers

Comparing adaptation responses to different types of drivers reveals additional patterns. In the livelihood sector, rationing is the most common response to drivers of vulnerability ($n = 6$) though other kinds of adaptation processes are also used depending on the context. In the household water sector, exchange and diversification forms of adaptation are most commonly associated ($n = 5$) with drivers that cause peri-urban vulnerabilities. This is irrespective of the type of driver or the pathway in which these drivers impact. If households do not want to rely on a private provider, their own agency is limited to access groundwater at the place of residence. The opportunities to adapt are broader for individuals with a higher socioeconomic status, because the clandestine commodification of water in peri-urban India means higher cost for all households. However, one common way of reacting to the increasing

uncertainty is the diversification of water sources. Instead of relying on one technical system and provider, households will rely on water from different sources – which is time and cost intensive. The latter is, however, only suitable for households with capital to invest or owning land.

4.3. Institutional arrangements for future adaptation pathways

In the future, we see that different kinds of institutional arrangements (both formal and informal) are needed to facilitate different adaptation processes by local communities across peri-urban India (Tables 3 and 4).

Comparing the institutions arrangements in different pathways, shows that they are especially important in the preferred and alternate development scenarios. In business as usual pathway, few institutions are identified for Anajpur and Hadia. In Anajpur, these are mostly informal in nature and refer to the use of village networks to find renters for peri-urban houses or find factory work in local industries. Whereas in Hadia, formal and informal institutional arrangements are needed to supplement aquaculture incomes from tourism activities. However, these already exist and are being used by the fishing cooperative. Similarly, in the household water sector, minimal institutional support is required in the business as usual pathway. Again, this is because the sources of drinking or domestic water are already available (e.g. packaged water plants in Anajpur) or are on the horizon (e.g. pipeline installation is underway in Hadia). Thus, peri-urban communities have some capacity to arrange household water services through existing local sources (e.g. groundwater, river water) or informal service providers (e.g. tankers and reverse-osmosis plants) in times of need.

The preferred and alternate development pathways for both livelihoods and household water rely significantly upon government interventions in all three peri-urban contexts. Without government action, peri-urban villages are unlikely to sustain their traditional livelihoods or meet household water needs. In the livelihood sector, local cooperatives offer some additional support in terms of market access (Anajpur) or access to government subsidies (Hadia). Further, collective action is needed in Hadia to reduce wetland pollution. All three villages, however, lack the necessary resources to independently sustain or improve traditional livelihood sectors. Instead government intervention is needed to provide critical inputs such as finance, technologies, market access or soil/water resources. Yet, creating new, alternate livelihoods also strongly depends on government interventions that exist at the time. This largely relates to financial aid (Hadia, Anajpur), develop entrepreneurial skills (Anajpur) or more general infrastructure and education support (Paud). In Anajpur, informal efforts will also be used to create or sustain alternate livelihoods through self-financing and market research.

Similarly, across the 3 preferred household water pathways, formal institutional interventions (e.g. water supply schemes, infrastructure installation & management) will be essential in all 3 peri-urban contexts. We also see a role for both governments and local communities for sustainable water management in the longer term through various kinds of water conservation efforts. This reflects that peri-urban areas will be extremely dependent on formal government interventions to achieve their preferred means of water security in the future. As the villages themselves are embedded in larger water supply networks, they depend on decisions taken at higher levels of governance. Context specific threats are related to slow moving infrastructure projects (Hadia) or experiences with weak infrastructure (Anajpur) or indirect rules and regulations affecting the access to water (Paud). Thus, although the preference in all three peri-urban villages is to have reliable, good quality piped water supply, different institutional interventions are needed to help realize this. In the alternate pathways for this sector, households will be able to secure water access using existing fall-back options. Similarly, households can pool resources to privately fund infrastructure to improve access to existing water sources (e.g. storage tanks or private borewells). However, formal interventions are

necessary to augment new water sources (e.g. rainwater harvesting in Hadia) or improve existing options (e.g. groundwater and packaged water plant regulation, storage tanks or recharge pits).

Comparing institutional arrangements for different types of adaptation processes shows that formal institutional adjustments are typically associated with intensification, innovation, and revitalization. Across household water pathways in different peri-urban contexts, these three adaptation processes were associated in 9 out of 10 instances where formal institutions are required. Similarly, in the livelihood related pathways across the three contexts, 8 out of 9 times, formal institutions are associated with one of the above mentioned adaptation processes. However, there are also some exceptions (e.g. livelihood revitalization in Paud and Hadia).

It is also important to point out that certain kinds of adaptation in the business as usual pathway are not accessible to everyone. For example, those who own their home can earn income from rentals whereas combined income from aquaculture and tourism can only be done by fishing cooperative members as subsidies are not available to private fishermen respectively. This has to do with the differences in both social and financial capital available between households. Here, informal arrangements play a key role in providing the capital needed to mobilize different adaptation processes. Similarly, in the household water sector, alternatives aside from improved piped water supply is not regarded as the preferred means of obtaining water security. Interviews reveal that packaged and tanker water is much more costly and is therefore only a feasible option for households who can afford it. Those without the necessary financial capital, will need to use other options for drinking purposes (e.g. groundwater) which are in many cases believed to be of lower quality. Similarly, in the alternate pathway, pooling strategies to informally invest in water infrastructure upgrades (e.g. storage tanks in Paud or borewells in Hadia) will not be accessible for socially-disadvantaged household without financial assistance from the government.

5. Discussion

Our study reveals that peri-urban villages across India, specifically, Paud, Anajpur, and Hadia will be shaped by four kinds of drivers: urbanization, climate change, natural resource management, and peri-urban governance. These drivers produce different kinds of vulnerabilities are opportunities that are unique to each peri-urban context. With regards to future adaptation strategies, changing water sources to achieve household water security is common across all three villages. Likewise, in the livelihoods sector, they share a similar adaptation strategy of safeguarding traditional livelihoods (fishing and farming). A closer examination of the adaptation processes within these strategies, however, reveals more interesting results. We see a wide variety of adaptation processes will be used across peri-urban areas. Similar findings can be found in other peri-urban regions (Ricci, 2012). Comparing adaptation processes to future vulnerabilities across peri-urban contexts highlights exchange and diversification as the most essential in the household water sector, whereas in the livelihood sector it relates to rationing forms of adaptation (Table 3 and 4). Therefore, ensuring that peri-urban communities can successfully adapt to future threats requires focusing attention towards these specific adaptation mechanisms.

Furthermore, comparing adaptation processes in different pathways reveals preferences for certain adaptation processes. In the business as usual trajectory, livelihood diversification is and will remain the dominant adaptation process in the 3 villages. Whereas in the household water sector, it is quite varied for this pathway, aside from rationing which is the only commonly occurring adaptation process. In the preferred development trajectory, we find more reliance on exchange, intensification, rationing and revitalization across the three household water sectors. Similarly, innovation and intensification forms of adaptation in the livelihood sectors. Finally, in the alternate development

trajectory, exchange and revitalization is the preferred adaptation process for livelihoods in the future, while in the household water sector, diversification and pooling are the only commonly occurring adaptation processes. These results highlight the specific adaptation needs of different peri-urban sectors under different kinds of future scenarios.

Analyzing adaptation using this typology of adaptation processes tells us that that adaptation strategies (used in each pathway) comprises of a combinations of adaptation processes. The adaptation categories appear to feed into one another. For example, exchange is often followed by some other type of adaptation process (e.g. diversification, intensification, etc.). In this way, adaptation can be viewed as a sequence of adaptation processes implemented over time rather than a single, standalone action. Also, some categories of adaptation processes are linked. For example rationing (referred to here as “wise use”) of piped water supply reflects revitalization of household water practices. Similarly, pooling forms of adaptation can also lead to revitalization as observed with the diversification to tourism by cooperative fisheries in Hadia. This points to the complexity of adaptation as a process.

Our study was particularly interested in the role of institutions in enabling future adaptation processes across peri-urban contexts. The literature indicated that given the formal institutional challenges that are notorious in this context, local agency is relevant when understanding adaptation. Thus, local institutional arrangements are important to consider. In this study we hypothesized that the type of adaptation processes we will see in the future will depend on the kinds of institutional arrangements that exist. Our results support this. Across the three villages, intensification, innovation, and revitalization are only possible with formal institutional support in both the livelihood and household water sectors. This is especially important if peri-urban areas are to transition away from the business as usual trajectory given that these were referenced primarily here. The comparison across three villages shows different challenges for adapting in quickly transforming environments. Local adaptation depends on social capital and the agency to effectively operationalize this capital. Active involvement in decision-making and power or influence in resource management can be used as two potential indicators of agency (Barnes et al., 2020). Although peri-urban communities are often excluded from formal decision-making networks, our results show that existing informal networks offer some form of social capital and agency to help households adapt in the future. Results highlight the potential of collective action and local cooperatives in future adaptation pathways. It is clear that peri-urban communities will consider a variety of adaptation strategies that they can either initiate individually or as part of their dialogue with decision-makers.

Yet, there are limits to local agency in steering development towards an idealized vision especially with regards to the larger systemic framework that is set by actors and processes beyond the local actors' control. In the livelihood sector, informal arrangements e.g. cooperatives or collective action help sustain traditional livelihoods but only to an extent. Beyond this, support from higher levels of government becomes essential. Similarly, in the household water sector, informal efforts to upgrade water infrastructure or privately augment alternatives (e.g. water tanker or packaged water) is an adaptation accessible to only those household who can afford it. However, securing good quality, reliable, affordable water supply is only achievable through government intervention. Our empirical work shows that local actors are demanding support from state actors. This can be local panchayats or sectoral agencies of the district or state governments, providing specific aid for the development of livelihood opportunities. With this support, peri-urban households see themselves in a position to actively shape adaptation. This highlights the need for a more active involvement of government agencies at different levels in consultation with local communities during peri-urban transformations. This would require supportive formal institutional re-arrangements, because in India this type of dialogue is not currently supported.

We also acknowledge the following limitations of this study that

open up avenues for future work. (i) Given the highly heterogeneous nature of peri-urban communities pathways responses reflect the views of representative members from each context. Due to covid-19 restrictions as well as methodological limitations we were unable to incorporate a large number of perspectives or further discuss the designed pathways with the entire village. Therefore, our results are indicative of what could be expected in terms of future adaptation based on the expert options of representative members. Future work can be directed towards expanding this study to other peri-urban contexts in India or using a larger dataset. (ii) The concept of maladaptation needs consideration, where responses in one (sub)system adversely impacts the vulnerability of another (sub)system, sector or social group (Barnett and O'Neill, 2010 in Butler et al., 2016). Understanding the impacts of adaptation strategies from one sector on another sector or in the wider region will offer additional insights about future transformations. (iii) This comparative analysis uses the typology developed by Thornton and Manasfi, (2010) for categorizing human adaptation processes. Results reveal that future transformations to sustainability will likely comprise multiple adaptation processes, some of which will occur simultaneously by different actors. This supports Thornton and Manasfi's (2010: 148) statement that "successful adaptation strategies may entail interconnected aspects of all of the eight major adaptation processes we have identified—and potentially more." While we were able to categorize future adaptation strategies using this typology, a further elaboration of the original 8 adaptation processes in terms of their definition for water use in peri-urban contexts (see for example, Thorn et al., 2015) or new adaptation categories is needed. Future work may check for other kinds of adaptation processes in rural–urban interfaces, beyond the categories by Thornton and Manasfi (2010) or expand this analysis with other ways of describing or classifying adaptation. For example, expansion, shrinking, intensification and de-intensification Butsch & Heinkel (2020) or explore the relationship between institutional arrangements and adaptive capacity (Eakin et al., 2010b). Similarly, we may also extend our study using historical adaptation data to explore the role of path-dependency during adaptation processes.

6. Conclusions

The purpose of this paper was to explore and compare peri-urban adaptations to future vulnerabilities and opportunities and understand the institutional adjustments needed to support local communities in this process. We explored this empirically across three peri-urban contexts in India through the perspectives of local actors who are typically excluded from formal policy and planning areas. To do this, we analyzed and compared adaptation pathways developed with local actors from Paud, Anajpur, and Hadia villages in peri-urban Pune, Hyderabad, and Kolkata cities respectively. Our study employed an analytical design that enabled a comparative examination of future adaptation pathways in peri-urban areas to develop specific theories about their development and future adaptation needs, despite their heterogeneous, dynamic and contextual nature.

Overall, results indicate that peri-urban actors have relatively conservative (or incremental) visions for their future livelihoods and household water needs. There is a strong emphasis on (and preference for) continuing traditional livelihoods. Whereas in the household water sector, all three villages are focused on securing piped tap water supply which either exists already or is being considered. Thus, most adaptation processes in the business as usual and preferred development pathways is aimed at achieving this goal.

This study reveals similarities and differences in the drivers. The reasons for these differences lie in the villages' different socio-ecological conditions, their connectedness to their respective urban agglomerations or the current state of transformation. Future adaptation strategies are furthermore dependent on existing development and institutional constellations. Yet, more broadly peri-urban vulnerabilities and opportunities will be shaped by four main drivers: urbanization, climate

change, natural resource management, and peri-urban governance. The directions that some of these take can lead to either opportunities or vulnerabilities in local livelihoods and household water needs. While urbanization and climate change drivers lead to mostly negative outcomes, peri-urban governance has the most potential to shape positive development trajectories.

Local framings of different pathways offer meaningful insights about the similarities and challenges across peri-urban contexts in India with regards to adapting to future vulnerabilities and opportunities. They reveal important insights about adaptation processes and their associated institutional challenges. Understanding the preferred adaptation processes under different development trajectories and drivers allows us to better direct policy efforts to support peri-urban areas. For example, rationing is found to be dominant for adapting to vulnerabilities in the livelihood sector whereas exchange, diversification is most commonly used for adapting to vulnerabilities the household water sector. Similarly, certain adaptations processes must be prioritized to help peri-urban communities shift away from the business as usual development trajectory e.g. revitalization, intensification, and innovation. Furthermore, informal institutions can only go so far in supporting adaptation towards an ideal or alternative livelihood or household water source. Local agency is limited to cooperatives, collective action, private investments, or pooling of resources. Support from higher levels of government is essential for local communities to utilize a wider set of adaptation processes in the future especially revitalization, innovation, and intensification adaptation processes.

Therefore, local communities will continue to expect and rely upon higher level government institutions to support them in the future. We highlight the limits of what peri-urban communities are able to achieve on their own. This gives government agencies a basis (in terms of legitimacy) and the duty to positively intervene in peri-urban contexts. Our analysis can inform policymaking on the kinds of government actions that will be required in future to guide development along a sustainable and locally desirable pathways or in preparing for alternative pathways. Taken together, our study underscores the importance of a more inclusive planning process for the longer-term strategic planning of peri-urban futures. This cannot be done solely by higher level government agencies and experts, but requires the support of community stakeholders, their knowledge and creativity in conceiving required and possible pathways.

There exists a disconnect between the visions of the peri-urban spaces from outsiders – who often view it as future cities – and locally favored development trajectories. This study enables peri-urban spaces to be understood through lenses such as identity, agency, and local practices. It supports the arguments by Ling and Dale (2014) about the role that agency shapes in community response and collective action to sustainable development challenges. Our comparative results show that exploring the future in a systematic way with local peri-urban actors, can help community empowerment. We find that some strategies can be influenced by communities themselves. Moreover, identifying local adaptation needs can help increase their agency as this articulation of needs and opportunities is a first step to mobilize or leverage adaptive capacity. Peri-urban researchers argue that this insight can support adaptation planning practice at the local level (Ricci, 2012). Peri-urban communities need to become partners in a constructive dialogue with decision-makers for long-term planning. Targeted support towards this from higher levels of policymaking can shape the view of peri-urban communities being agents of change towards sustainable development.

CRedit authorship contribution statement

Sharlene L. Gomes: Conceptualization, Methodology, Investigation, Formal analysis, Visualization, Data curation, Supervision, Writing - original draft, Writing - review & editing. **Leon M. Hermans:** Conceptualization, Funding acquisition, Project administration, Methodology, Writing - review & editing. **Shreya Chakraborty:** Funding acquisition,

Project administration, Formal analysis, Validation, Visualization. **Sarah Luft**: Formal analysis, Validation, Visualization. **Carsten Butsch**: Conceptualization, Funding acquisition, Visualization, Methodology, Writing - review & editing. **Partha Sarathi Banerjee**: Investigation, Validation, Resources.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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References

- Aijaz, R., 2017. Measuring Urbanisation in India (No. 218), ORF Issue Brief. Observer Research Foundation, New Delhi.
- Allen, A., 2003. Environmental planning and management of the peri-urban interface: perspectives on an emerging field. *Environ. Urban.* 15, 135–148. <https://doi.org/10.1177/095624780301500103>.
- Anum, R., Ankrah, D.A., Anaglo, J.N., 2022. Influence of demographic characteristics and social network on peri-urban smallholder farmers adaptation strategies - evidence from southern Ghana. *Cogent Food Agric.* 8, 2130969. <https://doi.org/10.1080/23311932.2022.2130969>.
- Barnes, M.L., Wang, P., Cinner, J.E., Graham, N.A.J., Guerrero, A.M., Jasny, L., Lau, J., Sutcliffe, S.R., Zamborain-Mason, J., 2020. Social determinants of adaptive and transformative responses to climate change. *Nat. Clim. Chang.* 10, 823–828. <https://doi.org/10.1038/s41558-020-0871-4>.
- Barnett, J., Graham, S., Mortreux, C., Fincher, R., Waters, E., Hurlimann, A., 2014. A local coastal adaptation pathway. *Nat. Clim. Chang.* 4, 1103–1108. <https://doi.org/10.1038/nclimate2383>.
- Barnett, J., O'Neill, S., 2010. Maladaptation. *Glob. Environ. Change* 20, 211–213. <https://doi.org/10.1016/j.gloenvcha.2009.11.004>.
- Bartels, L.E., Bruns, A., Alba, R., 2018. The production of uneven access to land and water in peri-urban spaces: de facto privatisation in greater Accra. *Local Environ.* 23, 1172–1189. <https://doi.org/10.1080/13549839.2018.1533932>.
- Beilin, R., Reichelt, N., Sysak, T., 2013. Resilience in the Transition Landscapes of the Peri-urban: From 'Where' with 'Whom' to 'What'. *Urban Stud.* 52, 1304–1320. <https://doi.org/10.1177/0042098013505654>.
- Bhave, A.G., Conway, D., Dessai, S., Stainforth, D.A., 2018. Water Resource Planning Under Future Climate and Socioeconomic Uncertainty in the Cauvery River Basin in Karnataka, India. *Water Resour. Res.* 54, 708–728. <https://doi.org/10.1002/2017WR020970>.
- Bosomworth, K., Gaillard, E., 2019. Engaging with uncertainty and ambiguity through participatory 'Adaptive Pathways' approaches: scoping the literature. *Environ. Res. Lett.* 14, 093007. <https://doi.org/10.1088/1748-9326/ab3095>.
- Bosomworth, K., Scott, H., Wilson, J., Brunt, K., Pitfield, C., Johnson, F., Brown, G., 2018. Exploring 'Adaptation Pathways' planning through an NRM lens: Insights from two exploratory case studies 51.
- Bosomworth, K., Harwood, A., Leith, P., Wallis, P., 2015. *Adaptation Pathways: a playbook for developing options for climate change adaptation in Natural Resource Management*. Southern Slopes Climate Change Adaptation Research Partnership (SCARP). RMIT University, University of Tasmania, and Monash University.
- Brook, R., Purushothaman, S., Hunshal, C., 2001. The Peri-Urban Interface Hubli-Dharwad, India Changing frontiers.
- Butler, J.R.A., Suadnya, W., Yanuartati, Y., Meharg, S., Wise, R.M., Sutaryono, Y., Duggan, K., 2016. Priming adaptation pathways through adaptive co-management: Design and evaluation for developing countries. *Clim. Risk Manag.* 12, 1–16. <https://doi.org/10.1016/j.crm.2016.01.001>.
- Butsch, C., Heck, A., Luft, S., Chakraborty, S., Gomes, S.L., Hermans, L.M., under review. Water transformations in periurban Pune. An upstream – downstream comparison. ERDKUNDE.
- Butsch, C., Chakraborty, S., Gomes, S.L., Kumar, S., Hermans, L.M., 2021. Changing Hydrosocial Cycles in Periurban India. *Land* 10, 263. <https://doi.org/10.3390/land10030263>.
- Butsch, C., Heinkel, S.-B., 2020. Periurban Transformations in the Global South and Their Impact on Water-Based Livelihoods. *Water* 12, 458. <https://doi.org/10.3390/w12020458>.
- Coulter, L., 2019. *User Guide for the Climate Change Adaptation Pathways Framework: supporting sustainable local food in B. C.*
- Denis, E., Zerah, M.-H. (Eds.), 2017. *Subaltern Urbanisation in India: An Introduction to the Dynamics of Ordinary Towns*. Exploring Urban Change in South Asia, Springer India.
- Díaz-Caravantes, R.E., 2012. Balancing urban and peri-urban exchange: water geography of rural livelihoods in Mexico. *Geogr. J.* 178, 42–53.
- Directorate of Census Operations West Bengal, 2011. District Census Handbook: Kolkata (Village and town wise primary census abstract No. 20 Part 12B), Census 2011. Kolkata.
- Eakin, H., Lerner, A.M., Murtinho, F., 2010a. Adaptive capacity in evolving peri-urban spaces: Responses to flood risk in the Upper Lerma River Valley. Mexico. *Glob. Environ. Change* 20, 14–22. <https://doi.org/10.1016/j.gloenvcha.2009.08.005>.
- Eakin, H., Lerner, A.M., Murtinho, F., 2010b. Adaptive capacity in evolving peri-urban spaces: Responses to flood risk in the Upper Lerma River Valley, Mexico. *Adapt. Capacity Glob. Change Lat. Am.* 20, 14–22. <https://doi.org/10.1016/j.gloenvcha.2009.08.005>.
- Gallopín, G.C., 2006. Linkages between vulnerability, resilience, and adaptive capacity. *Glob. Environ. Change* 16, 293–303. <https://doi.org/10.1016/j.gloenvcha.2006.02.004>.
- Garrick, D., De Stefano, L., Yu, W., Jorgensen, I., O'Donnell, E., Turley, L., Aguilar-Barajas, I., Dai, X., de Souza Leão, R., Punjabi, B., Schreiner, B., Svensson, J., Wight, C., 2019. Rural water for thirsty cities: a systematic review of water reallocation from rural to urban regions. *Environ. Res. Lett.* 14, 043003 <https://doi.org/10.1088/1748-9326/ab0db7>.
- Gomes, S.L., 2019. *An Institutional Approach to Peri-urban Water Problems: Supporting community problem solving in the peri-urban Ganges Delta* (PhD Dissertation). Delft University of Technology, Delft, Netherlands.
- Gomes, S.L., Hermans, L.M., Butsch, C., Banerjee, P.S., Luft, S., Chakraborty, S., 2023. A Delphi-based adaptation pathways methodology for co-designing future pathways with local actors: Methodological considerations and illustrative application in peri-urban India. *Environ. Dev.* <https://doi.org/10.1016/j.envdev.2023.100822>.
- Gomes, S.L., Hermans, L.M., 2018. Institutional function and urbanization in Bangladesh: How peri-urban communities respond to changing environments. *Land Use Policy* 79, 932–941. <https://doi.org/10.1016/j.landusepol.2017.09.041>.
- Haasnoot, M., Kwakkel, J.H., Walker, W.E., ter Maat, J., 2013. Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Glob. Environ. Change* 23, 485–498. <https://doi.org/10.1016/j.gloenvcha.2012.12.006>.
- Iaquinta, D.L., Drescher, A.W., 2000. Defining the peri-urban: rural-urban linkages and institutional connections. *Land Reform Land Settl. Coop. FAO*.
- Ling, C., Dale, A., 2014. Agency and social capital: characteristics and dynamics. *Community Dev. J.* 49, 4–20. <https://doi.org/10.1093/cdj/bss069>.
- Luft, S., Gomes, S.L., Chakraborty, S., Hermans, L.M., Butsch, C., 2022. Planning for Livelihoods Under Hydrosocial Uncertainty in Periurban Pune. *Front. Water* 4, 831464. <https://doi.org/10.3389/frwa.2022.831464>.
- Marshall, F., Dolley, J., 2019. Transformative innovation in peri-urban Asia. *Res. Policy* 48 (4), 983–992.
- Maru, Y.T., Stafford Smith, M., Sparrow, A., Pinho, P.F., Dube, O.P., 2014. A linked vulnerability and resilience framework for adaptation pathways in remote disadvantaged communities. *Glob. Environ. Change* 28, 337–350. <https://doi.org/10.1016/j.gloenvcha.2013.12.007>.
- McGregor, D., Simon, D., Thompson, D. (Eds.), 2012. *The Peri-urban Interface: Approaches to Sustainable Natural and Human Resource Use, The Peri-Urban Interface: Approaches to Sustainable Natural and Human Resource Use*. Earthscan, London, Sterling VA. <https://doi.org/10.4324/9781849775878>.
- Narain, V., Khan, M.S.A., Sada, R., Singh, S., Prakash, A., 2013. Urbanization, peri-urban water (in)security and human well-being: a perspective from four South Asian cities. *Water Int.* 38, 930–940. <https://doi.org/10.1080/02508060.2013.851930>.

- Narain, V., Nischal, S., 2007. The peri-urban interface in Shahpur Khurd and Karnera. *India. Environ. Urban.* 19 (1), 261–273.
- Oduro, C.Y., Adamtey, R., Ocloo, K., 2015. Urban Growth and Livelihood Transformations on the Fringes of African Cities: A Case Study of Changing Livelihoods in Peri-Urban Accra. *Environ. Nat. Resour. Res.* 5, p81 <https://doi.org/10.5539/enrr.v5n2p81>.
- Office of the Registrar General & Census Commissioner, India, 2011. 2011 Census Data [WWW Document]. Provisional Popul. Totals Pap. 1 2011 Maharashtra Table 2. URL http://www.censusindia.gov.in/2011-prov-results/prov_data_products_maha.html (accessed 8.31.12).
- Padgham, J., Jabbour, J., Dietrich, K., 2015. Managing change and building resilience: A multi-stressor analysis of urban and peri-urban agriculture in Africa and Asia. *Urban Clim.* 12, 183–204. <https://doi.org/10.1016/j.uclim.2015.04.003>.
- Rakodi, C., 1999. Poverty and Wellbeing in the Peri-Urban of Developing Country Cities: A Review (DFID NRSP Programme Development Report No. PD070), Review of the poverty relevance of the peri-urban interface production system research. UK Department for International Development (DFID) Natural Resources System Programme (NRSP), Hemel Hempstead.
- Randhawa, P., Marshall, F., 2014. Policy Transformations and Translations: Lessons for Sustainable Water Management in Peri-Urban Delhi, India. *Environ. Plan. C Gov. Policy* 32, 93–107. <https://doi.org/10.1068/c10204>.
- Ren, X., 2021. The Peripheral Turn in Global Urban Studies: Theory, Evidence, Sites. *South Asia Multidiscip. Acad. J.* 26 <https://doi.org/10.4000/samaj.7413>.
- Ricci, L., 2012. Peri-Urban livelihood and adaptive capacity: urban development in Dar Es Salaam. *Cons. J Sustain. Dev.* 7, 46–63.
- Roth, D., Khan, M.S.A., Jahan, I., Rahman, R., Narain, V., Singh, A.K., Priya, M., Sen, S., Shrestha, A., Yakami, S., 2019. Climates of urbanization: local experiences of water security, conflict and cooperation in peri-urban South-Asia. *Clim. Policy* 19, S78–S93. <https://doi.org/10.1080/14693062.2018.1530967>.
- Roy, M., Shemdoe, R., Hulme, D., Mwageni, N., Gough, A., 2018. Climate change and declining levels of green structures: Life in informal settlements of Dar es Salaam, Tanzania. *Lands. Urban Plan.* 180, 282–293. <https://doi.org/10.1016/j.landurbplan.2017.11.011>.
- Sen, S., John, A., Chakraborty, S., Jatav, M., 2019. Geographies of Drinking Water (In) securities in Peri-urban Hyderabad. *Econ. Pol. Wkly* 54, 43.
- Simon, D., 2008. Urban Environments: Issues on the Peri-Urban Fringe. *Annu. Rev. Env. Resour.* 33, 167–185. <https://doi.org/10.1146/annurev.enviro.33.021407.093240>.
- Smit, B., Burton, I., Klein, R.J.T., Wandel, J., 2000. An Anatomy of Adaptation to Climate Change and Variability. *Clim. Change* 45, 223–251.
- Thorn, J., Thornton, T.F., Helfgott, A., 2015. Autonomous adaptation to global environmental change in peri-urban settlements: Evidence of a growing culture of innovation and revitalisation in Mathare Valley Slums, Nairobi. *Glob. Environ. Change* 31, 121–131. <https://doi.org/10.1016/j.gloenvcha.2014.12.009>.
- Thornton, T.F., Manasfi, N., 2010. Adaptation—Genuine and Spurious: Demystifying Adaptation Processes in Relation to Climate Change. *Environ. Soc.* 1 <https://doi.org/10.3167/ares.2010.010107>.
- Thornton, T.F., Puri, R.K., Bhagwat, S., Howard, P., 2019. Human adaptation to biodiversity change: An adaptation process approach applied to a case study from southern India. *Ambio* 48, 1431–1446. <https://doi.org/10.1007/s13280-019-01225-7>.
- Tyler, S., Moench, M., 2012. A framework for urban climate resilience. *Clim. Dev.* 4, 311–326. <https://doi.org/10.1080/17565529.2012.745389>.
- UN DESA, 2018. World Urbanization Prospects: The 2018 Revision (Online edition).
- Vij, S., John, A., Barua, A., 2019. Whose water? Whose profits? The role of informal water markets in groundwater depletion in peri-urban Hyderabad. *Water Policy* 21, 1081–1095. <https://doi.org/10.2166/wp.2019.129>.
- Winter, A.K., Karvonen, A., 2022. Climate governance at the fringes: Peri-urban flooding drivers and responses. *Land Use Policy* 117, 106124. <https://doi.org/10.1016/j.landusepol.2022.106124>.

Further reading

- Gomes, S.L., 2022. Interventions to Strengthen Institutional Capacity for Peri-urban Water Management in South Asia. *Flows Across Frontiers: Water Security, Conflict and Cooperation in Peri-Urban South Asia*. Springer, Cham, Netherlands.