Visualizing peri-urban and rurban water conditions in Pune district, Maharashtra, India

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ABSTRACT

Drinking water programs in India treat urban and rural areas separately, generally neglecting the special conditions of settlements referred to as peri-urban or rurban. We show how the historiography of peri-urban areas acquired negative connotations of poor water and sanitation services while rurban places have come to be associated with positive well-disciplined conditions. Previous research on drinking water programs has taken two paths, one of which generates rigorous qualitative case studies that criticize neoliberal policies, while the other employs larger scale quantitative methods to advance neoliberal policy reforms. This paper adopts a hybrid pragmatic approach to visualize strengths and weaknesses of water and sanitation services in urbanizing rural areas of Pune district, Maharashtra. We re-assess demographic definitions of the rural-urban dichotomy in India, distance-based criteria used in Maharashtra, and Census of India water and sanitation data. A combination of field research and GIS mapping identified four main peri-urban patterns in Pune district: (1) megacity fringe; (2) highway corridor development; (3) industrial zones; and (4) block town expansion. We show that while water supply has improved in some rurban areas, sanitation and drainage problems have not kept up. A second pattern of deficiency was observed in transitional towns of 5000 persons. Annually updated water and sanitation datasets at the national and state levels will make this pragmatic combination of GIS mapping and field research approaches valuable for visualizing peri-urban and rurban conditions at the district scale of water governance and planning in India.

1. Introduction

Many countries distinguish rural and urban settlements, and have developed separate water supply and sanitation programs to serve them. There are large literatures on rural and urban water problems, and a growing literature that is concerned with hybrid settlements that are not well served by either rural or urban water programs. While much lamented, the rural-urban dichotomy has deep administrative, financial, and territorial roots that have constrained the development of effective water programs for hybrid settlements (Allen, 2003, 2010; Narain, 2016). Various concepts strive to bridge the rural-urban divide. Peri-urban and rurban programs have acquired salience in India and other developing countries, as have suburban and town and country planning concepts in North America and Europe. Some scholars regard these hybrid settlements as transitional sites of urbanization (cf. Brenner, 2014; Scott, 2013). A smaller group approaches them from a more rural perspective as evolving ruralities or agropolitan landscapes (Friedmann, 2011). Still others regard suburbanization as the ascendant mode of human settlement (e.g., Berger and Kotkin, 2017). All acknowledge the heterogeneity and “undisciplined” or “untamed” aspects of hybrid places, which makes them challenging to describe, visualize, and theorize, let alone serve (Allen et al., 2016; Woltjer et al., 2014). In terms of theory-building, we follow Friedmann’s (2016) view of peri-urban research as middle level grounded theory. There is growing recognition of middle landscapes between urban and rural that are extraordinarily dynamic and only “partially disciplined” in the language of this special issue.

Orthogonal to the rural-urban settlement dichotomy is a theoretical and methodological opposition between policies to ensure safe drinking water and sanitation. One position advocates economic and institutional reforms to remedy state and local policy failures. These reforms focus on devolution of water authority, responsibility, and financing from state to household levels (World Bank, 2014). They stress that water is an economic good that requires effective pricing to sustain capital investment, maintenance, and asset management. An opposing group starts from the position that water is a human right and common good, and that policy failures stem uneven development and unjust power relations. So-called neoliberal reforms are likely to exacerbate
these failures by further eroding and encroaching upon state and community duties (Sultana et al., 2011). The latter position employs rigorous field research that yields qualitative case studies of differential water access. The reforms literature tends to employ quantitative and graphic analysis. Interestingly, neither employs mapping methods of the sort presented below.

More recent water research in India and elsewhere has moved toward more hybrid positions that challenge these dichotomies. Bakker (2013) has critically assessed neoliberal and postneoliberal water arguments. Sangameswaran (2014) presents a range of successes in community water management in India, and socialist-bureaucratic middle income states. Allen (2010) and colleagues show how peri-urban research contributes to critical water planning practice. On the neoliberal side, Briscoe and Malik (2006) offer rules of “principled pragmatism” for incremental rather than radical financial reforms.

This paper also adopts a hybrid pragmatist approach to drinking water planning, but it is a pragmatism that is philosophical as well as practical. Pragmatism is problem-driven, pluralistic, empirical, and outcomes-oriented (Wescot, 1992; Wood and Smith, 2008). It eschews dichotomies of the spatial and theoretical sort discussed above, always searching for integrative alternatives that expand the range of choice for water users and communities. We note that similarly hybrid theoretical perspectives have associated peri-urbanization with Soja’s theory of third space and “thirding” (Vanier, 2003), though that approach is less closely connected with planning than the pragmatic approach adopted here (cf. Bridge, 2005; Healey, 2008) (Fig. 1).

This paper combines historiography, field research, and village-level mapping of demographic, water and sanitation variables in the 1919 Census settlements of Pune District, Maharashtra. Of these, 35 are towns and 23 are villages that have no Census data, leaving 1861 villages as the domain of this study.

We begin by re-tracing the historiography of peri-urban and rurban concepts, situating them within their evolving international contexts, and noting their associations with water and sanitation conditions. We then demonstrate an approach that links field research with GIS mapping to help clarify peri-urban and rurban water conditions and needs in Pune District.

### 2. Evolution of peri-urban and rurban settlement concepts

It is important to situate this study of India within the broader international context and historiography of peri-urban and rurban settlement research. Peri-urban areas are widely perceived as amorphous undisciplined places fraught with congestion, pollution, and water and sanitation problems (Allen et al., 2016). Rurban areas, by contrast, are increasingly regarded in positive terms as rural places that have urban amenities. However, the concepts of peri-urban and rurban are themselves undisciplined, with diverse and changing geographic denotations and connotations that are retracted in this section to better understand current usage and problems or, in pragmatic terms, “the current situation.”

Peri-urban has become a widely used term worldwide for settlement beyond the boundary of a city (Woltjer et al., 2014). The earliest English usage that we have found dates back only to the 1930s. Several University of Chicago economic geography dissertations and theses used the concept descriptively in case studies of Negaunee, Michigan and Pomona, California, in each case emphasizing the heterogeneity of peri-urban land uses (Miller, 1933; Whitaker, 1931). Other scholars of that period argued for terms such as “rural-urban ecotone,” “urban fringe,” and “fringe belt.” Early peri-urban references in the U.S. may trace back to Francophone literature introduced to the University of Chicago by visiting Swiss urban geographer Raoul Blanchard, as well as to references to problematic peri-urban conditions in French medical geography (e.g., Casenove de la Roche, 1884).

However, the most extensive formal application of peri-urban planning concepts occurred in South Africa, also during the 1930s when depression and drought drove rapid migration from rural areas to the boundaries of cities like Johannesburg and Pretoria where urban access was racially restricted and conditions were poor. The Thornton Committee on Peri-Urban Areas (1938–39) and Smit Committee on the Social, Health and Economic Condition of Urban Natives (1942) led to passage of a 1943 Peri-Urban Areas Health Board Ordinance in 1943. The connection between peri-urban areas, water, and health was central to the establishment of Peri-Urban Areas, as in the earlier French medical literature. An Anti-Peri-Urban movement arose in Alexandria, outside Johannesburg, in 1958.

Peri-urban research diffused slowly through mid-century, initially to other south and east African countries with occasional studies in other regions. Somjee (1964) advanced the field in India through an analysis of peri-urban politics, in which outlying areas were drawn into larger scale urban politics to the neglect of local needs. The late-1960s marked the development of a general definition of the peri-urban as “…a zone of transition in land use, social and demographic characteristics, lying between (a) the continuously built-up urban and suburban areas of the central city, and (b) the rural hinterland, characterized by the almost complete absence of non-farm dwellings” (Pryor, 1968, 206). International agencies began to prepare reports on peri-urban agriculture in Europe (OECD, 1970), which continues to grow (Wandl and Magoni, 2017). Important extensions occurred in East Asian and Southeast Asian studies of the extended metropolis (Ginsburg et al., 1991), which distinguished peri-urban settlements from desakota corridors between urban centers (McGee, 1991).

After the early period of diffusion in sub-Saharan Africa, peri-urban

<table>
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<tr>
<th>Theory/method/Context</th>
<th>Urban (town/city)</th>
<th>Peri-urban/Rurban/Suburban</th>
<th>Rural (village)</th>
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<tr>
<td>Neoliberal Policy Reform (quantitative; normative)</td>
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<td>Pragmatic Inquiry (mixed methods; planning)</td>
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<td>Critique of Neoliberal Policies (qualitative; critical)</td>
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Fig. 1. Pragmatic conceptual framework for peri-urban and rurban water research.
studies exploded in scope and location from 2000 onwards (Google NGram and Worldcat searches, 2017). Commenting on a special issue of *Pacific Affairs* on peri-urbanization in Vietnam and China, *Leaf* (2011, 525) noted that use of the terms peri-urban and suburban was more a function of the person and context in which the terms were used rather than their meaning. The early association between peri-urban population growth, water, and health in South Africa has been sustained worldwide and includes book-length guides to peri-urban water planning and engineering in developing countries (Deverill, 2002). Comparative peri-urban water and sanitation studies have flourished (Kurian and McCarney, 2010). They include comparative planning studies of Dar Es Salaam, Kolkata, Cochabamba, Lima, and Caracas by Adriana Allen and colleagues at the University College London (2003, 2006, 2010).

India has increasingly become a focus for research on peri-urban water, sanitation, and land use (Denis and Marius-Gnanou, 2011; Kundu and Sarawasti, 2012; Pradhan, 2013; Shah, 2012; Shaw, 2005, World Bank, 2013). Writing about the Gurgaon area adjacent to New Delhi, Narain (2016, 502) argues that the peri-urban should not simply be defined based on “proximity to towns” but should rather be seen as the, “existence of both rural and urban characteristics and the linkages and flows of goods and services between rural areas and urban centres.” Peri-urban areas may have good access to regional transportation and industrial employment, but they often lack the services, amenities, and regulatory controls that urbanism ought to provide.

The broader literature on peri-urban settlement in South Asia concentrates on population and land use studies around megacities like Delhi, Chennai, Dhaka, Karachi, Kolkata, and Mumbai, followed by million-plus cities like Bangalore, Hyderabad, Lahore, and Lucknow (Ahmed and Sohail, 2003; Anguelovou, 2007; Brook et al., 2003; Dahiya, 2003; Datta, 2012; Kennedy, 2007; Prakash, 2012; Shaw, 2005; Sreeja et al., 2017). These massive peri-urban regions are some of the most difficult to visualize. Planners in the Mumbai Metropolitan Region Development Authority (MMRDA) reported that their attempts to map massive areas of peri-urban change from satellite imagery have been hampered by changes in image resolution that lead to errors in time series analysis of urban growth and change (Adusumilli, pers. comm., 2015). Less attention has been directed toward small and mid-size census towns where much of the peri-urban growth is occurring in India (Denis and Marius-Gnanou, 2011; World Bank, 2013). Additionally, and central to this paper, there has been little research to date on peri-urban patterns at the district scale, which encompasses large cities, small towns, highways, industrial zones, and heritage centers.

Before proceeding to that analysis, however, we need to consider the emerging emphasis in India and elsewhere on “rurban” settlements. Rurban has different geographical connotations and a different historiography. A Google N-Gram plot in 2017 indicates less frequent use of rurban than peri-urban, but growing usage over the past half-century. Early definitions equated rurban with urban fringe areas (Oxford English Dictionary online citing a reference in 1915). Connotations diverged in the mid-20th century. Firey (1946) wrote that rurban areas had many of the problems but few of the benefits of urban areas. The rurban was associated with, “isolated residential areas in rural realms that were opening windows of opportunity to almost any economic activity and occupation that shortly relocated near the urbanized plots” (Madelano, 2004, 1). A positive view based on a study of Worcester, Massachusetts held that, “A rurban area has very definite advantages over a strictly agricultural or rural area from the farmer’s point of view” (Balk, 1945). In the 1970s planners developed similarly positive models of agropolitan development and Urban Functions in Rural Development (UFRD) (reviewed by Allen, 2010; Friedman, 2016). Use of the term rurban in English language books appears to have peaked in the 1980s.

However, rurban policies have dramatically increased since that time in India (Government of Gujarat, 2016; Government of India, 2016; Wescoat, 2016). Rurban places have largely positive connotations in contemporary India (Gupta, 2015; Kalam and Singh, 2011; Revi et al., 2006; cf. Kress, 2016). They are viewed as “disciplined environments” that link urban amenities with rural locations and life-ways. This idealized definition of the rurban implies socio-spatial connectivity between urban and rural places, outward-oriented rural community initiatives, and adoption of technologies associated with urban and regional development.

Notwithstanding recent policy initiatives, rurban concepts remain vague in socio-spatial terms. Rurban villages are perceived to be exceptions in their respective districts. Rurban policy design is at an early stage. The Government of Gujarat’s (2016) rurban program includes an eclectic mix of taluka headquarters (which are already towns not villages), selected villages with a minimum population of 10,000 persons, and tribal villages with at least 7000 persons. The Government of India (GoI) expanded this approach to a national level in the Shyama Prasad Mukherji Rurban Mission (2017). The GoI Ministry of Rural Development has disbursed three sets of state financial awards under this program to date, but it is difficult to assess how they relate to their larger geographic contexts or to each other. There are related model village programs, such as the Sansad Adarsh Gram Yojana that encourages the uplift of one model village by each national parliamentarian (http://www.saanjh.gov.in/). Model villages in Maharashtra, such as Malikapur in Satara district, Relegaon Siddhi and Hiware Bazar in Ahmednagar district, and Pathoda in Aurangabad district have become famous for their charismatic leaders and exceptional water and sanitation accomplishments. Problem villages are regarded as notorious exceptions. This exceptionalism distacts from the wider geographical distribution of water and sanitation needs and improvements. Our historiographical review sheds light on the evolving range of settlement denotations and connotations that have shaped the current situation.

3. Village conditions in Pune District, Maharashtra

To further clarify the situation, we undertook a study of the 1861 populated villages of Pune District in the State of Maharashtra, India (Fig. 2). This study was an independent university-funded part of the Government of Maharashtra Jalswarajya II (JS2) drinking water project designed to strengthen district water planning capabilities (World Bank, 2014). The Jalswarajya II project focuses on scarcity-affected villages, water quality-affected villages, and peri-urban villages. For the latter, the project uses an arbitrary distance of less than 10 km from a city boundary to select a small number of peri-urban infrastructure projects. It is a demand-driven program that selects self-nominated villages, and thus more capable, villages within the 10 km peri-urban buffer. The JS2 program did not analyze water and sanitation conditions in other villages within the 10 km peri-urban buffer zone or other urbanizing areas, which gave rise to this more comprehensive study of peri-urban and rurban drinking water and sanitation conditions in Pune District. To put the district role in perspective, it is useful to outline the levels of rural water planning in India.

The nodal agency at the federal level is the Ministry of Drinking Water and Sanitation (MoDWS), which was established as a cabinet ministry in 1999. Between that time and 2015, the MoDWS allocated drinking water project funds directly to local governments (gram panchayats) under the National Rural Drinking Water Programme (NRDWP), which combined neoliberal devolution with state welfare spending.

Water is primarily a state responsibility under the Indian Constitution, and water financing and policy reforms are also undertaken at the state level. Maharashtra has been active in advancing rural drinking water reforms particularly from 2000 onwards. It undertook the Jalswarajya I project in 2003, followed by the Jalswarajya II program from 2014 to 2020 (World Bank, 2014). These neoliberal reforms have received detailed analysis, scholarly critique, administrative evaluation, and programmatic adjustment (Prasad et al., 2014; Sakthivel et al., 2015; Sangameswaran, 2014; World Bank, 2012).

State governments comprise of districts or *Zilla Parishads* that are...
further subdivided into blocks also known as talukas or tehsils. Maharashtra, for example, has 36 districts and 358 blocks. District governments have a deputy CEO and Executive Engineer for drinking water and sanitation along with various engineering, social mobilization, and administrative staff. Each district also has a parastatal water engineering department known as the Maharashtra Jeevan Pradhikaran (MJP), and a branch of the state Groundwater Survey and Development Agency (GSDA) that conducts detailed groundwater mapping, monitoring, and certification that water sources have sufficient yield for proposed drinking water projects. While neoliberal reforms have accelerated since 1991, it should be underscored that India has had 150 years of policy debate and experimentation on the relative merits of devolution to district, block, and village level governments.

At present, block level governments compile requests for funding and technical support from local governments (gram panchayats), which they present for prioritization at the more powerful district and state levels. In 2016, further devolution of funding from the federal to state level led to increased state water financing (known as the MRDWP), and a shift in authority for water project implementation from the gram panchayats back up to the district level (cf. Birkenholtz (2015) on the dynamics of decentralization and recentralization). Several other parastatal organizations in Maharashtra shape local drinking water management. Foremost among them is the Maharashtra Industrial Development Corporation (MIDC), which develops water supplies, infrastructure, and wastewater treatment for industrial sites and affected villages in peri-urban areas.

Local water governance is complex and dynamic, but it can be outlined briefly as follows. In political and administrative terms, gram panchayats have authority over local affairs. Their local councils (gram sabhas) include a village water supply committee and water operator (jalswarajshak). Each gram panchayat may have more than one village, and each village may have more than one habitation, which is the smallest water community. The village is the smallest unit for Census data reporting while the gram panchayat is the most local level of government. The 2011 Census reported that Pune district had 1861 populated villages. At the larger scale, Pune district has 25 towns including Pune City and twelve block (taluka) towns; ten major MIDC state industrial areas; and extensive road and rail networks that connect them.

Pune’s identity with respect to water goes beyond these administrative characteristics (Chakravarty et al., 2006). In historical terms it was the capital of Maratha rule and culture from the late 17th to early 19th centuries located at the junction (sangam) of two rivers. During Peshwa and colonial periods it was renowned as an administrative and educational center of the Bombay Presidency. From the 20th century onwards Pune district has witnessed the development of irrigation agricultural cooperatives, manufacturing, and information technology industries. These strong urbanizing processes led to its selection for this study of peri-urban and urban water patterns and needs.

The core analytical methods in this study involved field research coupled with mapping of Census of India village data. Field research included landscape transects along major highways in the district and interviews in thirty peri-urban villages. Census data analysis and mapping was conducted to help visualize the seemingly undisciplined peri-urban water and unpredictable rurban patterns at the district level. We used 2011 Census datasets on population, household characteristics, urban amenities, and rural amenities.

There is a large literature on the limitations of census data analysis and mapping (e.g., Barrier, 1981; Denis and Marius-Gnanou, 2011; Nag, 1984; Schwartzberg, 1992). We share these concerns about census data accuracy, omissions, and aggregation effects, while noting that those issues have been continuously scrutinized from the first colonial census to the most recent one in 2011 (Barrier, 1981; Nag, 1984; Kundu, 2011). Thus, we also share Schwartzberg’s (1992, 230) commitment to rigorous analysis of Census of India data.

To put this in perspective, there are two main bodies of literature on rural water systems in India that may be described as critical social research and quantitative policy analysis. Critical social research focuses on differential access to water and the consequences of neoliberal water policy reforms, especially for vulnerable and oppressed groups. It examines the socio-spatial dynamics between “needs-driven” and “policy-driven” water practices (Allen et al., 2016; Birkenholtz, 2010; Marshall, 2016; O’Reilly and Dhanju, 2014). It addresses issues of governance and governmentality with ever-increasing sophistication,
documenting, for example, how disadvantaged groups become neo-liberal subjects who accept some policy reforms in a generally worsening situation. Failure of reform policies sometimes leads back to needs-driven strategies, along with post-neoliberal policies of re-centralization and re-regulation. These qualitative case studies are based in large measure on years of local field research. They rarely employ GIS mapping at larger scales of analysis. The peri-urban mapping literature, by comparison, analyzes large data sets and remote sensing imagery with statistical tools and tests, e.g., principal components analysis (Banerjee et al., 2014) and analysis of variance (Makita et al., 2010). It critically assesses spatial data quality (Denis and Marius-Gnanou, 2011; Jacqueminet et al., 2013). But it rarely cites critical social research. Here we begin to link these field-based and GIS mapping methods, as part of the hybrid pragmatic strategy described above. Our approach is empirical, which is central to the pragmatic tradition, and which we regard as a central task in a journal issue on visualizing undisciplined environments, though we acknowledge the need for explanatory modeling in future research. In this initial phase of research, our aim was to identify thresholds and intervals for mapping each variable, to consider population intervals just above and just below those deemed rural or urban, and to assess the gradient of “positive” and “negative” water and sanitation conditions (Section 4 below). Visits were made to selected villages designated as peri-urban or rurban in the initial mapping phase in order to identified errors, omissions, interpretations, and additional villagers’ concerns (Section 5 below).

4. Village population size in relation to drinking water and sanitation services

Peri-urban and rurban settlements can be any size, but it is interesting to examine them in relation to settlement classifications defined by the Census of India (Table 1). The Census employs three socio-economic variables to distinguish rural villages from urban towns: (1) population size greater than 5000; (2) more than 75% of the male workforce engaged in non-agricultural occupations; and (3) population density greater than 400/km². The density criterion is difficult to apply in rural villages that have variable land areas, and it is replaced in some studies by a simple population size criterion greater than 10,000 (e.g., Denis and Marius-Gnanou, 2011).

There is a population size overlap between Class VI towns that are less than 5000 and rural villages that are larger than 5000. Villages larger than 5000 are more likely to be peri-urban while those in the 2000–4999 bracket may be peri-urbanizing. Using these population size criteria alone, we would expected villages that are in the 2000–20,000 population size brackets to be peri-urban or peri-urbanizing.

Conversely, Class VI towns that have less than 5000 people may be functionally rurban. One would expect larger villages to have greater access to urban amenities and thus be more likely to have rurban conditions. On the other hand, very large villages may have some of the disamenities associated with urbanization. With these considerations in mind, we expect villages in the population brackets between 1000 and 10,000 to include rurban villages.

Fig. 3 maps villages in this full 1000–20,000 population range that are expected to be rurban or peri-urban. It shows that the majority of villages in Pune District are, or could become, peri-urban or rurban. Far from being limited to villages abutting a city, peri-urban sized populations exist in much of central and eastern Pune district. Rurban-size villages are even more spatially extensive. The only area of the district that has a concentration of small villages below the rurban threshold is the hilly terrain of western Pune district.

The Census Housing and Amenities tables report water and sanitation variables at the village level. Peri-urban areas were expected to have water and sanitation problems, due in part to competition for scarce water supplies in areas of population growth, and in part to waste disposal problems in those growing areas, while rurban settlements were expected to have high levels of water supply and sanitation facilities and services. We began with 31 water and sanitation variables in the Census, analyzed their correlation with village population size, and reduced them to 10 key variables grouped under the three major categories below. These categories begin to link empirical and normative aspects of water conditions in ways that become useful for water planning.

Water supply amenities include drinking water within premises, treated tap water, and tubewell water supplies. All of these amenities are positively correlated with settlement size. Historically, villages relied on dug wells and later on community standpipes. The movement toward piped water supplies within household premises has expanded rapidly during the past decade. O’Reilly and Dhanju (2014) have shown that piped water from public standpipes mainly benefits the elite in northern Rajasthan. Pune district is adopting a different system of elevated storage reservoirs that supply distribution lines throughout a village. Although these pipes reach the majority of residents, they still do not reach remote habitations or the most impoverished households. Treated tap water is also increasing, particularly in larger villages and those affected by fluoride, dissolved solids, and nitrates. Because dug wells often go dry during the hot pre-monsoon period from March to June, they are supplemented by tubewells that draw on deeper supplies for drinking water and irrigation, though these too are increasingly depleted, especially in irrigated areas (Birkenholtz, 2015).

Household sanitation amenities include improved pit latrines, bathrooms, and septic tanks. The most basic and widespread type of safe sanitation is the improved pit latrine. It is also a key component of the national Swachh Bharat Mission to eliminate open defecation. Interestingly, improved pit latrines are negatively correlated with population size. They have expanded in less densely populated areas but not in larger census towns, which makes this amenity more characteristic of rurban than peri-urban areas where pit latrines are being replaced by flush toilets. Bathrooms, i.e., bathing spaces, by comparison, are positively correlated with settlement size and reflect increasing sanitation standards associated with both rurban and peri-urban development. The majority of peri-urban villages and a significant number of smaller rural villages have attached or indoor bathrooms. Septic tanks are adopted when indoor water supply, toilet, and bathroom construction lead to increased water use and wastewater flows. As expected, peri-urban villages have a high percentage of septic tanks. However, when septic systems exceed infiltration capacity, they can contaminate shallow wells in high density peri-urban settlements. They are thus a transitional technology in urbanizing regions.

Sewerage and drainage variables in the Census include night soil disposed in open drains, piped sewers, wastewater connected to piped sewers, and use of closed drains. The most advanced systems have piped sewers. Peri-urban villages around Pune City have high
proportions of both open drains and piped sewers, i.e., a combination of disciplined and undisciplined urban development. A small number of outlying rural villages with piped sewers are good candidates for rurban designation. Similarly, the most advanced sewerage amenities discharge wastewater into closed drains. This technology has a peri-urban spatial pattern that follows major highways and industrial areas, as well as in major city and town peripheries. However, not all of the larger villages have closed drainage. Indeed, there is a very weak correlation between open drainage and village size. Large and small villages outside Pune City have open drains, as do villages near major highways and industrial areas. This mixed spatial distribution of open drainage exemplifies one of the major challenges in peri-urban environments.

When we chart selected water and sanitation variables by settlement population several patterns stand out (Fig. 4). First, water and sanitation amenities generally increase with settlement size. Peri-urban villages appear better off than smaller more remote places. The most widespread improvement is having drinking water within premises. Larger settlements also tend to have treated water near the source or at point of use. There is a similar pattern with piped sewerage, though it is much less common. Surprisingly, open wastewater drainage has a weak correlation with settlement size. While water supplies are improving in larger settlements, wastewater and stormwater drainage is not. Finally, the smallest Class VI towns (< 5000) have poorer conditions than large rural villages. These adverse conditions in the smallest Census towns may indicate a negative pattern of peri-urban conditions in transitional settlements.

5. Village field interviews

While useful for visualizing aggregate conditions, Census data analysis was complemented through village interviews. We wanted to know how villagers think about peri-urban and rurban conditions although, not surprisingly, neither of these settlement terms was salient among those interviewed. We selected villages that Census data analysis indicated were almost towns, i.e., they met the population size and non-agricultural employment criteria. Two of them, Dehu and Nigozhe, are in the Pimpri Chinchwad municipal area. On the ground, both villages exhibited strong peri-urban conditions – a burgeoning population, unprecedented infrastructural growth, waste disposal issues, rapidly changing employment profiles, and decreased cultivation of agricultural land. When searching for Dehu village, we were brought to a developed suburban neighborhood near an industrial zone, and residents no longer referred to Dehu as rural. In this case the Census classification was outdated.
We interviewed a larger sample of 30 villages in the peri-urban to rural bracket to identify local patterns, processes, and concerns. Selection was based either on participation in the Jalwsawariya-2 program or on our highway transect analyses conducted in 2016. We then created a list of peri-urban concerns drawn from the literature search and reconnaissance fieldwork. The concerns included water supply problems, water quality problems, wastewater effluents, solid wastes, sanitation problems, slum conditions, overcrowding, and unemployment. Gram Panchayat members ranked these peri-urban issues on a scale of 1–7, the most relevant ranked as 1 and the least relevant as 7 or “NA”. The interviews included open-ended and follow-up questions to explore the ranking rationale and identify additional unanticipated topics.

By far, the greatest concern was job opportunities and unemployment, which tended to render peri-urban locations favorable relative to smaller more remote places. Next in priority were water supply reliability and source water protection, as land holding farmers require water for irrigation as well as drinking. Some peri-urban villages flagged waste dumping near water sources as a concern. A third suite of priorities involved drinking water quality, wastewater, and solid waste disposal, followed by unsafe sanitation. Overcrowding was a lower priority, and slums were not present in any of the villages interviewed.

While some of these village responses were anticipated, albeit not in the rank order presented, three additional responses altered our perspective on peri-urban and rurban processes. First, villagers stressed the large growth of migrant labor, also known as floating population, as a concern. A second suite of priorities involved drinking water quality, wastewater, and solid waste disposal, followed by unsafe sanitation. Overcrowding was a lower priority, and slums were not present in any of the villages interviewed.

Second, our expectations about peri-urban overcrowding and slum conditions were not supported. Villagers reported that migrants generated new opportunities for rental housing income. Some villagers lease rooms to migrant workers and extended families. More prosperous villagers construct rental housing blocks with water and sanitation blocks. The scale of these local processes was unexpected.

Third, villagers reported occupational shifts from unskilled to skilled labor and from farm work to urban jobs, as well as the pursuit of higher degree diplomas. Many of younger generation commute to block towns and cities for education and jobs. When asked, “Where does the village see itself in the next twenty years?” respondents aspired to be near high employment zones with steady jobs, English medium schools, colleges, hospitals, and clean drinking water. These aspirations may reflect the bias here toward sampling peri-urban villages and limited sampling of the so-called floating populations in these villages.

6. Major types of peri-urban and rurban development in Pune district

Reconnaissance field research, Census analysis, and village interviews led to the identification of four major processes of peri-urban growth. Traditionally, peri-urban growth is associated with the boundaries of very large cities, and that is certainly the case with the Pune Municipal Corporation, which annexed eleven villages, including one of our peri-urban case study villages, in July 2017. However, transect analysis along highways, village interviews, and mapping revealed that peri-urbanization can emerge far away from a primate city, under the influence of other local stimuli, including the driving forces discussed below.

First, we found that the Maharashtra Industrial Development Corporation (MIDC) plays a substantial role in providing employment, piped water supply, and water treatment near its industrial sites. Villagers near an MIDC site were eager to be employed or provided for by MIDC. MIDC has policies on amenity provision based on proximity to the site. For instance, they offer free pipeline access for villages located from “deleted zones” (i.e., within the MIDC property). MIDC may also offer villages within a 2 km and 4 km radius access to their water supply pipeline at subsidized water rates. We used these radii to map the potential peri-urban influence of MIDC properties.

Second, highway corridors extend urbanization processes to distant communities. Highway gram panchayats reported that major roads affect real estate values, access to amenities, and location of commercial establishments such as hotel dhaba restaurants, markets, and retail
shops (e.g., fabric stores and outlets) that require improved water supply. These highway patterns are strongest at intersections with secondary roads. We used 2 and 4 km buffers to assess highway influence on peri-urban water and sanitation services.

Third, Block town (taluka) headquarters concentrate local administrative power, transportation hubs, and market opportunities. Proximity to block town headquarters can have positive implications for village access to government funding and support. Block towns are important secondary nodes for peri-urban development. Following the Jalswarajya II convention, we used an arbitrary ten kilometer radius to map water conditions in villages surrounding block towns.

Finally, cities with over a million in population have transformative effects on nearby settlements. Some villages seek to be annexed by the city, as their growth stresses cannot be accommodated by rural schemes. For example, Pharsungi village sits on the periphery of Pune city and has a staggeringly large population of over 50,000. Gram panchayat members expressed a desire to be part of the Pune Municipal Corporation (PMC) to access funds for improved infrastructure, such as piped water schemes, and relief from urban waste disposal. Peri-urban villages like Pharsungi often become a megacity’s “dump sites”. Despite having similar growth trends and settlement sizes, these peri-urban villages experience sharp water and sanitation disparities from their municipal counterparts. As with block towns, we used a ten kilometer radius around Pune Municipal Corporation for mapping visualization purposes.

Fig. 5 displays these four peri-urban types and their buffer zones as the peri-urban catchment of Pune District. They include 196 of the 1861 of the villages in Pune district (≈10.6%). The other 1654 villages are deemed rural. While distance is insufficient to fully delineate peri-urban processes, it is currently used by public agencies as an official planning and policy criterion. As noted, the Chief Secretary of MIDC described policies related to villages that fall within 2 and 4 km of MIDC properties. We also mapped areas that fell within none of the four peri-urban zones in order to identify rurban villages that lie outside peri-urbanizing areas.

7. Peri-urban and rurban water and sanitation index and planning maps

The final phase of this pragmatic study returns to the Census mapping methods, informed by field observations and interviews. It creates two indices to help visualize peri-urban and rurban conditions for planning purposes: a Drinking Water and Sanitation Index and a Dire Conditions Index.

**Drinking Water and Sanitation Index.** The Drinking Water and Sanitation Index combines six amenity variables that frequently surface as planning metrics and that were highlighted in village interviews. Duplicative and closely collinear variables were deleted from the analysis. The following six amenity variables, expressed as percentages, were averaged to yield a composite score: (1) drinking water within...
premises, (2) tap water treated, (3) bathroom facilities, (4) household latrines, (5) piped sewers, and (6) closed wastewater drains. Village scores were categorized into rough quintiles and given labels that range from Grave Needs to Basic Needs, Needs Watching, Mostly Sufficient, and Sufficient). These normative terms were adopted to move from descriptive analysis to planning implications.

Fig. 6 shows that the majority of villages in the top two quintiles of “mostly sufficient conditions” or better are peri-urban, which underscores the generally improving conditions in peri-urban areas. These 107 blue-colored villages are good candidates for consideration as rural models of water and sanitation, whether in the peri-urban corridors or not. It is highly feasible to follow up with interviews to ascertain the basis for their success, and the lessons they provide for others. At the other end of the spectrum, however, the red-colored villages with serious needs also include peri-urban settlements, which tend to be located near smaller block towns, along with a large number of remote villages in western Pune district. These 414 villages are high priorities for planning support.

Dire Situations Index. This index name may sound histrionic, but it focuses on the poorest water and sanitation conditions recorded in the Census that call out for attention. The Dire Situations Index was created by averaging the percentages of households with “No Latrine,” “No Bathroom,” “Drinking Water Away from Premises,” and “No Wastewater Drainage.” Fortunately, the majority of the villages in Pune district fall under the “sufficient” or “mostly sufficient” categories (55%). Only 22 villages district-wide are in the “grave need” category, and they warrant immediate attention. However, another 150 villages (8%) have clear “needs,” and a significant number of them lie in peri-urban areas. Fig. 7 shows that they are concentrated along highway corridors in central and eastern Pune District.

8. Conclusion

This study helps visualize the purportedly undisciplined environments of peri-urban villages and the purportedly disciplined environments of rurban villages at the district scale. Building on previous
research we linked field research methods with GIS mapping to visualize the relationships among population, water supply, and sanitation conditions in peri-urbanizing regions. We showed that peri-urbanization is more spatially extensive than is generally perceived. It surrounds small towns, highways, and industrial areas, as well as large cities like Pune. Empirically discerning these four processes of peri-urbanization was a major finding of the research. It was supported by field observation, interviews, and aggregate spatial data analysis. The buffer zone map for these four peri-urban processes provides a useful vehicle for visualizing where peri-urbanization has been occurring, and for where water planning could concentrate its financial, technical, and social support. This pragmatic approach may expand and improve as new annual data are collected at the village level by the Governments of India and Maharashtra.

We identified connections between settlement size and specific water supply and sanitation variables. Large peri-urban villages tend to have greater, not fewer, drinking water and sanitation amenities than small villages, but they are no different in drainage infrastructure, and thus their overall sanitation conditions will likely worsen. Census data indicated low levels of service in towns of around 5000. Towns that fall between urban and rural categories do not appear to be well served by either.

This research showed that in addition to the district Zilla Parishads, various governing entities have responsibility for supporting village water and sanitation improvement. Villagers near an MIDC zone often expressed an expectation for support from MIDC facilities. While we did
not interview highway departments, they too shape peri-urban growth and conditions. The intersecting nature of these peri-urban zones will require higher levels of coordination among government entities in the future. Hybrid rural and urban conditions are increasingly the norm rather than the exception in districts like Pune, which makes the urban-rural dichotomy increasingly problematic from a governance as well as material perspective, compared with hybrid pragmatic approaches (Lerner and Eakin, 2011).

Local officials and villagers mentioned that maps are the most valuable medium for visualizing and communicating water supply and sanitation conditions (data visualization interviews in Pune and Aurangabad districts, 2016). While maps are used in some planning processes, such as Participatory Rural Appraisal methods, GIS maps are rarely used in community meetings or in planning reports, which is a missed opportunity. However, further analysis is needed, e.g., of spatial autocorrelation in the index maps and overall district patterns, and of time series analyses of the water and sanitation indices.

The challenges of visualizing undisciplined peri-urban environments did not come as a surprise, and one is left with questions about what peri-urban conditions really are and how they are actually experienced at the scale of 1861 villages. The parallel challenge of visualizing the more disciplined situation in rurban villages warrants additional research. Are model rurban villages the exceptional accomplishments of a few charismatic leaders, as is sometimes suggested, or of more widespread collective action, innovation, and capability? Our empirical research suggests the latter. Do rurban villages have a socio-spatial logic analogous to that of peri-urban villages? Are they truly inclusive? Answering these questions seems as important for advancing the theory and practice of water supply and sanitation planning as the challenges of visualizing the undisciplined environments of peri-urban villages.

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Conflict of interest

None.

References
