Visualizing and Modeling Peri-Urban Drinking Water Supply and Sanitation Planning in Pune, Maharashtra

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SUBMITTED TO THE DEPARTMENT OF URBAN PLANNING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER IN CITY PLANNING

AT THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

FEBRUARY 2018

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ABSTRACT

As cities grow and rural fringes are urbanized, an in-between village state is emerging, that scholars are attempting to categorize as "Peri-Urban". Yet there are no existing models to quantify the population movements, infrastructure needs, and social characteristics of this rapidly emerging condition. The lack of diagnosis for the Peri-Urban State leads to uneven distribution of water resources, pollution of surface and groundwater, and unclear administrative lines.

This thesis presents a dialectical field research and Census data mapping approach for visualizing peri-urban and rurban patterns at the district (Zilla Parishad) scale using Pune district in Maharashtra as a case study. We adapt Census of India demographic definitions of the rural-urban dichotomy along with distance-based definitions used in Maharashtra, and compare them with Census data on water and sanitation services. Our key findings from our research are the following: From interviews with village Gram Panchayats, we create a framework for identifying peri-urban drivers and processes. Through GIS spatial analysis, we identify extensive settlement patterns and size relationships with access to amenities. District field research and interviews identified village concerns associated with four main spatial processes of peri-urbanization in Pune district: 1) megacity growth; 2) highway corridor development; 3) industrial zone development; and 4) smaller block town (taluka) expansion. The analysis returned to the construction of 2 Indices for Pune Zilla Parishad: The Water Supply and Waste Index, and a Dire Situations Index.

These findings and maps were then reviewed by the Pune Zilla Parishad, Maharashtra State Government, and the Maharashtra Industrial Development Corporation for feedback. Our frameworks are being evaluated for integration into Maharashtra's long-term water strategic planning. New, annually updated water and sanitation datasets at the national and state levels will make this combination of field and mapping research increasingly valuable for visualizing regional peri-urban and rurban conditions in the districts of India.

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I. PROBLEM STATEMENT

1. The Peri-Urban Problem

This chapter has 4 sections: The first outlines existing Peri-Urban definitions and their inefficiencies for planning implications. The second outlines the client work in which the research is situated within as a Government of India project for Jalswarajya II, a water and sanitation reformation. The third looks at existing initiatives being conducted within the Census of India context. The fourth describes Pune District and why it was an ideal district to test this research.

A Lack of Definition

Between the 2001 and 2011 Indian census, there was a 5% growth in India's total urban population, an addition that was significantly contributed by migration from the villages. As cities rapidly expanded and rural fringes frayed, it gave rise to an in-between village state that scholars are attempting to categorize: "Peri-Urban". Yet there are no existing models to quantify the population movements, infrastructure needs, and social characteristics of this rapidly emerging condition. More specifically, Peri-Urban villages have a host of complex problems such as uneven distribution of water resources, pollution of surface and groundwater, and unclear administrative lines. Nearby burgeoning industrial growth and highway development overshadow village needs, worsening water access and waste sanitation for Peri-Urban villages. As urban and industrial settlements nearby have greater reach and access to existing resources, nearby villages are not covered by urban mandate and often end up as victims to wastewater and pollution dumpling.

A status is necessary to grant schemes, yet there is not a framework to define peri-urban conditions. Peri-Urban villages are not accounted for by either urban municipal civic governments or rural gram panchayat governments due to their ambiguous state, which results

in no provincial way to spend on schemes or strategies. Without policy intervention to recognize Peri urban-specific situations, peri-urban settlements suffer impacts from, while not obtaining the benefits of, proximity to private, municipal, or industrial townships (e.g., MIDC).

What does "peri-urban" mean in the Indian planning context? Who is responsible for Peri-Urban development?

The literature on peri-urban settlements to date consists to a large extent of qualitative case studies that do not yet shed light on the variety, frequency, or spatial extent of peri-urban and rurban conditions. Peri-urban environments in India and elsewhere have largely negative connotations associated with a lack of spatial and socio-environmental order or discipline (Allen et al., 2006; Shaw, 2005). Peri-urban environments are inherently variegated and diffuse. They participate in metropolitan economies but lie beyond their boundaries, service areas, and administration. They have limited urban infrastructure in the way of utilities, social services, and environmental management. They may have good access to regional transportation networks and the industries they support, but lack the amenities and regulatory controls that increased mobility should provide. Peri-urban areas are widely perceived to have poor water supply, water quality, drainage, sanitation, and hygiene (Allen et al., 2006; Kurian and McCarny, 2010). The word peri-urban has largely negative connotations associated with a lack of planned and orderly development.

Few studies in India have attempted to visualize Peri-Urban varieties, configurations, or spatial distribution. Peri-urban development is often characterized as having a lack of spatial legibility and discipline over relatively large metropolitan regions, though it may also have positive improvements in water and sanitation amenities, compared with rural villages.

A Mumbai Metropolitan Regional Development Authority (MMRDA) report that attempts to map peri-urban change from satellite imagery was hampered by changes in image resolution that led to errors in time series analysis of urban growth and change (pers. comm. 2015). Current research tends to neglect secondary and tertiary cities where much of the peri-urban growth is occurring. Peri-urban development near block headquarters towns, highways, and industrial parks also deserves greater attention. These are the areas that are currently cheaper to build on, but projected to grow in the future. These areas are far beyond a mega city, but the development of these areas already begin to rapidly affect nearby settlements.

The growing emphasis on Peri-Urban policies in India is likewise hampered by selective case studies and limited systematic mapping. The Government of Gujarat (2016) is an exception as it was an early proponent of rurban development. Its rurban program includes taluka headquarters (which are already towns not villages), general villages with a minimum population of 10,000 persons, and tribal villages with at least 7,000 persons. The Government of India extended this program to a national level in the Shyama Prasad Mukherji Rurban Mission (www.rurban.india.gov). The Ministry of Rural Development has disbursed three sets of state financial awards under this program to date. In addition, there are model village programs such as the Sansad Adarsh Gram Yojana, which encourages the uplift of one model (*adarsh*) village by each parliamentarian (http://www.saanjhi.gov.in/).

While these model villages are noteworthy in their accomplishments, which villages are selected are often arbitrary, and villages that have greater growth needs are not held to the same accountability for growth. Moreover, the standards and baseline conditions to measure improved safe water and sanitation for Rurban and *adarsh* villages are still to be determined. In the meantime, exemplary rurban villages seem to be anomalies in a district. In Maharashtra some of the famous examples include:

- Malkapur in Satara District for achieving a 24 x 7 water supply

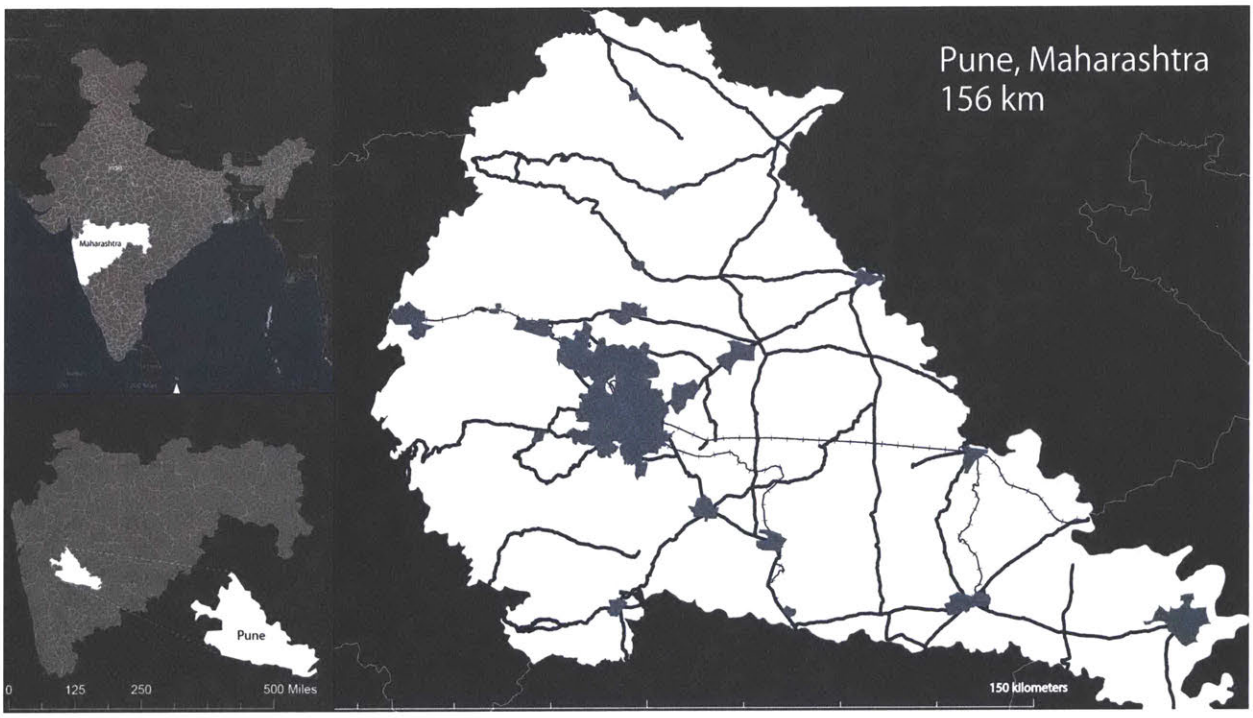
- Ralegaon Sidhi village in southern Ahmednagar district for village reforms by a leader named Anna Hazare.
- Hiware Bazaar outside Ahmednagar city for its communitarian approach to village water and irrigation conservation.
- Pathoda village in Aurangabad district, an Adarsh model village for its safe water, sanitation and other village amenities.

These exemplary villages receive growing case study attention, but that does not shed light on the wider geographic distribution and diffusion of rurban water and sanitation improvements. Instead, planners resort to the simple dichotomy between rural and urban. Yet, this binary status cannot account for the many nuances, problems, and physical planning needs in the transition zones between rural and urban areas. From a policy perspective, this makes grant funding, scheme design and implementation, and demand forecasting challenging for decision makers at the local, district, and state levels. Moreover, under this binary rural-urban simplicity, the pursuit to be classified under one status versus another might become perverse. For instance, many town-sized villages want to remain a village for eligibility for rural funding and schemes, while their urban symptoms require other interventions as well. Some large villages want to be reclassified as towns to get higher levels of water coverage that they may or may not be prepared to finance or manage (e.g., 70 lpcd rather than 40 or 55 lpcd).

I seek to add depth to the overly simplistic current definitions for Peri-Urban. We address this challenge using GIS methods that link three separate databases: the Census of India's Population data, the Census of India's Housing Amenities data, and the Ministry of Drinking Water and Sanitation IMIS drinking water supply database to take a holistic look at urbanizing settlements within Pune District. We take an exhaustive dive into analyzing settlement patterns and their access to infrastructural amenities. We then create maps to recognize spatial patterns and to determine how maps can be used to prioritize peri-urban villages in a

district. We ground our analysis through 5 trips over 2 years with implementing stakeholders within the Government of Maharashtra.

2. Pune Geographic Context



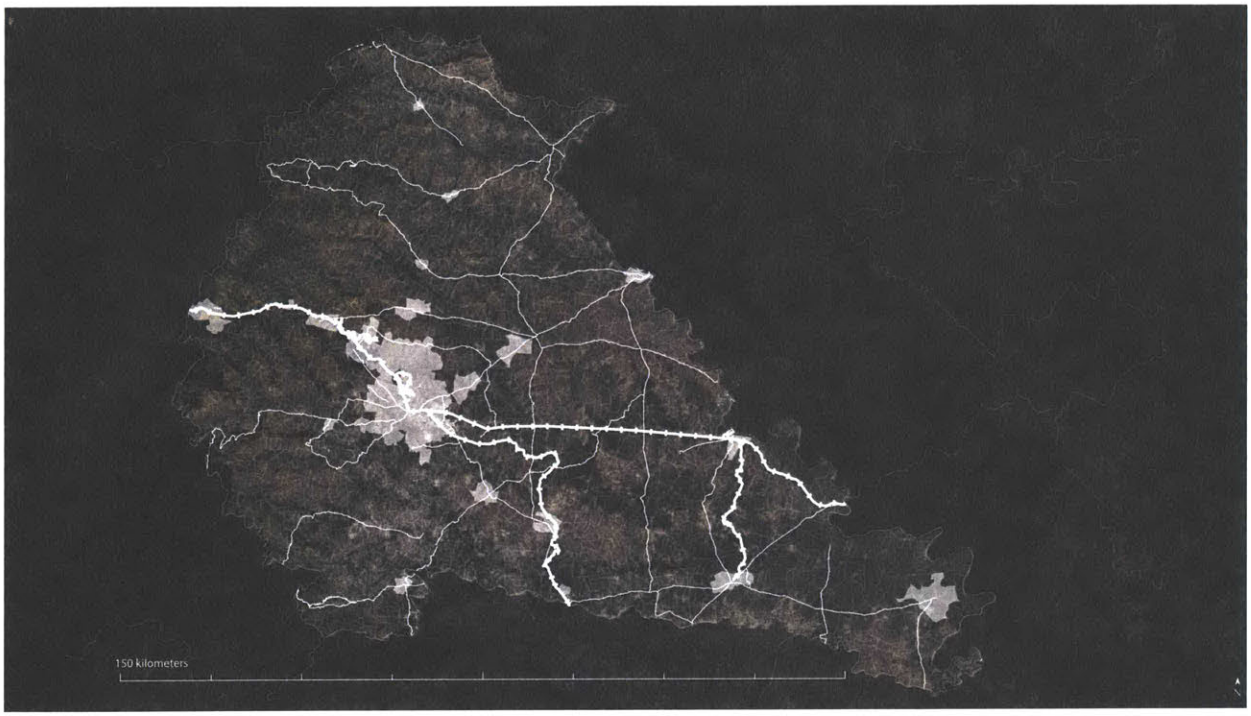


Figure 1. Pune District, in Maharashtra has 1919 villages and is divided amidst 18 Talukas

Pune's rapidly growing population, industrial and education sector focuses, and inbound migration makes it an ideal case study to understand Peri-Urban dynamics. Pune is the second largest metropolis in the state of Maharashtra and one of the fastest growing cities in Asia.The 2011 Census reported that Pune district had 1,919 villages. In addition, it includes a major metropolitan city and region, 12 block (taluka) towns, ten major MIDC state industrial areas, and an extensive highway network that connects them. Pune's identity with respect to water goes far beyond these administrative characteristics (Chakravarty, et al., 2006; Feldhaus, 2003). In historical terms, Pune was the capital of Mahratta 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. In the 20th century it had major development of irrigation agricultural cooperatives, manufacturing, and information technology industries. In particular, the establishment of the Maharashtra Industrial Development Corporation in 1960 rapidly spurred

Pune's development in a substantial way as MIDC's mandate was to provide critical ingredients - affordable land, water, and favorable business conditions - for entrepreneurs to set up. Historically, MIDC was the catalyst for many of Pune's metropolitan agglomerations today Pimpri Chinchwad was once an MIDC zone housing a number of automotive industries, yet today has a metropolitan designation. Pune's growth story is tied to the confluence of water access, favorable business policies for industrialization, its proximity to Mumbai city, and an entrepreneurial class.

In the fringes of Pune, villages are rapidly growing, and the demand for resources outpaces supply for water. Moreover, Pune's Zilla Parishad reported a severe challenge in infrastructure planning and investment decisions due to an inability to assess where peri-urban villages are, or how to project their rate of growth. This reported need, the magnitude and pace of urbanization processes, along with reconnaissance of other districts in the state led to the selection of Pune for our Peri-urban case study.

3. Jalswarjya II Context and Objectives

Our research on peri-urban water planning began in collaboration with the Government of Maharashtra and World Bank's Jalswarajya II (JS2) program for improving rural drinking water supply and sanitation planning. The development objectives of the proposed project are to: (i) increase rural households' access to improved and sustainable drinking water supply and sanitation services; and (ii) institutionalize decentralization of Rural Water Supply and Sanitation (RWSS) service delivery to rural local governments and communities (World Bank, 2014). Our role in the JS2 project involves studies and tools for strengthening district water planning. The JS2 project involves water stressed villages, water quality affected villages, and

peri-urban villages. After reconnaissance in four districts (Raigad, Pune, Aurangabad, and Jalgaon) we selected Pune for the magnitude, pace, and variety of its peri-urban processes.

As noted above, peri-urban villages in the JS2 program are self-nominated by local governments within 10 kilometers of a census town. We visited and interviewed these JS2 peri-urban villages and while they are all interesting cases, the JS2 sample is not random or stratified. Additionally, it does not include clusters of villages in the urban periphery, along major roads, or near major industrial development zones. This results in arbitrary rather than systematic selection of villages based on need.

After selecting Pune District as the case study for our peri-urban research in August 2015, we prepared draft GIS maps of drinking water coverage for district officials in January 2016. Ground-truthing visits were made to villages designated as peri-urban in the GIS analysis and to additional JS2 peri-urban villages in August 2016. This GIS analysis is thus grounded in field survey and interview research over a one-year period. The administrative and spatial framework for this research is outlined below.

This study is a contribution to the Government of Maharashtra and World Bank rural water and sanitation Jalswarajya II (JS2) project, which includes a component on water sector planning at the district level (World Bank 2014). Jalswarajya II includes three types of village water projects: scarcity affected villages, water quality affected villages, and peri-urban villages. For the latter, it uses an arbitrary distance of less than 10 kilometers from a city boundary for selecting peri-urban projects. It is a demand-driven program in which a small number of self-nominated villages are selected, which means that they are likely to be among the more disciplined villages in the 10 km peri- urban buffer. The JS2 program does not analyze water and sanitation conditions in other villages within the 10 km peri-urban buffer zone.

This study takes a step back to address the broader research question: What are the attributes

and patterns of peri-urban water and sanitation conditions at the district scale? Answering this question requires systematic identification, analysis, and mapping of peri-urban village attributes as they relate to water and sanitation variables for an entire district. It requires field testing to identify missing variables and clarify different patterns of peri-urbanization. As noted earlier, most peri-urban research focuses on single metropolitan areas rather than a district, which is the primary administrative level for rural development planning. It is also important to broaden out the context to a district level, because peri-urbanization can occur far beyond metropolitan boundaries. To put the district role in context, it is useful to outline the levels of rural water planning in India. This ensures that the research can be contextualized and be useful for policy planning.

4. Administrative Policy Context

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 constitutionally a state responsibility in India, and water financing and policy reforms were also undertaken at the state level. Maharashtra has been one of the most active states in advancing rural drinking water reforms beginning in 2000, which led to the Jalswarajya I project in 2003, followed by the Jalswarajya II program from 2014 to 2020 (World Bank 2014). These reforms have received detailed academic critique, administrative evaluation, and programmatic adjustment (Prasad, Misra, and Sohoni, 2014; Sakhtivel et al., 2015; Sangameswaran, 2014; World Bank, 2008, 2013).

State governments comprise districts, which are further subdivided into blocks (also known as talukas or tehsils). Maharashtra, for example, has 36 districts and 358 blocks. District

governments are known as Zilla Parishads, which 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 branch of a public water engineering corporation known as the Maharashtra Jeevan Pradhikaran (MJP), and a branch of the state Groundwater Surveys and Development Agency (GSDA) that conducts detailed groundwater mapping and monitoring, as well as certification that water sources have sufficient yield for proposed drinking water projects. While neoliberal reforms have accelerated since 1991, India has had 150 years of policy debate and experimentation on the relative merits of devolution to district, block, and village level governments (Wescoat 2017). 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. However, in 2016, an increase in federal devolution of funding to the state, rather than local, scale led to an additional water financing program, the MRDWP, that resumed greater authority over water planning from the gram panchayat to the district level (cf. Birkenholtz [2015] on the dynamics of decentralization and recentralization). Several parastatal organizations in Maharashtra also influence local water resources management. Foremost among them is the Maharashtra Industrial Development Corporation (MIDC), which develops water supplies, infrastructure, and wastewater treatment for industrial sites, often in peri-urban areas. The Highway Development Authority, responsible for planning new corridors, is also a notable actor in driving peri-urbanization. The third is the Pune Municipal Regional Development Authority (PMRDA), established in 2014, is in charge of laying out infrastructure and water layouts for some 800 villages. It is currently run by Mr. Kiran Gitte, the CEO of PMRDA. Regardless of mandates, these actors' decisions either drive urbanization or influence the water planning process in Maharashtra. This thesis will identify the extents of their influence and suggest a path forward for joint collaboration.

5. Census of India Context

The Census includes datasets on population, household characteristics, urban and rural amenities. Although there is a large literature on the limitations of census data analysis and mapping in general (e.g., Barrier, 1981; Denis and Marius-Gnanou, 2011; Nag, 1984; Schwartzberg, 1992), it is an important national dataset for the variables considered here. For each variable, the key was to identify thresholds and intervals for mapping, to consider population intervals just above and just below those deemed rural or urban, and to assess a gradient of "positive" and "negative" conditions.

Currently, the Government of India provides the following definitions that are proxies for Peri-Urban growths.

Out Growth (OG): Out growth should be a viable unit as a village or a part of the village contiguous to statutory town and possess urban features in terms of infrastructure and amenities such as pucca roads, electricity, taps, drainage systems, education institutions, post offices, medical facilities, banks, etc. Examples of OGs are Railway Colonies, University campuses, Port areas, that may come up near a city or statutory towns outside its statutory limits but within the revenue limit of a village or villages contiguous to the town or city.

Urban Agglomeration (UA): It is a continuous urban spread constituting a town and its adjoining urban outgrowths (OGs) or two or more physically contiguous towns together and any adjoining urban outgrowths of such towns.

Statutory Town (ST): Places with a municipality, corporation, cantonment board, or notified town area committee.

Census Town (CT): The 3 conditions, and the number of villages in Pune that satisfy each of the

conditions:

A. A minimum population of 5000: 166 Villages

B. At least 75% of the male main working population engaged in non agricultural pursuits:

C. A density of population of at least 400 per sq. km: 328 Villages

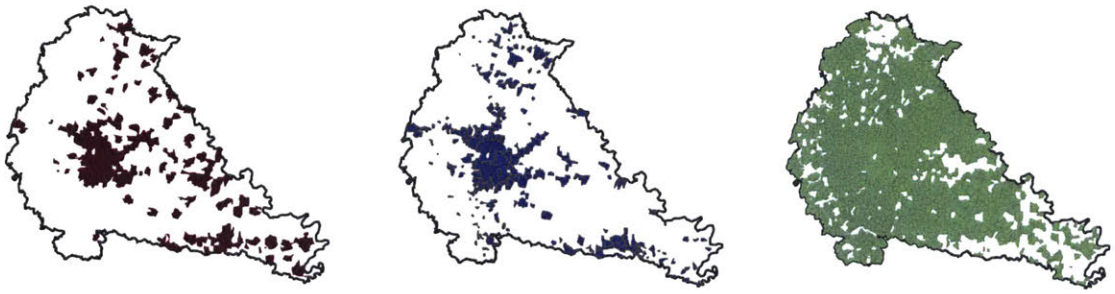
Number of villages where all 3 conditions met: 92

*Where work is defined as participation in any economically productive activity with or without compensation, which includes agricultural work. Agricultural laborers is defined as someone who works on another person's land for wages. Main Workers - workers who worked for more than 6 months (180) days.

Equation used to calculate condition B: (Male Workers [M_W] - Male Agricultural Laborers [M_AGLB]) / Male Workers [M_W] * 100

CENSUS TOWN

Defined by India 2011 Census



Total Population
> 5000

Density
> 4000 km2

Non Agricultural Male
Working Population
> 75%

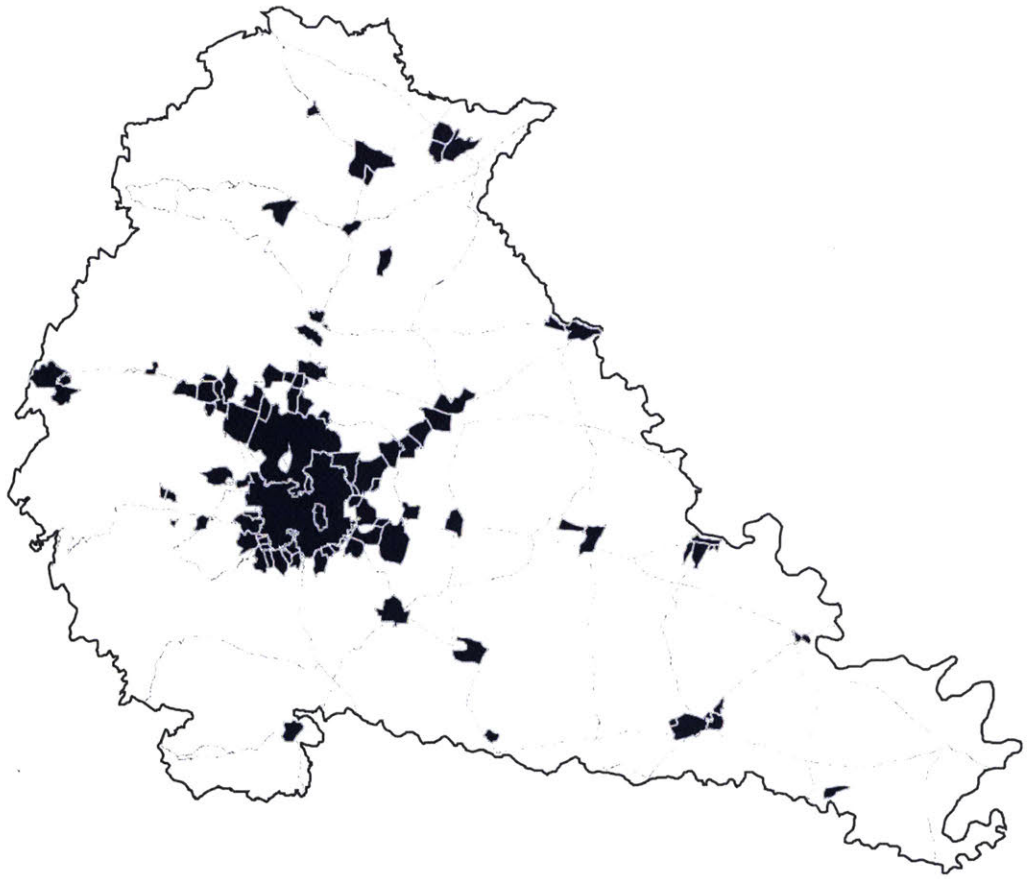


Figure 2. Census Towns as defined by 2011 Indian Census

The most empirically robust method for characterizing Peri-Urban Growth by the Government India is the Census town. But while settlement size or changing job aspirations are a starting proxy to determine peri-urban growth, it is simply an explanatory variable and is lacking in explaining urbanization growth drivers. Moreover, decisions based on settlement size in the Census will be inaccurate as peri-urban villages have huge fluctuating populations. Inaccuracy is further exacerbated by a 7 year gap between Census collections. Our research will later reveal that Peri-Urban corridors expand much beyond the census town definition (Figure 2), or the 10KM radius provision by JS2 (Figure 3). The 10 kilometer Peri-Urban criteria provided by JSII misses a large number of villages that have become Peri-urban due to other influences, for instance the development of highways (Balakrishnan 2013), or the emergence of industrial town centers (Shaw 2015).

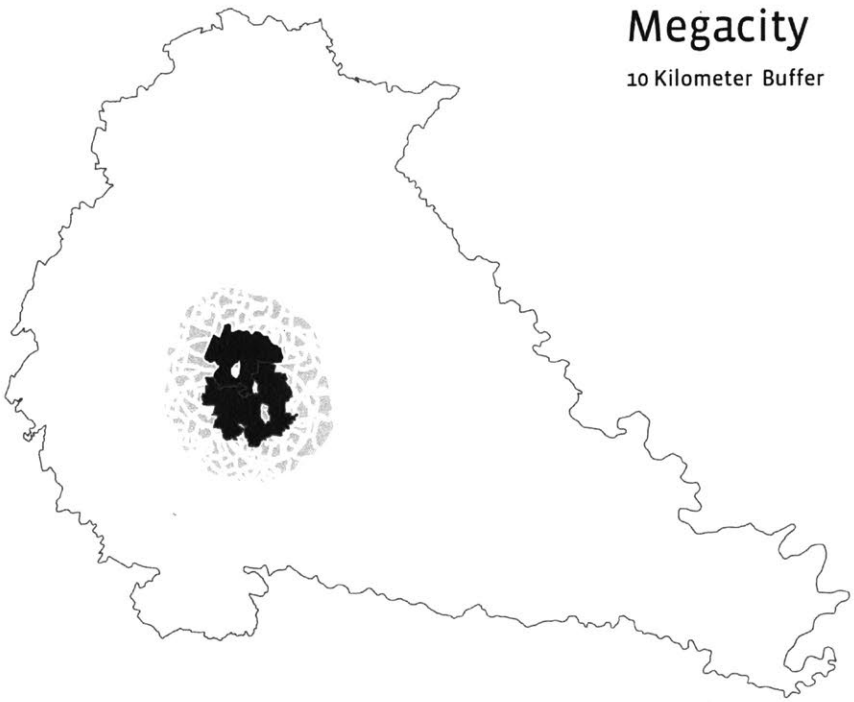


Figure 3. Peri-Urban Villages selected under Jalswarajya II by Pune Zilla Parishad are within 10 kilometers of a metropolis

The academic literature on peri-urban settlement in South Asia is biased toward megacities like Delhi, Chennai, Dhaka, Karachi, Kolkata, and Mumbai, followed by million-plus cities like Bangalore, Hyderabad, and Lucknow (Ahmed and Sohail, 2003; Angueleto, 2007; Brook et al., 2003; Dahiya, 2003; Dutta, 2012; Kennedy, 2006; Narain, 2009; Prakash, 2012; Shaw, 2005). Yet, peri-urbanization is occurring predominantly beyond million-plus cities such as JOKA near IIT Bombay. These rapidly growing cities are some of the most complex metropolitan regions to visualize. Planners in the Mumbai Metropolitan Region Development Authority (MMRDA) report that attempts to map peri-urban change from satellite imagery were hampered by changes in image resolution that led to errors in time series analysis of urban growth and change (pers. comm. 2015). Current research tends to neglect secondary and tertiary cities where much of the peri-urban growth is occurring. Peri-urbanization growth is beyond the metropolitan area. Peri-urban development near block headquarters towns, highways, and industrial parks deserves greater attention.

6. Outline of Thesis

My proposed thesis seeks to answer the question of what "peri-urban" means through a focused characterization of fringe areas in Pune, Maharashtra. My approach to create this focused definition and planning approach is several fold: The first step is to analyze the current rural-urban variables. Then we begin creating the association between water and sanitation access with census factors, and to also assess gaps in current government implementation and spending utilizing census data from the 2001 and 2011 census, IMIS, and AAP. By examining these associations using regression, covariance, and multivariate models, I seek to gain further clarity on how these factors may or may not influence water access for Pune's villages. This

analysis will also help me sample the complex geography of metropolitan Pune.

Second, given the scarcity of visual documentation for the Peri-Urban, I conduct a transect analysis at several scales (10 kilometers and above). Then organizing images collect, I begin classifying conditions for the Peri-urban. The objective of this transect analysis is to improve clarity on land use and classifications of peri-urban conditions along an evolving corridor through GPS photo documentation.

Once we have a grasp of current patterns and trends from existing data, I then collected a series of on-the-ground surveys with local Gram Panchayats in both quantitative and qualitative measurements. After understanding first hand from Panchayats what factors are driving Peri-Urbanization, the next step is to translate these factors into spatial data. We relate these new peri-urban corridors with India 2011 Census Houselisting data sets, which includes data on water supply, sanitation, and waste amenities.

By creating a framework to determine peri-urban conditions, we are able to create criteria to model and refine a status for Peri-Urban. After organizing and aggregating data sets pertaining to these key forces and symptoms, the solution ties these aspects together into a planning decision support tool that integrates visual maps to prioritize forecasting water and infrastructure demand (Chapter V). The planning tool will firstly enable decision-makers to understand more about this phenomenon, secondly, help them formally designate peri-urban areas for policy intervention, and thirdly help them inform policy decisions that are relevant and impactful on the ground -- from land use and infrastructure planning to wastewater management, social services, industry policy, and real estate needs.

The last step is implementation. Users of my peri-urban modeling tools will include national, district, and block level governance, wastewater management groups, infrastructure planning, and academia. They will also include the Tata Water Mission and Maharashtra Industrial Development Corporation. Scaling up, these methods could be potentially used as a model for other states in India and other countries that have analogous data resources and

peri-urban symptoms.

II. LITERATURE REVIEW

1. Search Aims

Conducting a literature review on Peri-Urban processes enabled me to better understand what others have done in attempts to understand and address this fuzzy area. First, I observed how other scholars have attempted to capture conditions that define the Peri-Urban. Second, I observed a gap between Peri-Urban descriptors that are used by researchers and their ability to effectively inform policy formation by stakeholders. Third, I learned about techniques that have been used to model Peri-Urban areas, including remote sensing, satellite imagery, GIS data, and qualitative interviews. Findings from this review can help improve water planning in Peri-Urban India by observing how Peri-Urban is currently defined, and what methodologies have been employed to model the Peri-Urban, in hopes to inform further work that can address unmet needs.

This chapter begins with the Search Methods, then highlights 4 topical subjects that emerge within the academic field of Peri-Urbanization: 1) Peri-Urban Terms 2) Spatial Analytics 3) Water and Wastewater Issues 4) Industrialization and Real Estate Proxies.

2. Search Methods

I approached my literature search by firstly coming up with a matrix of potential keyword terms relating to spatial, geographic, water, and planning categories relevant to peri-

urban development (Figure 3). Then within MIT Libraries and other online Libraries, such as SCOPUS,Compendex, and Web of Science, I created key term pairings and catalogued key word hits (Figure 4). The most substantial changes in results occur when key terms are filtered by geographic filters.

Spatial	Geographic	Water	Planning
Peri-urban	India	Waste water	Industry
Rural	Pune	Drinking Water	Corporation
Fringe	Thane	Industrial Water	Private
Periphery	Tier	Irrigation	Public
Territorial	Nagpur	Drainage	Planning
Landscape			Tension
Village			Status
Rurban			Management
Town			MIDC
Civic			Regeneration

Search TermPairs	Key Word Hits	Note for Follow up
"periurban" and "India"	7663	Many results returned were health related, some international returns
"periurban" and "wastewater"	1971	many scientific papers rather than planning
"periurban" and "wastewater" and "planning"	1534	Still International records, but closer to planning
"periurban" and "wastewater" and "planning" and "India"	1255	Getting more specific
"periurban" and "industrial" and "planning" and "India"	4480	Terms are more relevant to planning and real estate
"rurban" and "planning" and "India"	4963	Returns are not very specific, rurban term not as defined, but returns articles that are more optimistic or forward looking. More international returns
rural and "urban" and "fringe" and "India"	564982	Redundant returns from earlier searches
"rurban" and "civic status"	77	nonspecific terms, context agnostic
"rurban" and "tier"	3668	more broader international macro level terms
"periurban" and "pune" and "planning"	907	nonspecific to planning, mostly international
"periurban" and "maharashtra"	1356	nonspecific

Figure 4. Search Term Pairs and Results

Most of the literature written about Peri-Urban falls into the following categories: 1. Definitions of Peri-Urban 2. Challenges in Administrative Capacity 3. Industrial relocation and privatization of land 4. Methods and tools on how to classify urbanization and land use

coverage 5. Wastewater treatment. 6. Rural to urban migration patterns 7. Industrial Relocation from cities to outlying areas. 8. Storm and Sanitary Drainage. Competition for water or water scarcity has not been identified as an important issue, but have frequently emerged during site visits. This literature reveals that discussions of Peri-Urbanization remain theoretical, but lack practical guidance for policy and planning. The literature search also reveals a dearth of literature on how Peri-Urban is defined empirically and systematically.

C. Search Results: Peri-Urban Terms and Classifications

The search identified literature that describes the peri-urban as fuzzy and difficult to capture. Several synonymous keywords are suburb, exurb, fringe, or rurban. The evolution of the Peri-urban definition emerged during the 20th Century (Johnson, 1974), when the urban versus rural dichotomy began blurring into terms like banlieue (French), rurbanisation, peri-urbanization, and more recently, rural-urban interface. Rurbanization has limited use in scientific literature, but emerged to describe "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"(add source). The term Peri-Urban, on the other hand, seems to have a more transit-oriented association, "with the automobile, route and highway expansion, to sacrifice of time in commuting to the distant workplace" (Madaleno, year, 1). Vishal Narain argues that Peri-Urban should not simply be based on "proximity to towns", but described instead as a state that features the existence of both rural and urban characteristics and the linkages and flow of goods and services between rural areas and urban centers" (Narain, year, 502). Various definitions serve to demonstrate that the Peri-Urban condition is not simply a function of city proximity, but is also dictated by non-distance linkages as well such as commerce and technology advances.

However, these terms exist more as high-level academic descriptors rather than

enforceable concepts for governing. Scott (year, page) defines the peri-urban as "rural urban fringe (RUF) [...] a zone of transition in land use, social and demographic characteristics, lying between (a) the continuously built-up urban and sub-urban areas of the central city, and (b) the rural hinterland, characterized by the almost complete absence of non-farm dwellings". Scott also describes the "messy" aspects of the rural-urban fringe, which leads to 'disintegrated' policy and decision-making. Currently, literature acknowledges the ambiguity of the Peri-Urban, but there is much more potential to concretize the definition for policy-making based on regional-specific needs and empirical data.

3. Search Results: Challenges in Infrastructure and Administrative Capacity

The weak conceptualization of Peri-Urban makes governance in such areas challenging to enforce. Most of the current literature on administrative capacity for Peri-Urban areas describes ambiguity of peri-urban legal jurisdiction between beyond cities' municipal boundaries. But for Peri-Urban status to have weight in governance, the Peri-Urban definition needs to answer region-specific needs. Yet in this literature search, keywords narrowed down by geography overwhelmingly limited relevant results, particularly in the case for India and even more so for Maharashtra (Figure 1—actually, this figure indicates a large number of hits for "India"; the Maharashtra hits are mostly health related, but that may have some relevance as a proxy variable for water issues). This result demonstrates that existing Peri-Urban research remains mostly theoretical rather than as a pertinent term for place-specific policy applications.

Annapurna Shaw's 2015 journal article, "Peri-Urban Interface of Indian Cities", describes symptoms of Peri-Urban villages from a pan-India perspective. Many of Shaw's observations are similar to the observations I made during my fieldwork. For instance, she brings up the plaguing issues of environmental vulnerability of peri-urban areas since they are often sitting on fringe

lands, which often have mixed industrial uses. As a result, village water sources often become contaminated by industrial run-off, yet village governance does not often have the agency against these larger actors. She also explores reasons for neglect of the Peri-Urban, which is that Peri-Urban towns do not fall easily under existing urban civic status, yet these complexities are too overwhelming for simpler rural governing structures. She ultimately calls for a strengthening of local government, and granting civic status to peri-urban areas to have greater agency. This is also a sentiment I have also observed from fieldwork, hearing complaints from villagers who have appealed to the government regarding industrial pollution, the need for infrastructure investment, and increased administrative capacity needs.

Without a strong peri-urban status, it is difficult to hold entities accountable for resource provision. Narain outlines the issues for Peri-Urban governance in the case for Gurgaon, "the government entity HUDA is responsible for the maintenance of the road that cuts through the village, but the village panchayat on the other hand is responsible for the roads within the village, HUDA provided a single water point from the Basai water treatment plan, and the village Panchayat developed the internal distribution network" (Narain, year, 509). He highlights the disjointed coordination between governments and the villages in completing projects and schemes since there is no joint accountability. Policies that outline governmental structures, organization hierarchy, and civic duties would be useful in determining how urban and rural governance could work together to enhance policy formulation and execution.

4. Search Results: Spatial Analytical Tools to Measure Peri-urbanization

The peri-urban definition can be strengthened through visualization of data using empirical methods. As peri-urban areas are dynamic, there need to be ways to measure change

through the inputting of periodical data to monitor growth. So far land cover classification maps have been conducted through remote sensing or satellite imagery to compare with ground truth data. In Kantakumar's 2015 article, "Spatiotemporal urban expansion in Pune Metropolis, India using remote sensing", he devises quantifiable methods to model urban expansion to identify three types of urban expansion patterns in the Pune metropolis: i) coalescence phase of urbanization in main city areas ii) diffusion phase in the suburbs iii) marginal growth in the cantonments. This study begins to identify that growth patterns are beyond metropolitan areas quantitatively. These patterns should be connected with ground realities.

There is an emerging field of visualization based on machine-learning, where rural and peri-urban settlements are classified with supervised digital image processing. Machine-learning has several exciting opportunities. First, A machine can be discerning at a large scale: In Jacqueminet's 2013 article, researchers map the progression of peri-urbanizing areas by analyzing very high-resolution (VHR) optical images to model land cover classes, vegetation coverage, and ultimately model sub-catchments. Teaching the computer to read Roof-top types can become an indication of infrastructure development. Second, it can continuously read large data sets: Facebook's Connectivity Lab has developed machine learning techniques on a massive scale to model settlement patterns in last mile communities. Third, a machine can advise on the planning process: The Reference Electrification Model (REM), developed out of the MIT-TATA Center uses machine learning to recognize settlement patterns, and suggest an optimal plan for where electric lines should should be laid.

However, using satellite imagery alone has several limitations. For instance, the accuracy of machine-learning techniques for identifying peri-urban settlements from is nascent and needs further refinement. With variegated roof-top types, a computer may not be able to easily discern the difference between residential or commercial based on rooftop imagery. Peri-

Urban settlements especially may not be discernible given their rapid transition state. Second, water sources drawn from local underground reserves and basins are resources hidden from satellite imagery, or occluded by clouds or weather conditions, with the exception of GRACE satellite imagery which could be useful for large scale depletion analysis. A mixed approach between satellite machine learning and also ground verification could be an exhaustive combination. Other researchers have been able to add depth to satellite imagery with additional geographic data sources in lithology, geological structures, and landform GIS data sets. In Jaiswal's 2010 article, "Role of remote sensing and GIS techniques for generation of groundwater prospect zones towards rural development", a GIS based model enhanced identification of suitable locations for extraction of potable water for rural populations in Madhya Pradesh.

Given that high-resolution satellite maps or land use maps are not readily accessible in many parts of India, the challenge in classifying Peri-Urban areas comes down to methodologies to identify land use patterns and change. Remote sensing or satellite imagery analysis is a topological step to identification and has benefits over traditional data sets as it can continuously provide updated conditions versus just a snapshot in time, but also needs to be matched with ground truthing approaches. Later in this paper, we examine visualization of data sets based on government housing amenities, and census data, followed by ground truthing techniques such as transect analysis and interviews.

5. Water and Wastewater Issues

An emerging symptom of Peri-urban situations is the distribution of public resources

that are quickly becoming crowded or altered by other actors such as corporations or large-scale farming. In particularly at stake is water. In Nagendra's paper, "Applying the social-ecological system framework to the diagnosis of urban lake commons in Bangalore, India," Nagendra talks about the evolution of several tanks and lakes that was "once managed by adjacent village communities but are now administered by a number of government departments involved with aspects of lake management, with multiple overlapping jurisdictions" (Nagendra, 2014, page). They often see major pollution in former water drinking resources, yet villagers' concerns hardly have weight in court cases.

Moreover, as a result of increasing industrial presence in city fringe areas, source treatment is one of the most prevalent concerns for Peri-Urban India. In Kurian's 2013 article, "Wastewater Reuse for peri-urban agriculture: a viable option for adaptive water management?" Kurian argues for systems of drinking water discharge to be reused for irrigation. This is a potent idea considering how drinking and irrigation water are thought of in different spheres, yet both are critical in the context of rural planning.

There exists some literature on policy frameworks to address waste concerns in rural communities. From a participatory angle, Luthi presents two proven frameworks, "the urban focused household-centered environmental sanitation (HCES) and the rural-focused community-led total sanitation (CLTS) approaches (Luthi, 2009). From a top-bottom perspective, Gnanasekaran (year) describes "Urban appropriation of rural waters in India: Applying a complex social-ecological system (SES) perspective in policy development. He describes two possible scenarios, 'Regional Resilience' and 'Regional Transformation', as ways to create water transfers between rural and urban areas.

However given the strong influence of Industry in Peri-Urban areas, there needs to be more policies addressing the ways that Industrial sectors interact with Peri-Urban villages in

source extraction and treatment, employment, and corporate social responsibility.

6. Industrialization and Real Estate Acquisition

As mentioned above, one of the most salient aspects of Peri-Urban areas is the concurrent presence of industrial development and privatization. While many articles focus on industrial development, few offer solutions or recommendations on how industrial groups can support village communities financially or administratively. For instance, Banerjee's 2013 article, "Impact of Industrial Waste Effluents on River Damodar Adjacent to Durgapur Industrial Complex, West Bengal, India," is useful for an isolated case but does not make the connection between industry, urbanization, and even less so the impacts that industrial places have on the surrounding villages in the Bardhaman District. While industrialization is thought of as a positive influence, the distribution of benefits and impacts is often not equitable. In Meher's (year) article, "The social and ecological effects of industrialization in a tribal region [...]," she looks at the consequences of industrialization on Schedule Caste and Tribe communities, in particular the ecological degradation of resources that were previously used by these communities.

Land use rights are also being drastically transformed in the urbanization process from private actors. In Vishal Narain's (year) piece "Growing City, Shrinking Hinterland: Land acquisition, transition, and conflict in Peri-urban Gurgaon, India", he describes the growing resentment by farmers facing forced land acquisition, and also voiced the ways that they could be compensated such as being employed by the industrial areas that were being built, or allowed to enter direct negotiations with buyers rather than go through government. Narain advocates for a participatory process that enables Peri-urban dwellers to be made more of an integral part in the policy formulation process. He advocates for the re-visitation of the Land

Acquisition Act of 1894, which allows land to be acquired "for public purpose". This discussion of community development is integral in undefined spaces.

Currently, industries' answer to their own mandates and believe they are only responsible for their areas. Yet, the influence of their activities far exceed such boundaries: migrants seeking to be employed by industries live in nearby settlements, waste effluents from industries flow into rivers, and urban growth spurs real estate prices. Planning for peri-urban settlements must extend beyond mandated property boundaries.

7. Conclusion and Next Steps

Upon reflection from my literature search, there is greater need to narrow Peri-Urban empirically for policy implementation. There also need to be methods that have regional-specific specificity, and methods to scale across districts and states. Peri-Urban characterization is often described from a pan-globe perspective, with the most descriptive studies at a metropolitan level like Delhi or Mumbai. There is a neglect of secondary and tertiary cities, where most of the peri-urban condition is emerging. However, governing entities that can benefit the most from a policy perspective exist at a block or Gram Panchayat level. Peri-Urban research in current literature seems to generally exist more as an academic theory, rather than providing implementable strategies for governments to employ on a regional level.

Findings from this review demonstrated a breadth of academic theories on peri-urban definitions. However, the field of peri-urbanization is lacking strong spatial evidence or planning and policy. Geographic tools such as remote sensing and satellite analysis have been conducted but without substantiation from field research. This thesis addresses this by linking

empirical and spatial data with qualitative, ground-truthed data. We began by conducting a reconnaissance and transect analysis along the highway corridors of Pune.

III. FIELD SURVEYS AND GROUND TRUTHING

To validate learnings from literature search and data with ground realities, we began identifying possible peri-urban areas to collect ground data and interviews. As mentioned in the literature search, current attempts to characterize peri-urban areas are conducted through remote sensing or machine-learning of settlement patterns through satellite imagery. However, this analysis limits the understanding of what is driving urbanization on the ground. What we seek to bring forth in this chapter, beyond empirical methods, are ground level observations and informant insights conducted over over 300 hours of interviews to inform our analysis. This chapter has 3 sections: The first is a transect reconnaissance along Pune's four peri-urban corridors. The second is an in depth questionnaire that was conducted with the Gram Panchayats of 15 peri-urban villages. The third are interviews with senior managers and engineers of the Maharashtra Industrial Development Corporation on strategic water and infrastructure policies.

1. Transect Reconnaissance and Fact Checking

We first wanted to get an overall sense of what the landscape across Pune's major state highways looked like to assess what we may have missed from a high level. We attempted to capture what was along the roads through a loose "transect" framework. We did this by:
1. Taking GPS logged photos at 30-second intervals along major pune highways to observe urbanization changes. Each circle represents a GPS logged photo. (Figure 5)

2. Driving off the main highway 10 kilometers on either side to get a lateral transect. (Figure 6)

3. Selecting villages across the transect where we interview the Gram Panchayats with an initial questionnaire about several peri-urban driving factors.

Figure 5. Transect of highway corridors in Pune, demonstrating that urbanization patterns are often where we least expect them

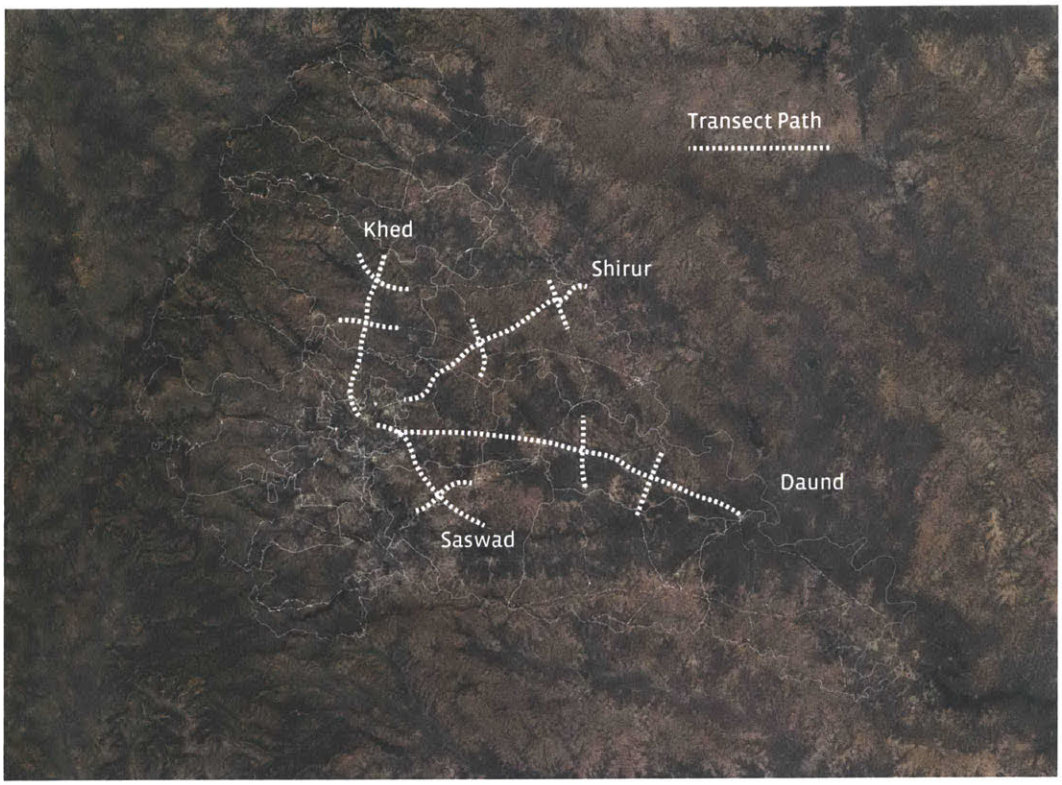


Figure 6. Routes taken along Pune highways, dots represent GPS tagged at 30 second intervals.

Characteristics of Pune Highway Corridors (Figure 6)

Four Talukas - Shirur, Saswad, Khed, and Daund - define the end nodes along Pune's main state highways. Below we describe the general characteristics of each corridor.

A. Shirur - Peri-urbanization along the eastern corridor has been largely driven by 3 MIDC sites along the Ghod River: Koreagon, Sanaswadi, and Ranjangaon. Many of the villagers we talked to along this corridor expressed desire to be employed by MIDC along with their CSR initiatives. Several industries along this MIDC corridor are chemical plants, making the relationship between the river, water supply, and waste responsibility a relevant topic.

B. Saswad - South of Pune city, Saswad's urbanization is driven by its proximity to Pune City and

its Taluka headquarters. Compared to the other corridors, Saswad has strong public transportation links with Pune city, hosting one of the largest bus depots and also includes the Pune railway station just a stone throw away. The ease of transit allows Saswad residents to have easy access to opportunities in Pune city while not having to pay Pune city rents. Conversations with Gram Panchayat villages near Saswad often involve annexation into the city, problems with municipal dumping and waste, and a diminishing association with agricultural practices. The educational opportunities are also abundant: There are a number of colleges in Saswad as well.

C. Khed - Khed is in the northern fringes of Pimpri Chinchwad, an industrial zone-turned city. Consequently, Khed, which was formerly rural, is now experiencing rapid urbanization from the planning of "Smart Industrial Parks" by MIDC, such as Kalyani with attractive fiscal benefits for corporations moving in. Two Automobile-driven MIDC Sites, Chakan and Talegaon, are also driving urbanization substantially in the Khed corridor.

D. Daund - Daund taluka is the only major urban area in a predominantly rural block. But despite being at the edges of Pune district, Daund has prominent connectivity with Pune because of the Daund Junction Railway, a major stop in the Mumbai - Pune - Wadi Railway. Consequently, migrants from within and outside Maharashtra can arrive in Daund as a transit point for work, as evidenced by higher reportings of floating populations.

The initial transect analysis revealed several discrepancies between online data and ground realities. Our initial conversations with 12 gram Panchayats helped us generate a more systematic and pointed questionnaire. Our key observations from the transects are as follows:

1. **Observed Peri-urban conditions compared with Census Towns definitions:** Referring back to the census town definition in chapter 1.5 on the Census of India context, we

were able to validate that there is indeed a discrepancy between what the census defined as a town, versus what should be considered a town. Overlapping the 3 conditions defined as a town demonstrates the declared towns, but sorely misses a number of places that are also expanding rapidly. In summer 2016, we proceeded to visit villages that are almost towns. Two of them were in the Pimpri Chinchwad area: Nigozhe and Dehu. On the ground, both villages exhibited strong peri-urban conditions - burgeoning population, unprecedented infrastructural growth, waste and resource issues; rapidly changing employment profiles, and decreased cultivation of agrarian land. When asking residents for Dehu Village, people responded in confusion. We were brought to a developed suburban neighborhood near an industrial zone, and residents no longer referred to Dehu as a village. It was very apparent that in contrast with its Census classification five years earlier, Dehu was no longer a village. This brief ground truthing exercise indicates how empirical data alone cannot fully reflect ground realities. It also indicates that that the census is conducted too infrequently given Pune's growth to provide an accurate baseline for Peri-Urban Planning.

2. **Peri-Urbanization is variegated and diffused**: When running along a transect corridor, where one may predict urbanization, it is not always as expected: Corridors along main highways (A) were much more developed than lateral transects (B) (Figure 6). Lateral transects often had many more small, landholding farmers rather than commercial activities. Even along highly developed highway corridors, as soon as one moves orthogonally onto side streets, it can instantly feel rural.

3. **Administrative boundaries are conflicting and unclear for Peri-Urban villages**: Villagers seemed to not have a straightforward understanding of which municipal bodies were in charge of administration and accountability in their region. Some believed that MIDC held jurisdiction, yet others believed Taluka officers were in charge. The confusion in

administrative lines emerged while sitting in a meeting between two Sarpanches and a representative from the Pune Zilla Parishad as mediator. The two villages had been warring over a reservoir water supply, which had been severely stunted by a private company that had begun siphoning from the lake. The villages felt powerless in being able to confront the company, so resorted to warring with the other village. They asked the Zilla Parishad to mediate, but the ZP also did not have a process for confronting private industries about their water usage. Despite having influence in villagers' minds, when speaking with various governing bodies, the MIDC, Pune Zilla Parishad, and other administrative bodies were not aware of each other's policies, presence, and agendas. As influences bleed across boundaries, governing bodies need to be as jointly collaborative as possible.

4. **Peri-Urban Villages had little contesting power in water conflicts:** Villages in downstream situations suffering from wastewater disposal from corporations expressed little ability to change their situation. Even villages that won in court for dumping grievances expressed that the corporation continued to dump in their water supply after winning the case. Peri-Urban Villages increasingly confront dynamics with industries, but accountability was hard to enforce.

The transect interviews enabled us to observe emerging patterns on the ground. This led to the construction of a questionnaire that enabled us to further refine the Peri-Urban definition. We were able to test quantifiable and comparative results through structured village interviews.

2. Village Questionnaire and Interview Methods and Results

Next, we sought to compare our initial mapping results and literature insights with ground comparisons. Census data needs to be tested and supplemented by Gram Panchayats' feedback. We created a sample size to identify local patterns, processes and concerns. We selected 30 peri-urban villages to interview based in part on their participation in the Jalswarajya-2 program, and also in part on a highway transect analysis conducted in winter 2016 (Figure 5). (Appendix I for questionnaire responses).

The questionnaire is structured in two phases: PeriUrban Causes and Peri Urban Effects (Figure 7). Six causes and effects were identified under each and explained in full below. Under each category, we created questions that sought to assess how Peri Urban causes and effects influenced water supply and sanitation issues. The topics included: water supply problems, water quality problems, wastewater effluents, solid waste, sanitation, access to amenities, real estate development, slum conditions, overcrowding, occupation change and unemployment.

causes

Occupational Switches

Villagers are disconnecting from the land to look for new opportunities; the transition from cultivators to laborers and the increase in marginal workers

Population Growth

Many periurban villages in Pune have seen 30% increase in population between 2011 and 2015, where many commute to the nearby cities for employment.

Changing Land Use

Real estate developers have increasing development interests especially near highways and railroads

Floating Populations

Increased temporal and migrant communities

Proximity to Rural Industry

Peripheral areas are often prime areas for industrial settlements and growth given its proximity to the city but expansive area, giving way to new dynamics

Is land use changing from rural to urban: 4 very fast; 3 somewhat fast; 2 slowly; 1 not at all

Is population growing: 4 very fast; 3 somewhat fast; 2 slowly; 1 not at all

Are urban jobs growing: 4 very fast; 3 somewhat fast; 2 slowly growing; 1 not at all.

Is demand for higher education 4. growing fast 3. somewhat fast 2. neutral 1. slow

Are migrants settling here: 4 very fast; 3 somewhat fast; 2 slowly; 1 not at all

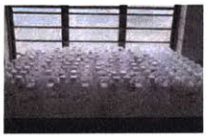
Is industry in this block growing 4 very fast; 3 fast; 2 not so fast; not at all? MIDC Beneficial to the community? 4. Very Beneficial 3. Beneficial 2. Not Benefcial 1. Harmful

Is water use increasing: 4 ve fast; 3 somewhat fast; 2 slowly; 1 not at all

effects

Water Competition

Due to an increase in population, corporations, and industrial use, water resources are tight and villagers have to negotiate water access



Waste Water Effluents

Villages experience mix contamination of drinking water and waste water not delineated, where environmental damage and pollution are acute

Overcrowding

Increased population means less permeable land, storm water issues, crowding, creating difficulties in infrastructure planning

Poor Access to Amenities

Many villages are geographically inaccessible to basic needs (schools, hospitals, banks, etc.).

Unemployment

The switch from rural to urban laborers is prominent as opportunities in the city and cost of living increase, and dwindling of cultivable land

Is monsoon water scarcity: increasing, decreasing, about the same?

Is water scarcity the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?

Is water pollution the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?

Is monsoon drainage the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?

Are slums the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?

Is overcrowding the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?

Is improved solid waste management the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?

Is access to closed sewers the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?

Is unemployment the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?

Figure 7. Peri-Urban causes and effects, associated questions

The following causes and effects have been described below:

Peri-Urban Causes

Water Competition - Due to an increase in population, corporations, and industrial use, water resources have become higher in demand and stakeholders increasingly engage in conversations around water uptake and use. How do Panchayats engage with one another to resolve water conflicts? How do private and industrial entities hold responsibility in providing water to nearby settlements?

Wastewater Effluents - Villages often experience mixed contamination of drinking and wastewater due to industrial or urban run-off. Increasing urbanization has also exacerbated pollution damage

Exurban Slums - Due to increased floating populations, migrants begin renting houses in villages. But if there is not enough housing capacity, they often start exurban settlements nearby

Overcrowding - Increased population means less permeable land, stormwater issues, crowding, which can pose problems in infrastructure planning

Poor access to amenities - Increase population necessitates greater amenities such as access to schools, hospitals, roads, and other resources

Unemployment - The dwindling of cultivable land along with shifts in modes of labor create a new set of employees

Peri-Urban Effects

Occupational Switches - Villagers are disconnecting from cultivation and subsistence and looking towards new laboring opportunities, resulting in an increase of marginal workers

Population Growth - Many Peri-urban villages in Pune have seen a 30%+ increase in population between 2011 and 2015, where many commute to the nearby cities for employment

Changing Land Use - Real estate developers have increasing development interests especially near highways and railroads

Floating Populations - Increased temporal and migrant communities coming from out of district and out of state, generally propelled by unsettlement in their home states

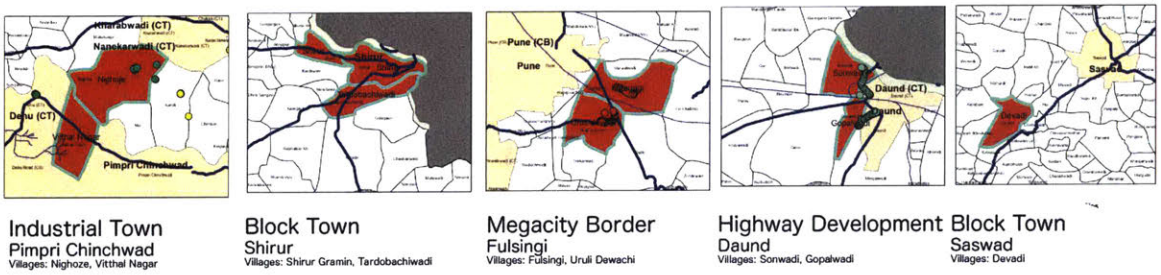
Proximity to Rural Industry - Peripheral areas that are often prime for industrial settlements and growth, given its appropriate distance to the city, yet affordable and developable land potential

Higher Water Demand - With increased household activities such as going to school or changes in lifestyle, households are demanding more water up to 90 - 150 LPCD

In addition to questions about data quality and rapid settlement change since 2011, we also wanted to know how Gram Panchayats ranked and perceived what their problems and solutions could be. In order to measure the magnitude of each process, Gram Panchayat members ranked these peri-urban issues on a scale of 1 - 7, the most relevant problem was ranked as 1 and least as 7 or "NA" (Figure 8). However, the discussions were widely open ended to assess which peri-urban factors were most salient and to unearth overlooked forces and outcomes of peri-urbanization.

Peri-Urban 4Type		Village	Water Supply	Water Quality	Waste Water Effluents	Slums	Overcrowding	Access to Amenities	Unemployment	Solid Waste	Sanitation	Alcohol	Sand Selling
Industrial	1	Vittal Nagar											
Industrial	2	Dehu Goan		6	1	1				1	7		
Industrial	3	Nigoje			1	1		4		2	1	6	
Industrial	4	Kulkori		2	7	6	NA			6	6		
Block Town	5	Shirur Gramin		1	6	6	NA	7	7	1	1		
Block Town	6	Tardobachiwari		1	1	3	NA	6	5	2	3	5	
Highway	7	Gopalwadi		6	6	3	NA	5	4	1		2	
Highway	8	Sonowari		4	1	2	NA	5	6	1		3	2
Megacity	9	UrliDevachi		2	2	1	NA	6	3	5	1	4	
Megacity	10	Fulsingi				1	NA				3	2	
BlockTown	11	Devevan Puri		1		6	NA	6	7	1	NA		
Highway	12	Junnar		1	2								
Highway	13	Maan Village		1	2								
Blocktown	14	Davadi											

Figure 8. List of villages interviewed, ranking top problems in villages, with 1 being the most severe issue and 7 being the mildest, and NA as not applicable



Industrial Town
Pimpri Chinchwad
Villages: Nighoze, Vitthal Nagar

Block Town
Shirur
Villages: Shirur Gramin, Tardobachiwadi

Megacity Border
Fulsingi
Villages: Fulsingi, Uruli Dewachi

Highway Development
Daund
Villages: Sonwadi, Gopalwadi

Block Town
Saswad
Villages: Devadi

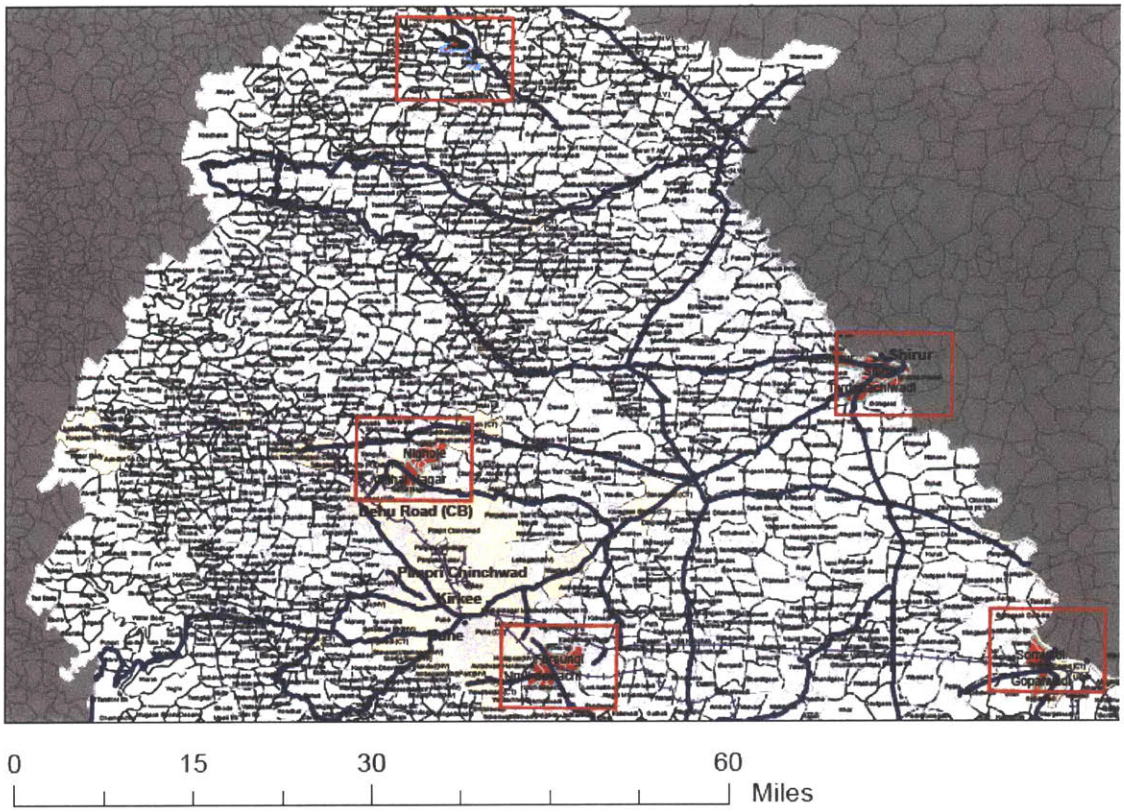


Figure 9. 2+ villages from each of the 4 peri-urban driving factors were selected for interviews

3. Major Learnings from Village interviews

Figure 10. Field Team in Village Interviews

While some village responses were anticipated, others altered our understanding of peri-urbanization, and of the initial mapping results. These results were discussed and critiqued in meetings with Pune Zilla Parishad. They include:

Drinking Water Source Protection and Wastewater Disposal: Wastewater and Drinking Source delineation emerged as the top priority across most peri-urban villages, as land holding farmers require water sources for farming as well as drinking. Waste dumping is often done near a drinking water source, and there is little enforcement of protections beyond an annual inspection of the source.

Figure 11. Photos from Field Work

Floating Populations: The significance of floating population was so huge that it demands a re-evaluation of how census data is calculated. Gram Panchayats heavily emphasized the inability to measure floating populations, which were sometimes as high as 30%.

They include migrants from other regions of India who take seasonal or permanent positions, particularly near industrial estates. Floating populations are not counted in the census. On

the other hand, our expectations of unemployment, overcrowding, and slum conditions were not as much of an issue as expected in peri-urban villages (as compared with Pune City).

The perception of slums and rental housing: The idea of a "slum," to our surprise, was not prevalent in peri-urban villages. Villagers also did not feel that overcrowding was an issue. In fact, many villagers saw the rising migrant population as an opportunity for additional housing income and new opportunities for infrastructure and water construction. The issue of "slums" and "overcrowding" may perhaps may just be an urban construct, as urbanites see their spaces being encroached upon. More prosperous villagers are constructing rental housing blocks with water and sanitation blocks. In rapidly urbanizing villages near industrial zones, such as Maan Gaon or Maan village, many villagers have begun replacing farm income with rental housing income. The scale of these local processes was unexpected, but prevalent.

Transitions in Jobs and Aspirations between Generations: Villagers reported occupational shifts from unskilled to skilled labor and from farm work to white-collared jobs, as well as the pursuit of higher degree diplomas. Many of younger generation seek to commute to larger block towns and cities for education and jobs. When asked the question, "Where does the village see itself in the next twenty years?" Many responses mentioned their aspirations to be near employment zones with jobs, English medium schools, colleges, hospitals, and clean drinking water. In over 90% of our responses around Pune, the older generation believed that the younger generation should be engaged in non-agrarian jobs. The only exception for when the younger generation should still continue being farmers is when there seems to be no other job, and when holding land could maintain a vital source of revenue.

A need for constant ground-up feedback and the critical role of community mobilizing organizations: Throughout village visits, the relationship that community mobilization groups such as STAPI have with villages is critical in resolving conflicts. Groups like STAPI dispatch a

group of community organizers on the ground to go door to door to collect critical metrics and information about each household. Beyond survey data, STAPI also provides integral tools towards consensus building. I sat in heated gram panchayat meetings discussing water schemes in Junnar moderated by the social community group STAPI. The meeting revealed discrepancies in MJP / ZP implementations versus need on the ground. MJP was suggesting the creation of a second well, but one village had wanted the current water source to be repaired and no schemes to be created. At the end of a 3 hour meeting, one village did not feel that their needs were attended to, and that the MJP officer had neglected their needs. Disgruntled villagers rushed to speak with STAPI officials after the meeting to voice their candid concerns. STAPI then relays the information back to the Zilla Parishad. The power dynamics in a group meeting between the villagers and MJP made it difficult for the villagers to voice their concerns or felt they were being listened to, and made them feel more comfortable to speak with STAPI. On the other hand, Zilla parishads revealed that implementation of water schemes by the ZP were often ill-informed and villagers were left with schemes that were not necessary or not targeted to the context. Moreover, government data on a habitation level remain limited and sparse. In the status quo, this leaves decision-making to arbitrary selection. As a result, access to resources for Gram Panchayats are based on arbitrary measures of proximity, social connections, rather than true need. There needs to be an avenue for unbiased and objective feedback between villagers and implementing organizations to circumvent political interests and disjointing planning.

4. NOTABLE VILLAGE CASE STUDIES

MIDC Influenced

Maan and Manjuri villages are situated in Hinjewadi, a former MIDC site that has now become a sprawling multi-phase zone including commercial and residential properties. Hinjewadi is one

of the most expansive "Smart city" initiatives in northern Pune taken from the Government of Maharashtra. It began in 1998 with Phase I 1998 (96 hectares), Phase II in 2004, Phase III in 2007, and there are three additional phases planned for IT Industries, Infosys, and biotech. These 2 villages are examples of villages that have undergone drastic transformation into towns in a matter of half a decade due to industry influence.

Within the land that MIDC acquired, Maan village is an "affected village". Affected villages have water, infrastructure, and other provisions by MIDC. Affected by this rapid urbanization, Maan village will take the Census Town status by 2017. We met with the Gram Panchayats of both villages along with Hinjewadi MIDC officials. They reported that Maan had a substantial leap in real estate prices pre and post MIDC set up: Prior to formation, their land was worth INR 70,000 per acre (~4000 sq meters). Post MIDC establishment, the land is now worth 5 crores per acre. Both villages experienced a tremendous influx in migrants. In 1998, there were 6,000 migrants. In 2011 - 8,200, 2016 - 15,000, comprising 30% of the total population of the 35,000 people in Maan. Moreover, the agrarian to urban job ratio is notably low: 1200 out of 8200 in the population are still farmers, indicating a real shift towards urban jobs. Naturally, many villagers have taken on leasing their properties for money in lieu of farming. The Gram Panchayats also report that prior to the formation of an IT park, there were no diploma holders. Now 2% have professional degrees, with the majority of the second generation pursuing higher-level studies in commerce and sciences, engineering, and management.

On water provisions, Maan and Manjuri were both receiving 70 LPCD. But post MIDC's collaboration, they are now getting 130 - 140 LPCD through piped water systems. The village also has its own source of water supply through river water, supplying 2.5 Crores per 1000 liters metered by water supply.

On the contrary, although Shirur is near an MIDC and its presence looms greatly in villagers' minds, MIDC's interactions with villages not under "affected status" are limited. Shirur Gramin's growth is characterized by a significant floating population, accounting for approximately 25% of the village's total population. It is surrounded by highway access, MIDC, and also Taluka headquarters. Shirur is a major access point for the Pandharpur pilgrimage, with about 50,000 people visiting per day.

Villagers often desire employment by MIDC, yet they are seldom employed because they lack the technical skills to work in MIDC. A select few MIDCs have CSR engagements for job skills training, but many do not engage with peripheral communities. Shirur village is an example of a village heavily influenced by MIDC's activities, yet it does not have MIDC's contributions because of MIDC's policy mandate.

Longer term migrants come to work at nearby sugarcane factories. On water supply, there are 900 connections out of 1200 households, and the remaining 300 have private borewells with no metering connections. Only 10% of people are getting water from March - June, while the other 90% have their own bores (or private tankers), due to less percolation. Villagers' long term aspirations include a large and clean hospital, road facilities and accessible, treated water, hospitals in Shirur Gramin, and professional degree colleges. Villagers have reported that MIDC is letting their liquid waste into the river and is mitigated by temporary treatments like chlorine tablets.

As villages under MIDC's "Affected Village" status, Maan and Manjuri villages receive generous support from MIDC on infrastructure and water provisions. But villages immediately outside MIDC such as Shirur are affected by MIDC's influences, but are often not granted the "affected" status. It would therefore be important to redefine the buffer for MIDC's influence, and to

redefine to what extent industries should be held accountable for the externalities they produce.

Megacity Influenced

The most seminal examples of the ills that Peri-Urban villages face are settlements that are flushed against a metropolis's borders. Fursungi embodies case in point a peri-urban village majorly influenced by a mega city's growth, but (for a long time) was not provided by the Pune Municipal Corporation. Fulsingi Village is on the border of Pune city and experiences rapid growth. In January 2016, Fulsingi's land acquisition is telling of a growing real estate market: More than 60% of the land is being sold and has been converted into residential properties, and 4000 - 5000 rooms are rented every year to influx villagers, with 1 month's rent approximately 3000 rupees. Part of Fulsingi has been separated and annexed into the city, while the rest remains a village. Panchayat members were eager to become annexed into the city, lauding the amenities PMC could provide such as piped water systems, transportation, and other amenities. However, Fulsingi has major waste water and sanitation issues both from its growing population and from Pune city. Solid waste has been openly dumped in the river from nearby industries.

Although Fulsingi was recently annexed in July 2017, Fulsingi long embodied issues that peripheral villages near megacities face with wastewater and sanitation. The Fulsingi Gram Panchayat have asked the Pune Municipal Corporation for an extension of piped sewer systems, but since Fulsingi did not fall under PMC's responsibility, they were unable to access vital amenities to accommodate their rapid growth. Looking for other resources, Fulsingi Gram Panchayats have also applied to be part of Jalswarajya 2 funding, but was rejected by JS2 due to being way above the population threshold for "rural eligibility," and the funding amount far surpassed what JS2 was able to offer. Fulsingi village embodies a troubling yet common peri-urban predicament: Peri-urban villages fall under neither rural or urban mandates, and

therefore suffer severe water and sanitation challenges by the influences of a nearby metropolis. Yet, they have no legitimacy in soliciting further support.

5. Maharashtra Industrial Development Corporation

Next, I sought perspective from MIDC Pune on their policy and planning process. MIDC has in many ways been responsible for driving urbanization in Pune historically and also present day. Pimpri Chinchwad, which has now officially fallen within the Pune Municipal Corporation's boundaries, was once an MIDC site hosting predominantly automotive industries. While MIDC begins with a starter kit for corporation set-up (water, infrastructure, low tax rates, etc.), MIDC sites have sprawled into other mixed uses for workers such as mixed retail and residential zones.

Today, the MIDC sites most rapidly expanding and transforming the rural fringe are Chakan, Hinjewadi, Kalyon, and Talegaon, sites east and north Pune respectively, where we conducted interviews. We spoke with senior MIDC managers, engineers, along with corporates addressing topics related to land, water and infrastructure planning, village interactions, and corporate social responsibility. I spoke with several senior members of MIDC at MIDC sites, and was given a number of maps regarding MIDC's expansion plans. The informants I interviewed are the following:

Mr. S.B. Patil, Pune Chief Officer
Mr. Sonje, Mumbai Chief Officer
Hinjoli Engineering Department
General Manager, Larsens & Tourbo, CSR Department

Mr. Pagrut, Deputy Engineer of Pune MIDC.

In the following sections, we begin to describe the policies and effects of MIDC on nearby villages on water supply and infrastructure planning, followed by recommendations for MIDC which may be integrated into the village planning process.

Land Acquisition Process

MIDC's planning process is driven by land acquisition and demand-based analysis. At times when the land is immediately acquired, people are interested in purchasing. The land gets deleted if it is not developed after purchase.

When MIDC establishes a site, MIDC becomes the landholder and sells their land for industrial activities only, not for residential or commercial uses. MIDC requires that land plots are connected with each other for multiple phase developments. Having multiple phase planning enables continuity between road networks and metered power. The process for planning is comprehensive within their sites: MIDC's site selection process is driven by 2 critical factors: water supply availability and land for multiple phase development. MIDC Zones are designed to have conditions for business growth: low taxes, low costs of operations, access to water and electricity, and other incentives. Then, they take a traffic survey from the nearest control points, connecting roads, then design capacity based on the Indian road concrete guidelines.

In planning any MIDC zone, consent is taken from villagers in MIDC acquired land, which MIDC refers to as "affected villages". MIDC has a process for negotiating with villagers on land acquisition, a process that could take between 2-4 years. Once a group of farmers are willing to give the land to MIDC, a land selection committee visits the area and identifies the land. If the committee finds the land suitable for infrastructure development, then the DAM committee

passes it as a proposal to a higher level committee who takes decisions and signals it as an industrial area. Once DAM confirms the land's potential, they look at the compensation and declare the reward to the villagers. Overall, villages that fall under MIDC's "affected land" policy benefited greatly from urban amenities provisions along with being able to receive land revenue for years to come. But villages that did not fall under "affected land" status, would be greatly affected by MIDC growth and not accounted for.

Villagers are compensated by the land's market price as determined by the government. Currently there is no proof for what fair market price is, but a process that MIDC reports is taken with the villagers and sarpanch. After selection of the MIDC site, villagers get a property tax per year in crores to the gram panchayat. Land is given at 4 cubic meters. If it is pollution affected, then the land is given at 2.5 cubic meter.

MIDC's term for lands that are directly in MIDC territory and are irrigable are called "Deleted lands". MIDC officials report that deleted lands are only 2-4% of the entire MIDC purchased land. 50% of the time villagers are not cultivating on deleted lands, before and after. It appears that farmers do not have a choice in giving up their land. Farmers who are resisting may go to court, where their requests usually are to delay the acquisition of the land or to receive additional compensation. The person of mediation is the district collector, as they talk and ensure that the farmers cooperate with MIDC. If farmers want more compensation, with the order of the court they will get more compensation. From the villagers' end, it did not appear that this was an unfair or unjust approach. Mr. Sonjay, Chief Deputy Engineer of Pune MIDC, was of the perspective that villagers who sell their land and receive property taxes - even if it is a small portion of the land -- receive handsome profits from the process.

Water Planning Process

MIDC planning is fundamentally premised on water availability supplied through pipelines. Although it is not MIDC's mandate, villages connected to MIDC pipelines benefit greatly in both water quantity and quality.

Industrial use compared to urban water usage is a meager 5% within Pune district. Sources between drinking water and irrigation are sanctioned by the irrigation department and are often mostly rainwater, surface water, or dams. The irrigation department will sanction amounts for industries, then they decide different schemes (Intake well, pipeline, water treatment, distribution network, etc.). MIDC believes that Gram Panchayats have a limited understanding of water engineering and supply, and that Gram Panchayats are not efficient in maintaining their water supplies. If a bill is not paid for, within 45 days, the pipelines are disconnected.

Water pipelines are planned in the following manner: MIDC first identifies the source and the optimal area for a distribution line around the area which they do not extend beyond. If villagers want to be connected to the water source, MIDC offers a pricing scheme for villagers (for drinking water and not irrigation):

The water pricing scheme is as follows:
Villagers' Rate: Ranging from 100 - 120 liter per capita per day average for MIDC supply source, 2 MLD per day, 3.75 rps per 1000 liters per person. For villages, it is subsidized at 4.5 rps per cubic meter.
Industrial Rate: 21 rps per 1000 liters, but can vary depending on industry.
Chemical industries: 25 cubic meters per hectare per day
Non chemical industry: 15 cubic meters per day. On the basis of water consumed, per cubic

meter, ranging for industrial purposes (average) 20 rps

Beyond MIDC, MJP also provides the scheduled rates (data provided by MJP Chakan):

Industrial: 31 rps / 1000 L

Villages: 7.30 / 1000 L for 400 industries.

MIDC receives INR 300 crores from villages in water revenue annually. The officials' perspectives of village interactions is often that MIDC is providing great benefits. They report that some villages can pay for water, yet most default. When villagers default, MIDC reduces and shuts off the water supply in 48 hours.

Waste Effluent and Pollution

A Comment Effluent Treatment Plant (CETP) is installed wherever chemical industries in MIDC zones are present. There are CETPs in Talegaon ad Kurkumbh. Some manufacturing companies will have CEPTs, such as Volkswagen, not dropping any wastewater outside. For the construction of the CETP, there is a subsidy rate (25%) to the industry for common facilities. The villages never pay for effluent systems.

Pollution accountability on corporates is enforced through the Municipal Pollution Control Board (MPCB) instead of MIDC. If industries violate pollution laws, MPCB may cut the water supply, the electricity supply, or industries forfeit their deposits.

Corporate Social Responsibility

In 2014, India became the first country that required corporations making revenues of more

than $105 M to give away 2% of their net profits to charity. As corporation set up is a fundamental influence in Peri-Urban areas, we sought to understand what they were spending on, and whether they were regional investments. We then conducted interviews with corporates in MIDC zones to understand their additional interactions with villagers. Our first interview was with Larsens & Tourbo, a large engineering conglomerate based in Chakan.

For Larsens & Tourbo, projects were spent on water schemes and infrastructure projects. Larsens & Tourbo made a concrete road to connect the village, the pipeline, water tank, and storage tank. At times CSR could include roads, medical camps, schools, medical facilities, engineering facilities. Discussions on Corporate Social Responsibility spending happens in the following manner: Firstly they prioritize school and plantations, books, the gram panchayat and MIDC association, presentation of each company will have a dialogue with the village governing body, and then decisions on CSR budgeting.

As mentioned in village interviews, MIDC provides coveted opportunities for employment. However, there exists a sharp disparity between blue collar skilled and white collared labor (<10% of villagers qualify for white collared skilled labor jobs). To address this issue, many of the corporates' CSR budgets are focused around skills training. MIDC has Industrial Training Centers for skilled labor for jobs such as welder, turner, filter, mechanical, for people with less than income of 10,000 rps per year, or 10th and 12th standard and need a job in the area. They are selected by these industries and are given training. There is then a hiring absorption process where a 3-6 month program is given to villagers for hiring within the 5-10 kilometer buffer that they live in.

6. Summary - Analysis and Discussion of Field Research Findings

Our field research findings demonstrate that the entities driving urbanization are varied and not just municipal actors as expected. The dynamism of the interviews round out attributes that static maps cannot inform us, such as a great floating population or the impact of MIDC or highway sites on nearby villages. We find that urbanization happens far away from metropolitan centers. Urbanization happens near block town headquarters, highways, and other economic development sites. We also find that villages provided by MIDC or other urban entities substantially outperform villages who are not within their mandate. There are exceptions to be considered from the villagers' reports: Interviews were taken while MIDC officials were present, and therefore Gram Panchayats had an incentive to present their interactions with MIDC to be favorable. There are several challenges in confirming this framework.

Identification and description of four peri-urban patterns: Throughout our interviews, the 4 peri-urban forces that frequently emerged as determinants of peri-urban growth were four distinctive patterns: industrial growth, corridor development, large city growth, and block town growth. Traditionally, it is assumed that peri-urban growth is mostly influenced by proximity to a nearby city. But transect analysis and field observations revealed that peri-urban phenomena can emerge far away from a city, under the influence of other stimuli. One of the most substantial forms of growth - industrial growth - is propelled by industrial settlements through actors such as the Maharashtra Industrial Complex (MIDC) and their corporations in fringe areas where land is available and still cheap. Corridor development occurs when a major highway or road is built, generating a real estate for proximal areas. Block Town development growth is caused by proximity to block administrative headquarters and markets.

Four driving processes were identified as the main drivers of urbanization due to the rapid transformation of nearby villages. The framework extends the mega city proximity assumption to include the following drivers:

Maharashtra Industrial Development Corporation: Developed in 1961, MIDC provides businesses with startup ingredients: Plot of land, water, infrastructure, and capital. They act as a special planning unit to industrial zones

Highways: The development of highways can have transformative effects on nearby communities, as it creates great access and infrastructural layouts for further real estate development.

Blocktowns: The administrative office of a blocktown often become concentrated places of power, where markets, bus stops, and other aspects grow out of

Megacities: Cities with over a million in population; their fringe is often a transformative edge that recreates the places it touches

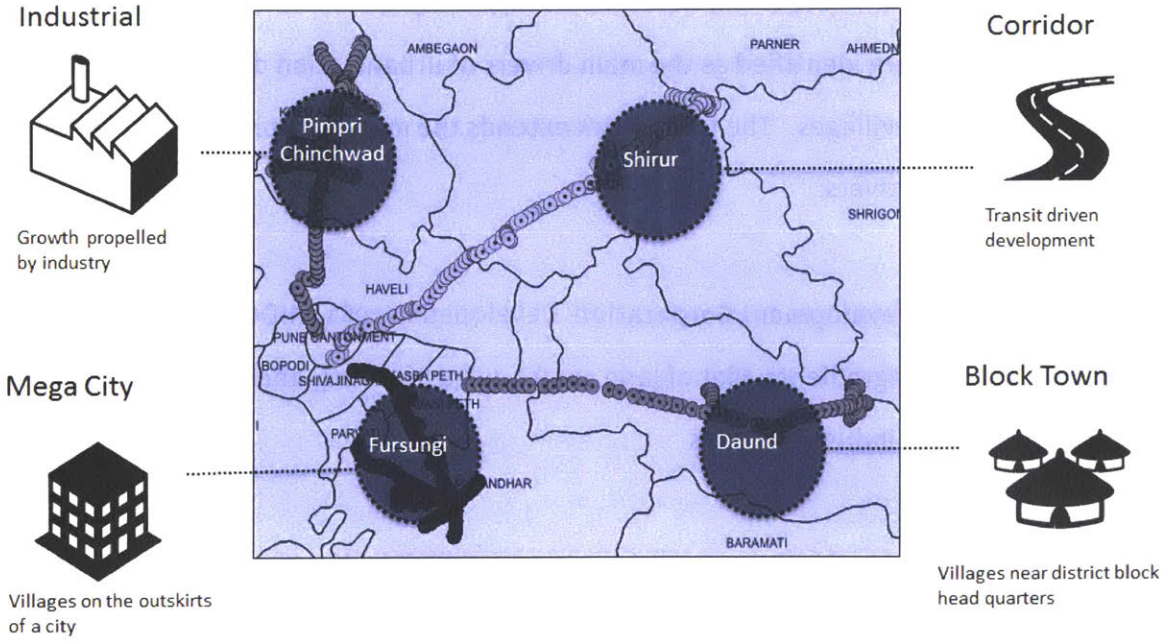


Figure 12. 4 Peri-Urban Driving Forces

There is a growing need to shed light on the wider geographic distribution and diffusion of Peri-Urban water and sanitation improvements. In this next chapter, we address this challenge using GIS methods that link three separate databases: the Census of India's Population data, the Census of India's Housing Amenities data, and the Ministry of Drinking Water and Sanitation IMIS drinking water supply database. We lay out the conceptual framework for mapping these population, water supply, sanitation amenities variables. Subsequent sections discuss the mapping results.

IV. MAPPING THE PERI-URBAN

1. Amenities and Settlement Size

We begin by using settlement size as a heuristic for peri-urban growth. Peri-urban or rurban settlements can be any size, but we posit here that they fall within ranges defined by the Census (Table 1). As mentioned in Chapter 1.5, the Census of India distinguishes rural villages from urban towns based on three socioeconomic variables: 1) population size greater than 5,000; 2) more than 75% of the male workforce engaged in non-agricultural occupations; and 3) population density greater than 400/km2. The last of these criteria is particularly problematic and is replaced in some analyses by a simple size criterion of greater than 10,000 (Denis and Marius-Gnanou, 2011). There are other distinctions between rural and urban settlement, and we explore several of them below, but we start with the Census population criteria as a first step. The database used is the 2011 Census Population Enumeration Data, which provide population totals by gender, caste, tribe, literacy, and occupation. There is also a designation of each village as either urban or rural.

a. Population and settlement classification. The 2011 Census Population Enumeration Data, provides population totals by gender, caste, tribe, literacy, and occupation. It designates each settlement as either urban or rural, based on the size classifications in table 1.

	Census of India Urban and Rural Settlement Classification
City	Class 1 (>100000)
	Class II (50000-99999)
	Class III (20000-49999)
	Class IV (10000-19000)
	Class V (5000-9999)
Town	Class VI (<5000)
	2000-4999
	1000-1999
Rural	500-99

Table 1: Classifications for City, Town, and Rural based on Settlement Sizes

Expected peri-urban village size: There is a population size overlap between Class VI towns that are less than 5,000 and rural villages that are larger than 5,000. Villages larger than 5,000 may be peri-urban while those in the 2,000-4,900 bracket may be peri-urbanizing. By these initial population size criteria alone, peri-urban conditions may be expected in villages that are in the 2,000 to 20,000 population size brackets.

Expected Rurban village size: Conversely, Class VI towns that have less than 5,000 may be functionally rurban. One would expect larger villages to have greater access to urban amenities thus be more likely to have rurban conditions. However, larger villages may also have more of the disamenities associated with peri-urbanization. With these considerations in mind, we expect villages in population brackets between 1,000 and 10,000 to include rurban villages. Figure 2 maps village size patterns in the 1,000 to 20,000 size range that are expected to be associated with peri-urban or rurban settlement. The main observation from this map is 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.

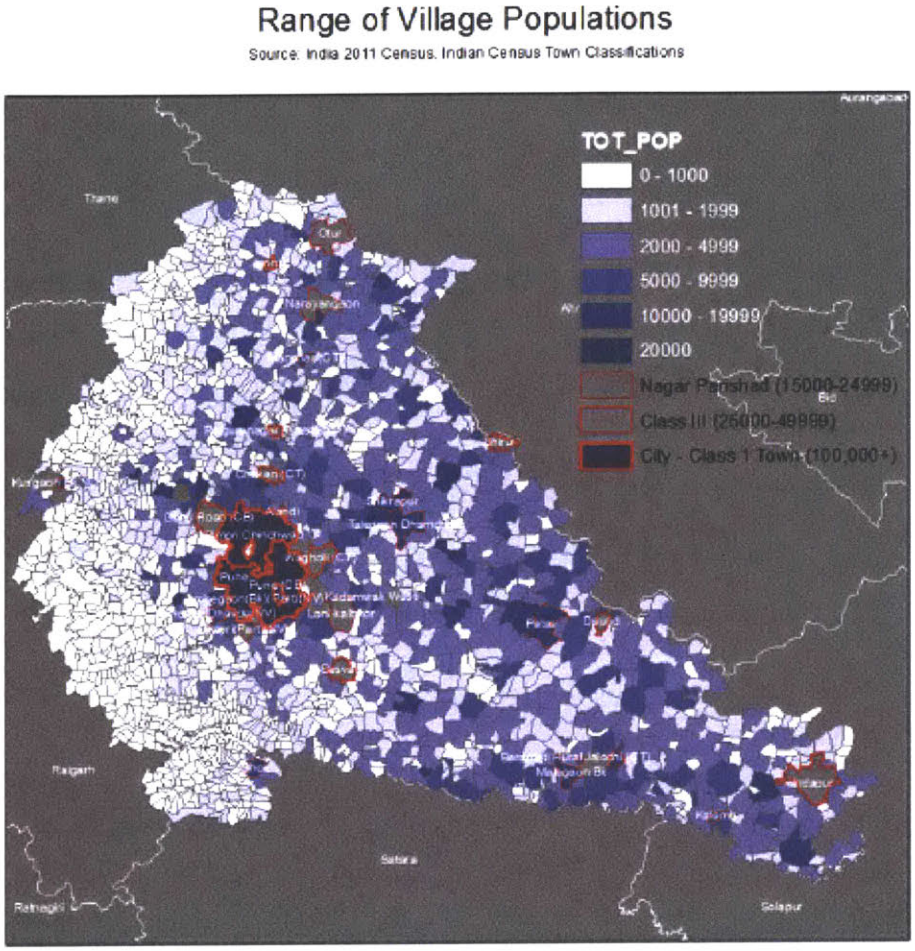


Figure 13: Population in the rurban to peri-urban size range (1,000 to 20,000)

b. Village Water Supply and Sanitation (WSS) Services. Census Housing and Amenities tables report key water and sanitation variables at the village level. Peri-urban areas are expected to have water and sanitation problems while rurban settlements are expected to have high levels of water supply and sanitation. Figure 3 maps a key set of water and sanitation variables in the Census.

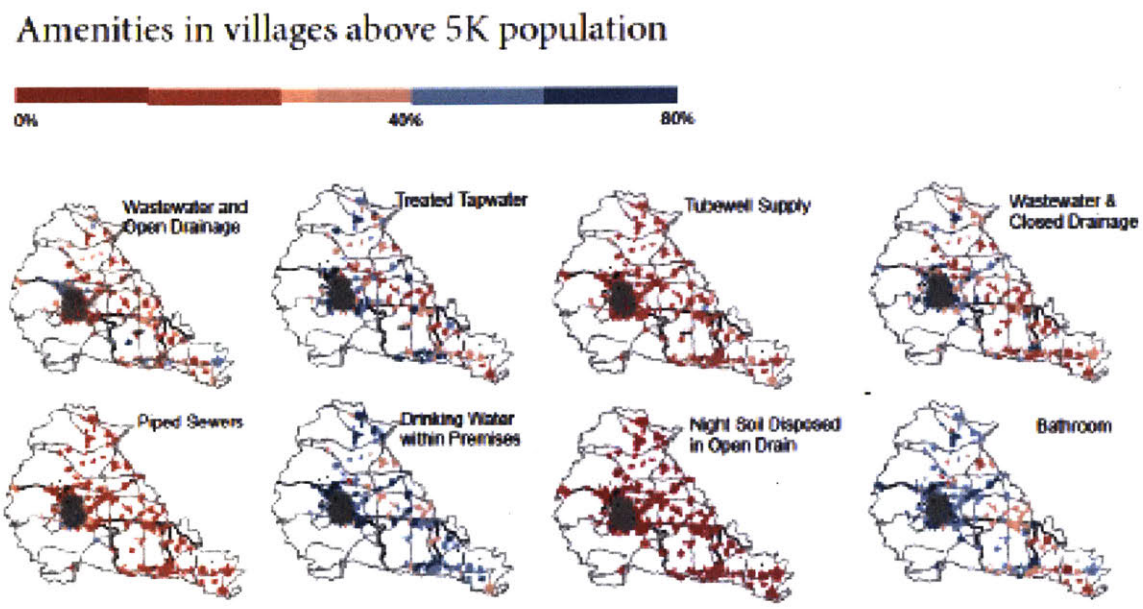


Figure 14. 8 amenity variables mapped for villages above 5000 in population

1. **Water supply amenities:** Village water supply amenities include drinking water within premises, treated tap water, and tubewells -- all of which 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. O'Reilly and Dhanju (2015) have shown that piped water from public standpipes benefits the elite in northern Rajasthan. Pune district has a different system of elevated storage reservoirs that supply distribution lines throughout a village. Although they reach a majority they not reach the poorest and most remote habitations. 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 pre-monsoon period from March to June, they are supplemented by Tubewells that draw on deeper supplies for drinking water and irrigation, and these too are increasingly depleted (Birkenholtz, 2015).

2. **Household sanitation amenities:** Sanitation amenities include improved pit latrines, bathrooms, and septic tanks. The most basic type of safe sanitation is the improved pit latrine. It is also a key component in the national Swachh Bharat Mission to eliminate open defecation. Interestingly, improved pit latrines are negatively correlated with population size. It has 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, are positively correlated with settlement size and reflect increasing sanitation standards associated with orderly peri-urban development. The majority of peri-urban villages, and many smaller rural villages, have a high proportion of bathrooms.

Septic tanks are often adopted when indoor water supply, toilet, and bathroom construction lead to increased water use and wastewater flow. As expected, peri-urban villages have the highest percentage of septic tanks (40% to 80%), though these become problematic in high density settlements.

3. **Sewerage and drainage conditions:** Three closely correlated sewerage variables were selected for visualization: night soil disposed in open drains, piped sewer coverage, and wastewater connected to closed drains. As in the previous sections, we proceed from the most basic amenity to the most advanced. The more advanced system of piped sewers is a peri-urban type of infrastructure employed in some areas around Pune City. Most peri-urban villages around Pune City have high proportions of both open drains and piped sewers, i.e., undisciplined and disciplined development. A small number of outlying rural villages with piped sewers are good candidates for study as potential Peri-Urban places. The most advanced set of sewerage amenities are those that discharge wastewater into closed drains. This technology also has a peri-urban spatial pattern, albeit one that follows some of the major

highways and industrial areas, as well as major city and town peripheries. However, not all of the larger villages have closed drainage.

4. **Mapping a weakly correlated variable:** While closed drainage is positively correlated with village size, and no drainage is negatively correlated, open drainage is weakly correlated with village size. Large and small villages outside Pune City have open drains. Peri-urban villages along major highways and industrial areas also have this practice, though they also have a higher proportion of closed drains. This mixed spatial distribution of open drainage exemplifies one of the challenges of visualizing peri-urban environmental conditions.

5. **Summary of Water and Sanitation Amenities Maps:** These eight maps of water and sanitation amenities begin to help us visualize the diverse patterns of peri-urban water and sanitation conditions on a district scale in Maharashtra. They indicate positive and negative aspects of peri-urban development. Overall, they support a positive model of peri-urban development in which larger villages have greater amenities. They also indicate that larger villages are more likely to be rurban than smaller villages. However, some weak correlation coefficients indicate sanitation problems that are prevalent across village sizes, e.g., open drainage, which are present in large as well as small villages. Comparing these maps also suggests that peri-urban areas have increasingly sanitary indoor environments and increasingly unsanitary outdoor environments. They indicate improved toilet and bathroom facilities and piped water systems to household taps, offset by continued reliance on open drainage.

6. **Charting Water and Sanitation Amenities by Settlement Size:** We chart several of these water and sanitation variables by Census settlement size classification and observe three important patterns (figure 4). First, as noted above, amenities generally increase with settlement size. Second, "drinking water away within premises" shows a pattern of adverse

conditions in the smallest towns, with better conditions in large villages. They are also more likely to have open drains or no wastewater drainage. These adverse conditions in the smallest Census towns indicate negative peri-urban conditions. Finally, the chart of open wastewater drainage graphically displays the weak correlation between that problematic variable and settlement size.

GIS analysis of water and sanitation problems and amenities

Peri-urban areas are widely perceived as having sanitation problems while rurban settlements are perceived as places with high levels of sanitation. To assess these perceptions, we analyzed and mapped water supply and sanitation (WSS) variables compiled in the Census of India's Houselisting and Housing database. These variables range from house types to building materials, utilities, and communications, as well as water and sanitation amenities. The categories of water supply and sanitation amenities include: source of drinking water (tap, open well, tubewell); location of drinking water (within, near, away from the premises); wastewater connections (closed, open, or no drainage); and toilet facilities.

b. Mapping Village Water Supply and Sanitation (WSS) Amenities: As discussed above, the Census of India tracks a broad list of water and sanitation amenities. Our objective is to visualize how these amenities vary with population size and geographic location to highlight where amenities are available or not. This enables district water planners to see which areas need additional attention and which may stand as models for others.

The nine variables selected in the correlation analysis represent a good mix of water supply (#1-3), household sanitation (#4-6), and wastewater drainage (#7-9) conditions. Amenity levels are

mapped on a blue scale at 20% intervals with the 0-20% interval displayed in white. Map symbols for larger villages and towns are:

- Bright Red Lineweight: Declared Census Town by the Government of India
- Darker Red Lineweight: Nagar Parishad (15,000-24,999 in population)
- Burgundy Lineweight: Rural V (10,000-14,999 in population)

1. Water supply amenities

The three village water supply variables mapped are tubewell supply, treated tap water, and drinking water within premises (Figures 7-9). Historically, villages in this region relied upon dug wells excavated in basaltic hard rock terrain. Dug wells recharge during the monsoon and supply water through the winter months, but they often go dry during pre-monsoon period from March to June. From the mid-20th century onwards, tubewells have drawn upon deeper supplies both for drinking water and irrigation. Domestic water users have first priority on surface water reservoir supplies. Access to tubewells can thus be an indicator of more reliable supplies. Figure 15 indicates a somewhat peri-urban pattern of tubewell access, with a significant number of high access villages in the immediate periphery of Pune city, along the highways east to the block town of Daund and northeast to the block town of Shirur. However, many of the villages with high tubewell access have smaller population size, which suggests that Tubewells are constructed as much for irrigation purposes in rural areas (e.g., for sugarcane) as for drinking water purposes.

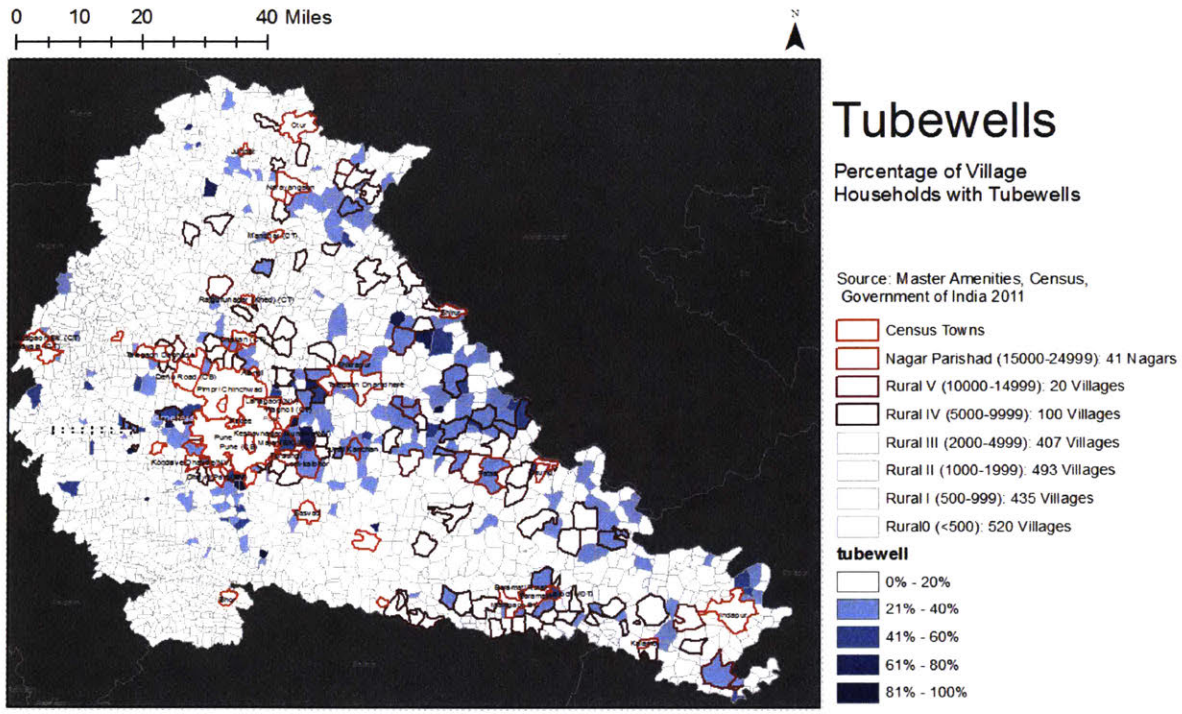


Figure 15. Tubewell water supply

A second indicator of improved water supply is the percentage of villagers who receive treated tap water. Most rural drinking water is untreated. An increasing number of villagers have point of use treatment (e.g., household filters or even reverse osmosis units), but the most developed villages are installing water filtration, flocculation, and disinfection systems at their elevated storage reservoirs, prior to distribution. Figure 8 indicates that this amenity is found in cities, larger towns, and some but not many of the larger villages. It also occurs in a fascinating array of small villages in the western and southern hills of Pune district. Some of these may be Peri-Urban villages or villages adversely affected by fluoride or dissolved solids.

Supplying drinking water to individual homes is a major trend in Maharashtra and other states. Figure 9 indicates the proportion of households with drinking water access within the premises, and it is highest in all four types of peri-urban development, from Pune City radiating

out along major highways to industrial areas and block towns. It is also higher in the villages of central and eastern Pune District than those in the western hills.

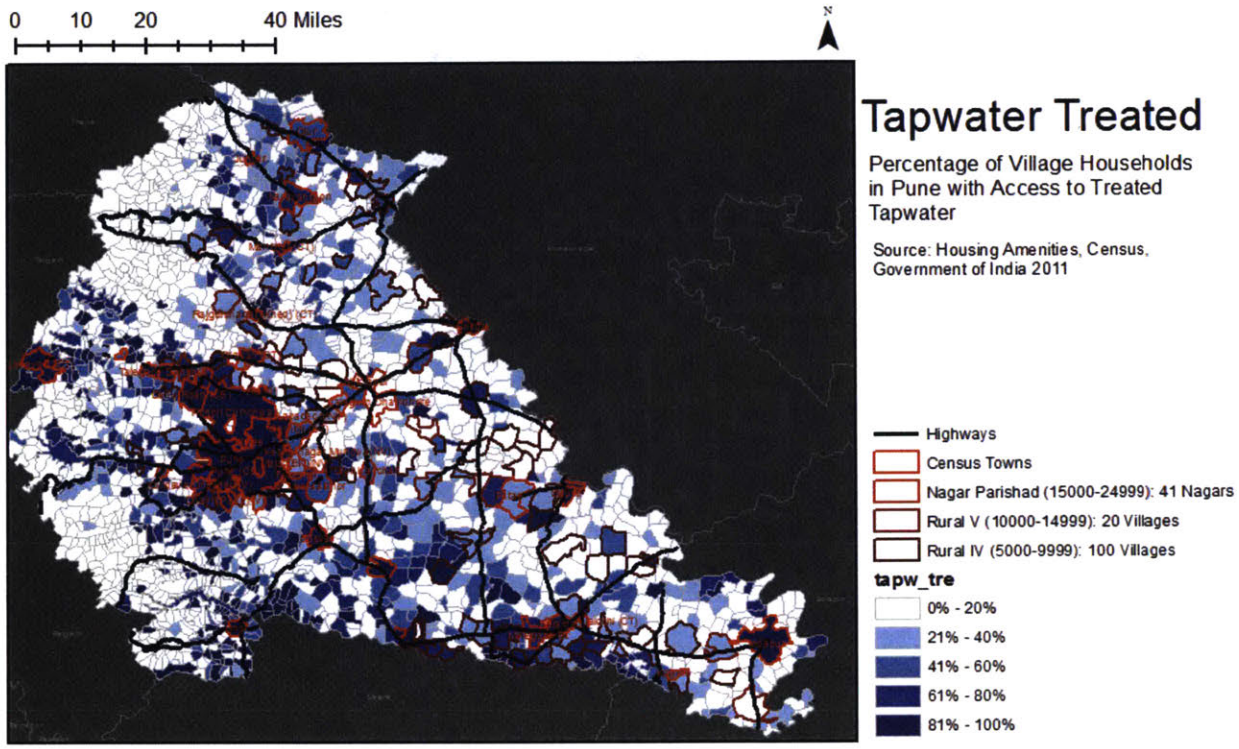


Figure 16: Tap water treated

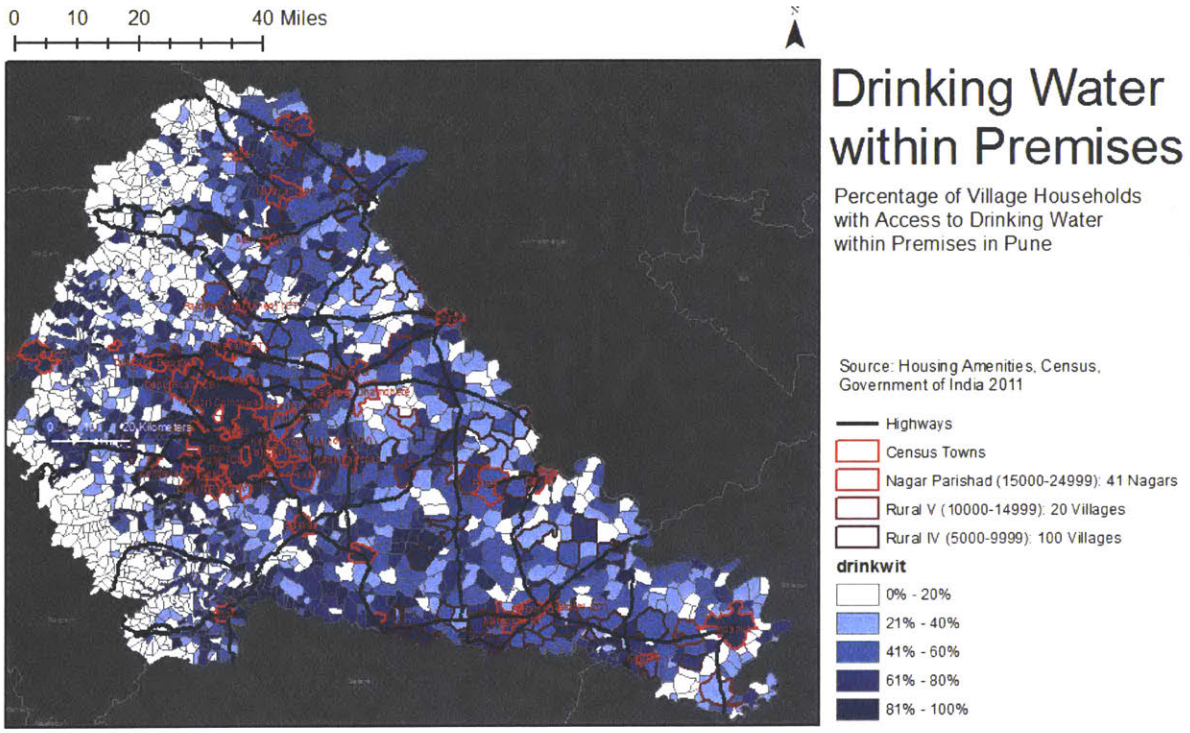


Figure 17. Access to drinking water within premises

2. Household sanitation amenities.

The three household sanitation amenities variables selected for mapping are the use of improved pit latrines, indoor bathrooms, and septic tanks, which are discussed below (figures 18 - 20). The most basic type of safe sanitation is the improved pit latrine. It is a key component in the national Swachh Bharat Mission to eliminate open defecation. Access to improved pit latrines is pervasive in the least densely populated areas, and not in larger nagar parishads or census towns (Figure 10). This makes sense because as population increases outdoor pit latrines are replaced by other forms of improved toilets and sanitary wastewater disposal.

Construction of indoor bathrooms indicates increasing household sanitation standards associated with rurban and orderly peri-urban development (figure 12). They include bathing as

well as toilet facilities. The majority of peri-urban villages and many smaller rural villages have a high proportion of indoor bathrooms. In smaller households, outdoor latrines are preferred due to space constraints and to maintain indoor sanitation. But as house size increases a clean indoor bathroom becomes a source of status as well as convenience.

Septic tanks are a good example of the types of structures adopted when indoor water supply, toilet, and bathroom construction are improved. Increased water supply is required for indoor flush toilets, in contrast with the seepage and composting methods of two-pit latrines. The increased sanitary wastewater produced by the home is ideally collected in septic tanks to settle out solids and seep liquids into the soil; excess wastewater is discharged into a septic field or sewer. As expected, peri-urban villages have the highest percentage of septic tanks (40% to 80%). As can be seen in figure 19, however, not all large villages have adopted septic tanks, and many small villages have. The fact that there is a lower percentage of septic tanks than bathrooms further indicates that outdoor wastewater disposal is or will be a serious problem, particularly in peri-urban areas. Comparing bathroom and septic tank maps leads us to envision that peri-urban areas may have increasingly sanitary indoor environments but increasingly unsanitary outdoor environments.

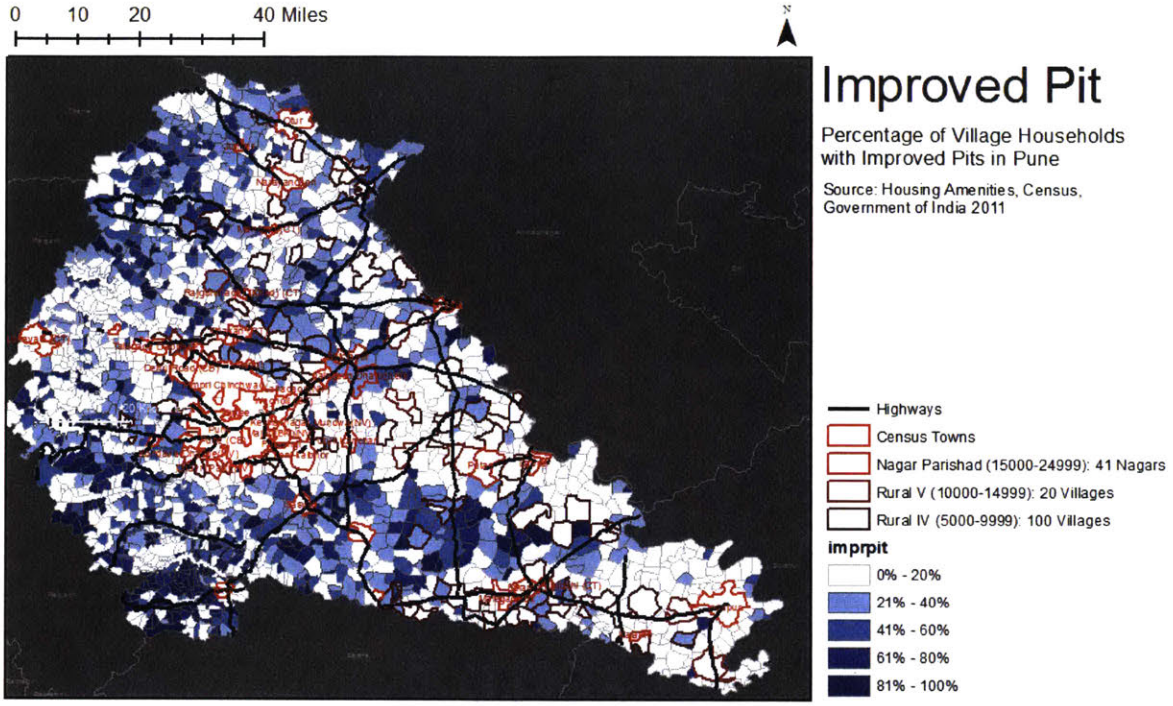


Figure 18. Percentage of Village Households with Improved Pit Latrines

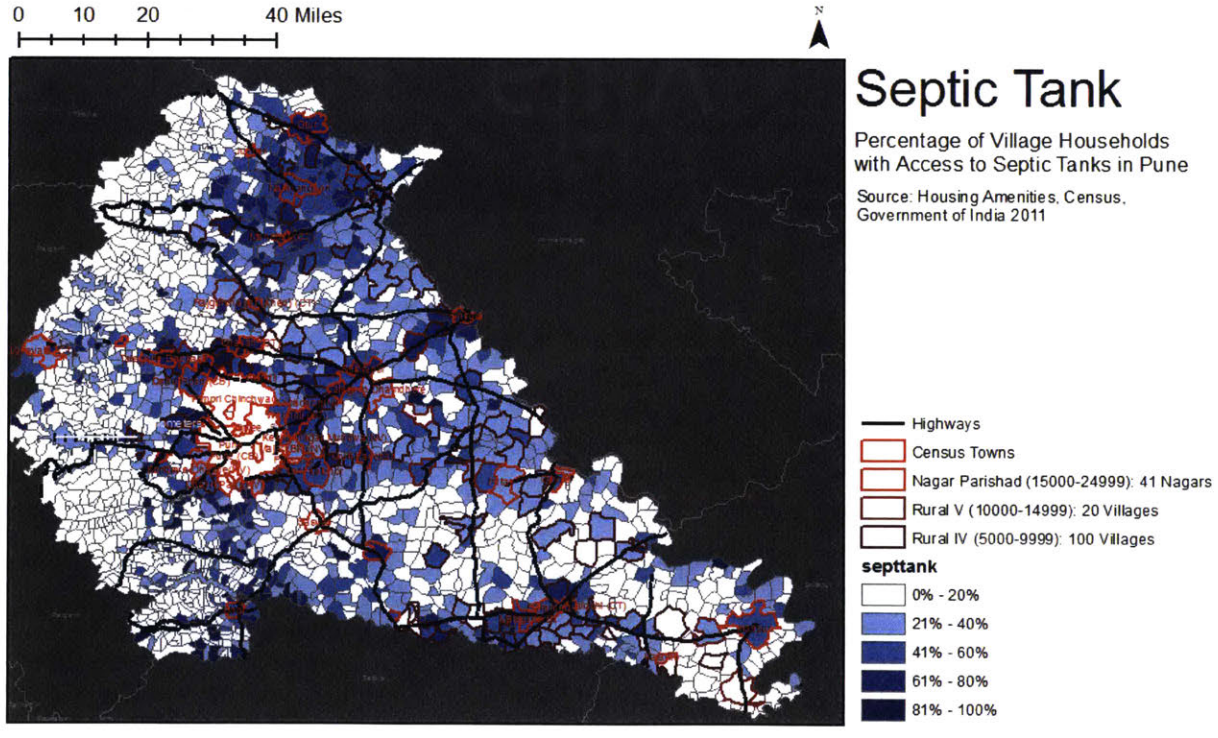


Figure 19. Use of Septic Tanks.

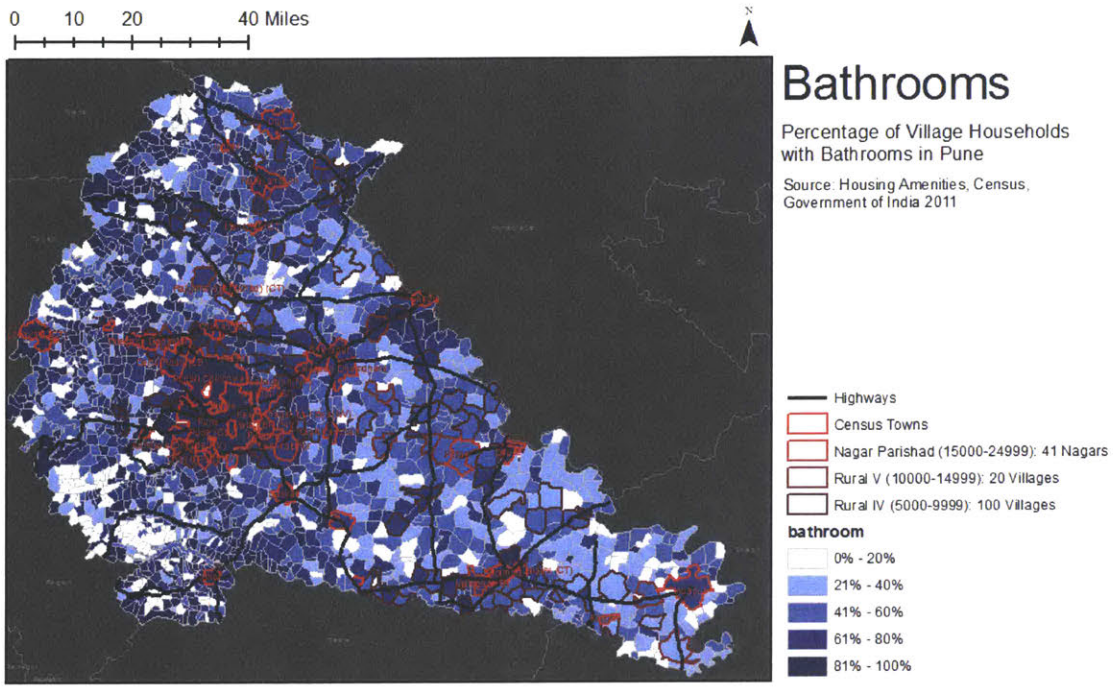


Figure 20. Percentage of village households with access to bathrooms.

3. Sewerage and drainage conditions

Three closely correlated sewerage variables were selected for visualization: night soil disposed in open drains, piped sewer coverage, and wastewater connected to closed drains (figures 21-23). As in the previous sections, we proceed from the most basic amenity to the most advanced. Night soil disposed in open drains occurs in areas where single-pit latrines become full, manual scavenging is still practiced (even though illegal), or there are no sanitary sewers. Although it is an unsanitary practice, open sanitary drains are still used to improve sanitation in and around the household. Figure 21 indicates limited disposal of night soil in open drains with villages

that do have this practice operating in the 0 to 20% range. A significant proportion of large villages are among those that dispose of night soil in open drains outside Pune City.
At the same time, the more advanced system of piped sewers is a peri-urban type of infrastructure employed in the vicinity of Pune City (Figure 14). The small number of outlying rural villages with piped sewers are good candidates for study as potential rurban places. Peri-urban villages around Pune City thus have high proportions of both open drains and piped sewers, i.e., undisciplined and disciplined development. Smaller rural villages, by contrast, are often categorized as having no drainage, which although literally incorrect bespeaks a lack of well-defined drainage facilities.

The most advanced set of sewerage amenities are those that discharge wastewater into closed drains (Figure 15). This technology also has a peri-urban spatial pattern, albeit one that follows some of the major highways and industrial areas, as well as major city and town peripheries. Interestingly, not all of the larger villages have closed drainage, and some of the smaller villages just beyond peri-urban growth areas do have closed drains. It is also noteworthy that villages that have closed drains average 40-60%, rather than full coverage.

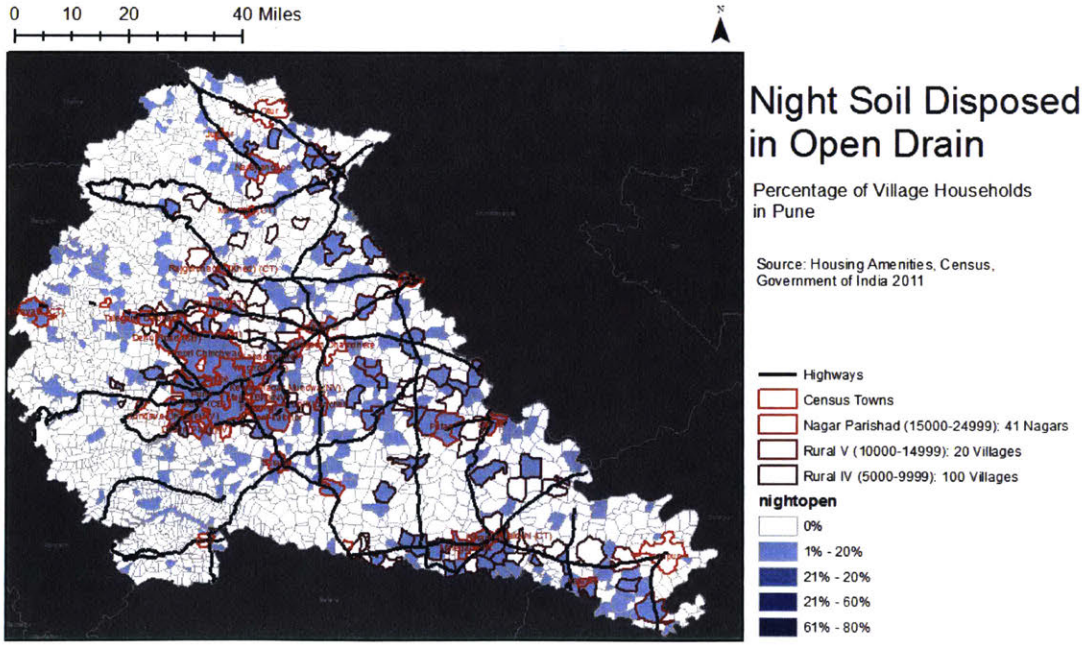


Figure 21. Night soil disposed in open drain does not exceed 20%

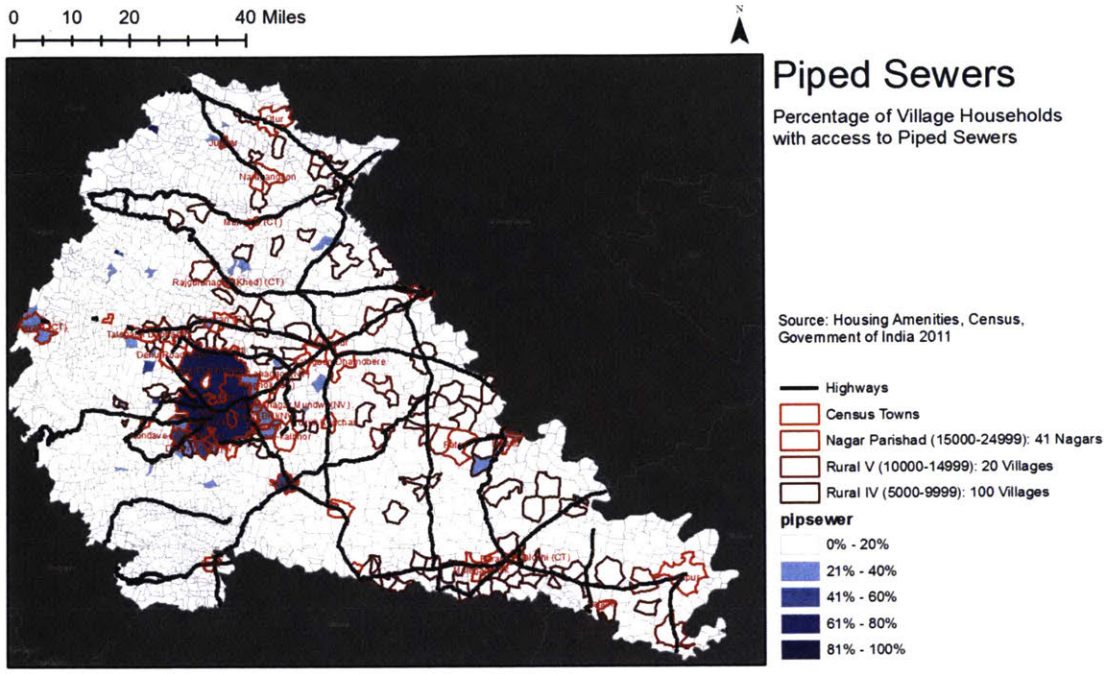


Figure 22: Percentage of village with piped sewer coverage.

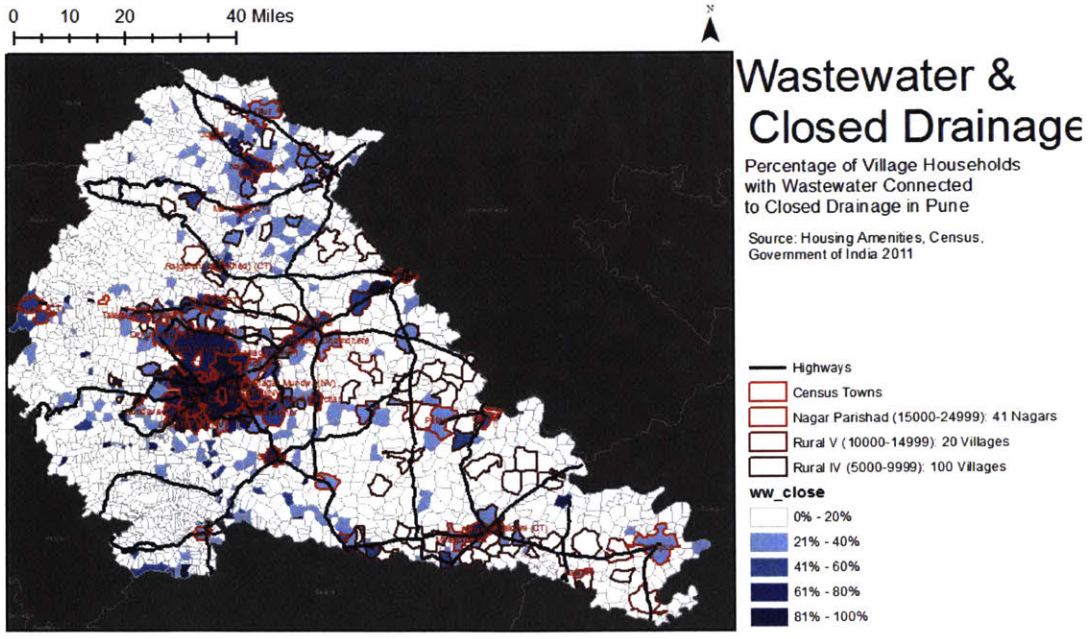


Figure 23. Wastewater discharged into closed drains

4. Mapping a weakly correlated variable.

While closed drainage is strongly positively correlated with village size, and no drainage is strongly negatively correlated, wastewater disposal in open drainage was weakly correlated with village size (Figure 24). This is surprising because night soil deposited in open drains is positively correlated with village size (Figure 21). The difference is that the frequency of night soil disposal in this manner is low even in large villages, while the prevalence of open wastewater drains by themselves is high in large and small villages. This is confirmed by direct observation. What is interesting in figure 21 is that large and small villages outside Pune City have open drains. Villages along major highways and industrial areas also have this practice, but they also have a higher proportion of closed drains. This mixed spatial distribution of open drainage exemplifies the challenges of visualizing peri-urban environmental conditions.

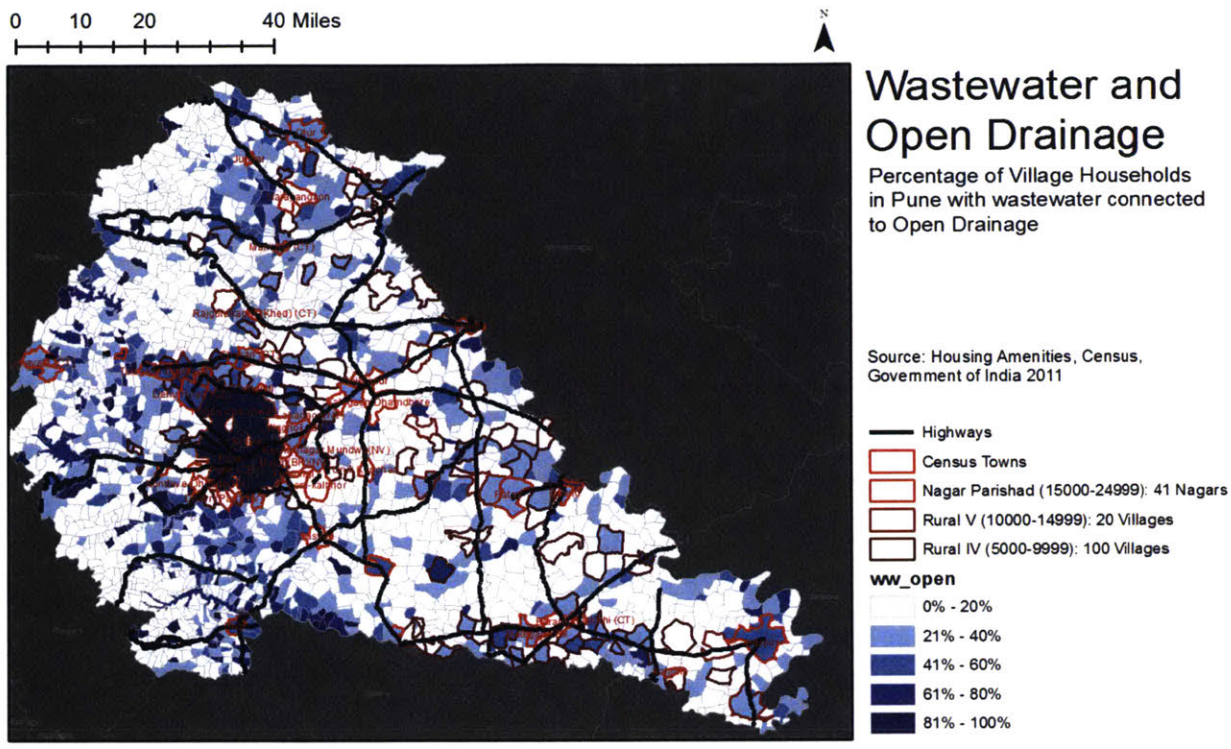


Figure 24. Wastewater disposal into and open drains

5. Summary of Water and Sanitation Amenities Maps

These ten maps of water and sanitation amenities, analyzed by village size, help visualize the clear and mixed patterns of peri-urban conditions on a district scale in Maharashtra. They illustrate how and where the positive and negative models of peri-urban development have occurred. Overall, they indicate major advances in toilet and bathroom facilities, and piped water systems to household taps. These trends resonate with both peri-urban and rurban models of development. In the peri-urban context, open-drainage is an issue that is pervasive across on settlement sizes. Further analysis of the levels and reliability of water supply service

is needed to complement this parsing out of the types and standards of toilet and drainage facilities.

2. Rural Amenities, Urban Amenities, Transitional Amenities, and Disamenities

Thus far, the work has been a nose dive specifically for each amenity. To further refine the definition of Peri-Urban, we want to look at how these amenities are affected by settlement size in relationship with one another. 15 amenities were selected to be analyzed together representing 3 categories: drinking water, sewage, and drainage. These amenities were chosen based on their correlation strength with settlement size, along with relevance to the JS2 objectives. Based on 2001 census classification of settlement sizes, amenity provision is defined by the percentage of households with or without the amenity. We then chart this percentage against the classes and categories of settlement size (Table 2). Understanding which amenities are accessible at certain settlement sizes is a starting step to knowing where there might be need yet not enough provision.

Variable Names in Amenities She	India Census
Tap Water Treated	Tapw_tre
Tap Water Untreated	Tapw_u
Drinking Water within Premises	drinkwit
Total Household Latrines	tothhlat
Piped Sewer	pipsewer
Bathroom	bathroom
Wastewater Closed	ww_close
No Latrine	tot_no_lat
No Bathroom	no_bat
Drinking Far Away	drinkaway
No Wastewater Drainage	ww_no
Uncovered Well	uncov_well
Hand Pump	handpump
Tubewell	tubewell
Improved Pit	imp_pit

Table 2. Amenities List from 2011 India Census

1. Selecting and Averaging Amenities

We first averaged drinking water amenities, and urban sanitation amenities as a whole and chart them across settlement sizes (Table 3). We also created created averages for rural and transitional amenities.

		Drinking Water Sources							
		1	2	4	5	6	7	12	13
	Pune Settlement Sizes	Tapwater Treate	Tapwater Untrea	Uncovered Well	Hand Pump	Tubewell	Drinking within F	Drinking Nearby	Drinking Away
City	Class 1 (>100000)	97.25	0.75	0.10	0.10	0.70	89.05	9.80	1.20
	Class II (50000-99999)	86.67	8.87	0.68	0.30	1.60	82.42	14.47	3.13
	Class III (20000-49999)	76.44	3.97	5.69	1.23	9.85	77.75	16.62	5.66
	Class IV (10000-19000)	54.57	13.59	9.09	5.32	14.04	71.99	19.39	8.63
	Class V (5000-9999)	40.20	13.20	19.45	8.40	14.73	59.58	28.42	12.00
Town	Class VI (<5000)	26.53	18.72	25.00	12.25	6.50	39.71	38.45	20.58
	2000-4999	31.16	15.27	26.99	10.93	10.87	51.04	33.42	15.54
	1000-1999	27.67	17.32	28.20	13.45	7.70	43.57	36.79	19.64
Rural	500-99	18.84	21.24	26.06	12.32	2.87	24.71	47.80	27.49

Table 3. Averages for Drinking Water Amenities in India 2011 Census

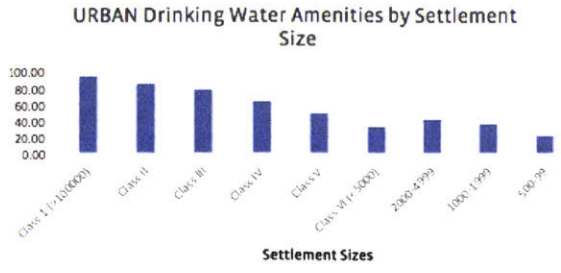
8	9	10	11
Sanitation			
Urban Amenity	Urban Amenity	Transitional Amenity	Transitional Amenity
Total Household Latrines	Piped Sewer	Septic tanks	Improved Pit
81.85	69.80	8.50	1.15
77.18	36.37	38.15	0.97
79.02	22.79	49.14	4.31
72.16	15.27	45.94	8.51
63.85	6.70	42.62	12.30
56.13	1.86	22.41	29.42
55.11	2.36	33.35	17.37
58.67	2.03	26.33	28.06
57.53	1.52	10.59	42.32
53.44	1.84	20.39	28.78

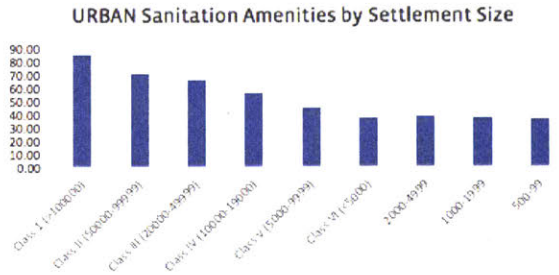
Table 4. Amenities comprising the sanitation score

12	13	14	15
Drainage			
Disamenity	Urban Amenity	Transitional Amenity	Disamenity
No Bathroom	Waste Water Closed	Waste Water Opened	No waste Water Drainage
2.50	87.60	8.80	3.60
3.48	71.12	21.55	7.30
6.67	64.88	16.50	18.63
10.83	43.52	24.74	31.75
16.01	24.71	23.67	51.62
18.97	7.77	20.50	70.48
19.50	12.79	22.17	65.04
20.24	7.66	20.16	72.18
19.44	4.44	19.33	76.23
20.59	7.04	18.08	74.19

Table 5. Amenities comprising the drainage score

Interesting enough, there is a consistent anomaly that happens at the 2000 - 4999 settlement size (Figure 25). To understand if this holds true for each amenity, we invert settlement size onto the x axis, and amenity provision as the dependent variable.





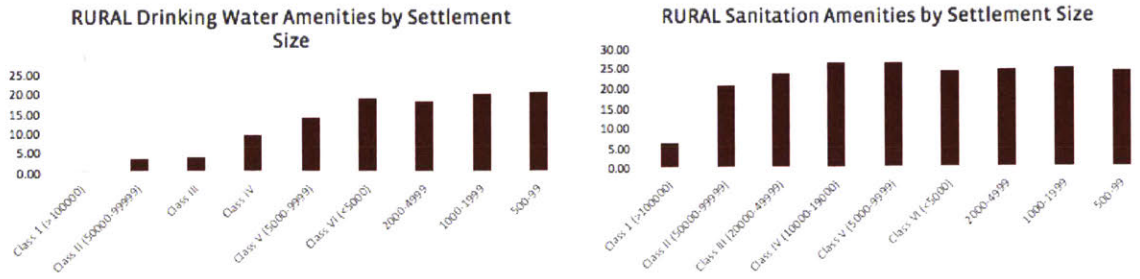


Figure 25. Sum of all variables for rural amenities by settlement size

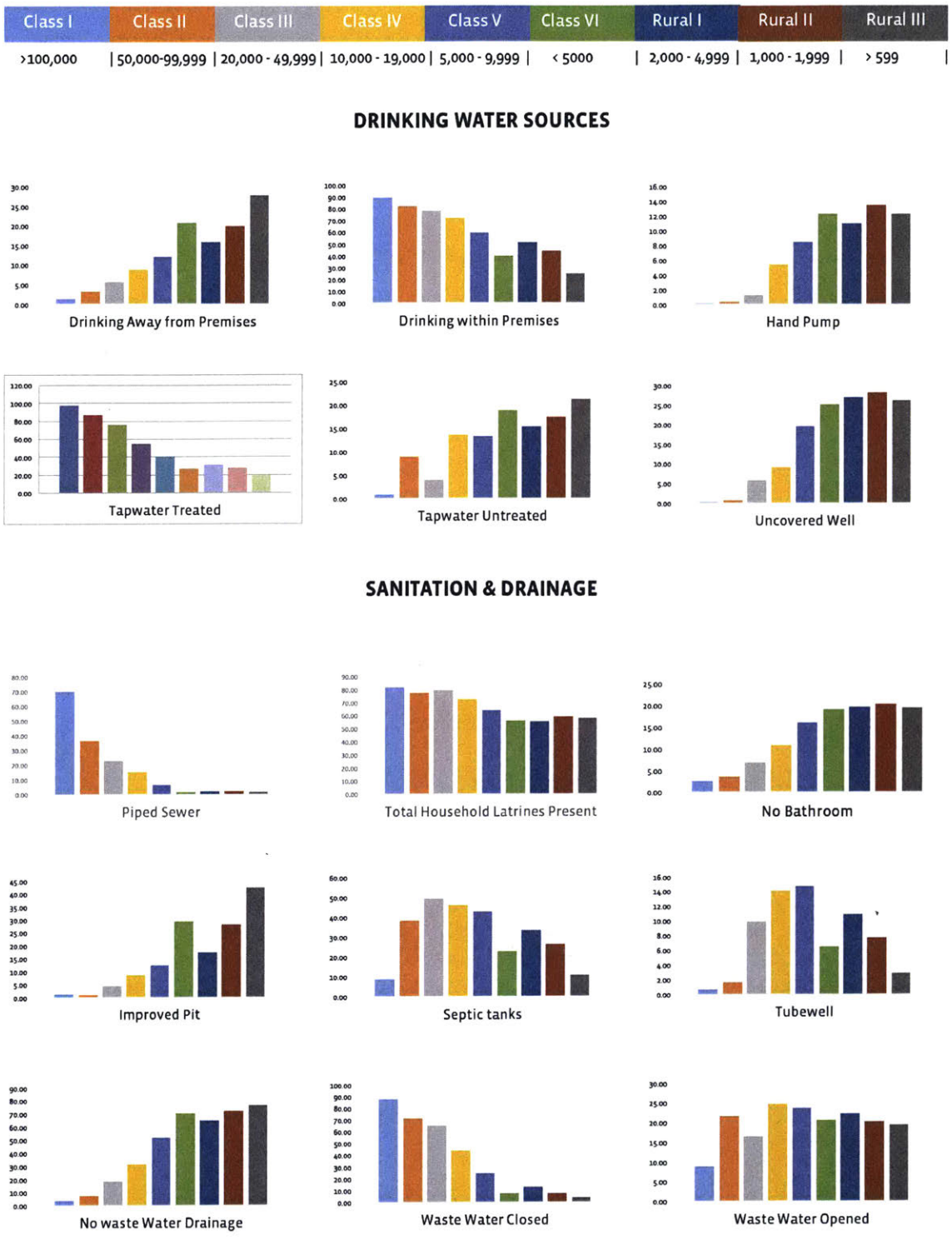


Figure 26. Dependent Variable: % of households with amenity provision as the dependent variable. Independent Variable: Settlement Size

2. Settlement Patterns and Trends

Most trends within amenity provisions and settlement size are contextual with current Indian Government rulings. The positively correlated variables are more pervasive in higher size settlements as they are municipal provisions. Negatively correlated variables such as uncovered well or hand pump are ad hoc, off the grid provisions found frequently in small settlements often in mountainous regions. In regards to bell curve amenities which see highest usage in middle settlement areas could have interesting peri-urban implications. Contrary to most rural or urban amenities which have positive or negative correlations depending on direction, transitional amenities follow a bell curve with a sheer drop towards higher settlement sizes.

By charting all 21 variables relationships with settlement size together, 3 patterns emerge. The amenities that fall within the direction of each amenity are:

Positively Correlated: Drinking Water within Premises, Tap Water Treated, Piped Sewer, WasteWater Closed
Negatively Correlated: Drinking Water Away from Premises, Uncovered Well, Hand Pump, No Bathroom, Improved Pit, No Wastewater Drainage
Bell Curve: Septic Tanks, Tubewell, Wastewater Opened, Septic Tanks

To investigate more deeply how to isolate peri-urban conditions, a combination of amenities were added together to investigate what urbanization patterns become salient. The intention of understanding each amenity as a part of this larger whole is to create relative scales

of urbanization and to create aspirational goals in amenity provision for growing settlements.

Based on the three trends of positively correlated, negatively correlated, and bell curve, four classifications were created to group amenities: Urban Amenity, Disamenity, Rural Amenity, and Transitional Amenity. Urban amenities are often found in metropolises and are generally reliable, widespread, and gridded infrastructure. This includes gridded electricity, piped water systems, and sewage systems. A variable that falls under the "Disamenity" category means that the presence of this variable is damaging towards a settlement's progress, such as drinking water far away from premises, or a household with no latrine. A rural amenity is one that is often found in more remote areas, such as uncovered wells, improved pits, or hand pumps. Lastly, a transitional amenity is an upgrade from rural amenities but is not sufficient for a large population, such as a septic tank or tube wells. These classification helps stack composites to determine a path towards peri-urban planning provisions.

Amenity Type	Description
Urban Amenity	Amenity that provides consistent provision, generally permanent
Disamenity	Negative repercussions, complete lack of provision
Rural Amenity	Amenities in isolated or remote villages
Transitional Amenity	Improved rural amenities to accommodate growing settlements, transient

Table 5. 4 Categories of amenities based on geographic situation

These four amenity classifications were then used to create composite scores were created in order to more closely assess whether growing villages are meeting their needs in terms of water and sanitation provisions. The composite score serves to become a quantitative indicator of benchmarks and thresholds for the government. Two composite score categories - 1) Drinking Water 2) Sanitation & Drainage, were created as a way to holistically assess level of provisions both visually and quantitatively from the Government of India amenities data sets.

Next, we seek to understand how the 4 Peri-Urban driving factors discovered through the Transect Reconnaissance and Interviews from Chapter 3 relate with amenities provision.

3. Buffering the 4 Forces of Peri-Urbanization

So far, settlement size has been used as a proxy for urbanization. We now refine our peri-urbanization definition based on proximity of the 4 Peri-Urban driving factors to settlement sizes (Chapter 3.6). In the following section, we create spatial buffers to these 4 peri-urban drivers to analyze their effects on amenity provision.

1. Methodology

The objective of the peri-urban buffer analysis is to detect how villages are affected by the presence of each of the 4 driving peri-urban factors. Figure 27 displays all four of these peri-urban types and their buffer zones. While distance alone is not a sufficient factor to measure the influence of one of these forces, boundaries and catchment areas are often used by entities in their planning process. For instance, in interviews with MIDC from Chapter 3.5, MIDC has clear provisions to support villages that fall within their catchment areas (called "deleted" or "affected" lands). But for villages beyond this status, they are often neglected. As a settlement is further removed from the MIDC zone, the quantity of water provided along with pricing is affected. However, there are instances when buffer analysis is not as effective in measuring influence, such as a buffer around a highway. In interviews with Gram Panchayats, highway development in certain villages had significant influence on real estate value or access to amenities, but it was often confounded where there were also other commercial establishments such as Hotel Dhaba restaurants, markets, and other retail markets (wedding or

fabric stores). For highway development to be influential in the urbanization process, it is generally coupled with stopping areas.There is a real possibility or instance for small villages near highways to be in an insignificant passing zone for cars, which is why the buffer zone is smaller.

2. Data Cleaning

Buffer distances around each peri-urban force were determined based on each factor's influence. All 4 buffers were then unioned together in GIS. Pune City, Haveli, and Pimpri Chinchwad were excluded. Only areas below 70,000 in population were considered. Waterbodies also had to be excluded from the data sets. Explicit excel and GIS instructions can be found in Appendix II.

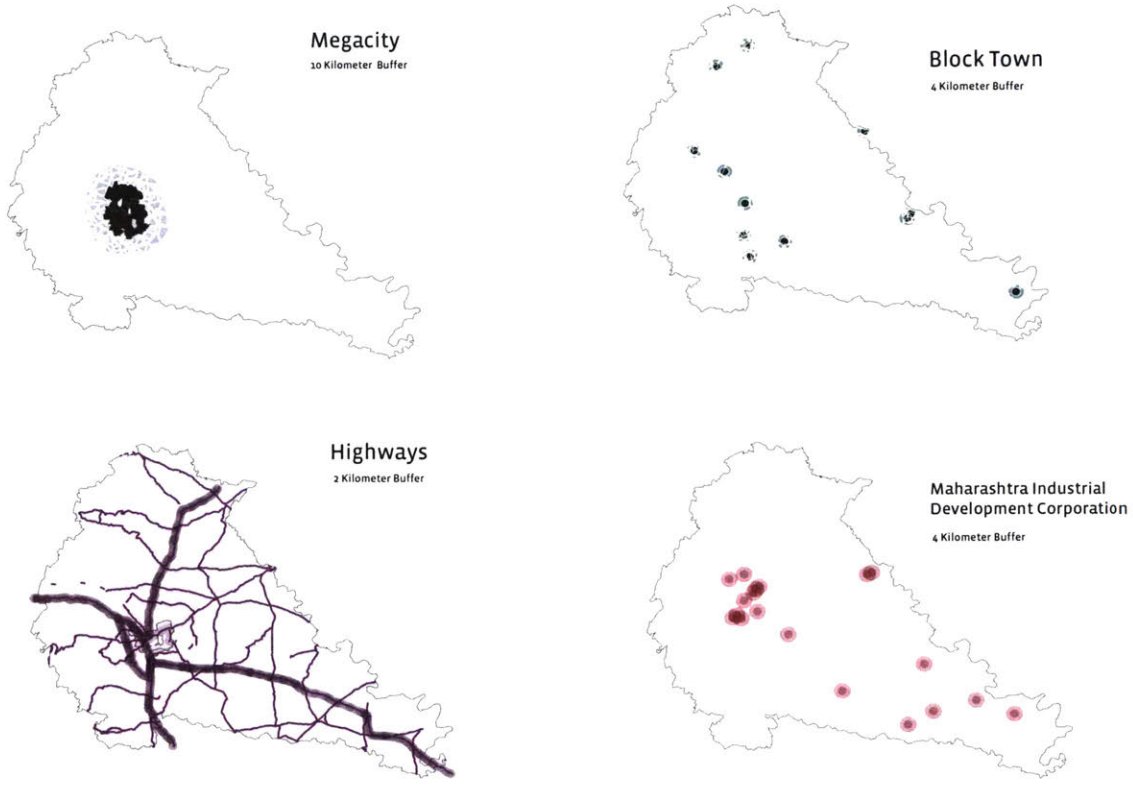
The Maharashtra Industrial Complex - MIDC sites were manually generated in GIS from identifying MIDC sites from the Maharashtra Industrial Development Corporation Website, and created as point data in GIS. A 2 kilometer and 4 kilometer buffer were both created to indicate extent of influence.

Highways - A 2 kilometer buffer was generated around all Pune highways. The 4 kilometer buffer did not include significantly more villages (1038 villages fall in the 2 kilometer catchment area, and only 327 incrementally more villages in the 4 km catchment).

Block Towns - A 4 kilometer catchment area was created around Taluka Head Quarters. Taluka sites were given by Pune Zilla Parishad.

Mega City - A 10 kilometer buffer was formed around the most outer edge of Pune City and Pimpri Chinchwad. This buffer was based on JS2's definition of a metropolis's influence (Chapter 1.3).

None of the Above Analysis - A none of the above category was created to compare places where villages that do not fall within the catchment buffers of the 4 forces. The widest buffer catchment areas from all 4 forces were clipped out, resulting in 1711 villages that had none of the 4 influences. The methodology to create this "none of the above" category in GIS is was through 3 steps: 1. Start editor tool 2. Select overlaying periurban buffer forces 3. Clip away villages that do not touch Peri-Urban Corridors. Averages for each amenity was also created for "None of the Above" settlements as a benchmark comparison.



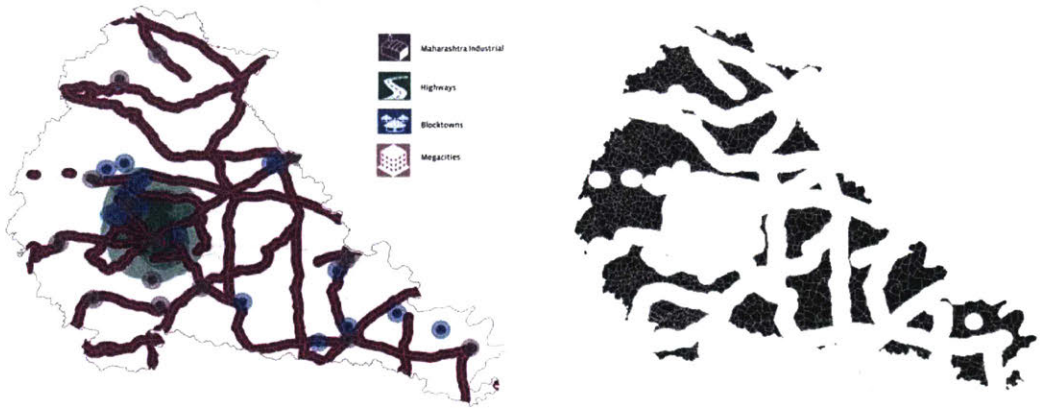


Figure 27. Left: Four major types of peri-urban driving factors buffered in GIS. Right: Villages that fit the "none of the above" category, where none of the 4 peri-urban forces reach.

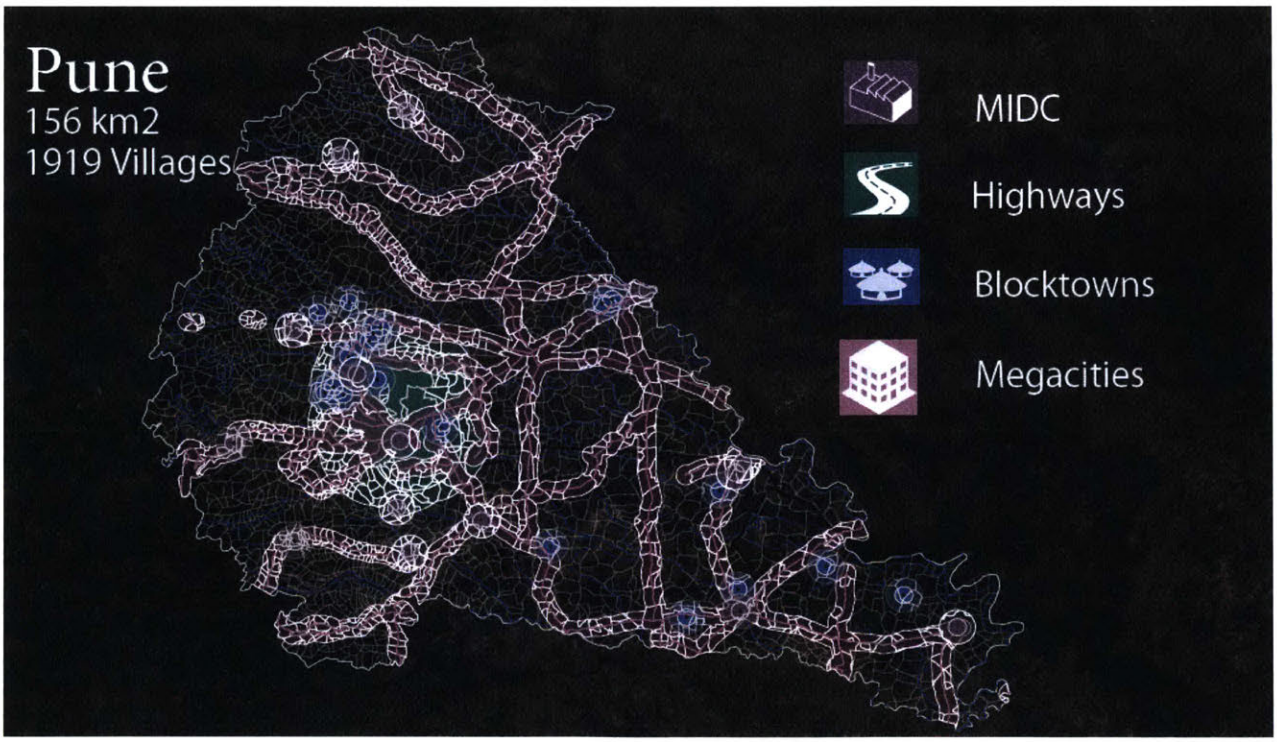


Figure 28: What Peri-Urban corridors ought to look like, driven by 4 urbanizing forces

Influence of Amenities by Distance to Villages				
Layer	No. Villages		Pune Percent	
	2 KM	4KM	2KM	4KM
Megacity (10KM)			5%	6%
Blocktowns	93	123	6%	16%
MIDC	107	306	54%	17%
Highways	1038	327	61%	0%
"None of the Above"	1165	- -	-	
Total Pune Villages	1920			

Table 6. Percentage of villages influenced distances

We then averaged variables together based on 2 kilometer and 4 kilometer buffers to see how access to amenities would change over distance.

MIDC Buffer	Tapwater T	Tapwater t	Covered W	Uncovered	Hand Pum	Tubewell	Spring	River	Tank Pond	Other	Drinking w	Drinking Ni	Drinking Ai	Total Hous	Piped Sews	Septic tank	Other Syst	Improved f	Open Pit				
2KM	39.34557	12.73115	1.732787	19.25508	8.92459	14.54984	0.762295	0.693443	0.256721	0.771475	57.86262	27.93508	13.21836	68.6729	6.395327	45.5785	1.094393	15.25234	0.108411	12.25981	22.42243	21.86075	54.78692
4KM	33.11849	13.0563	1.659664	25.71765	7.283193	15.43529	0.392437	0.621849	0.183193	0.837815	51.73866	30.71681	15.8563	65.27227	4.517647	32.22773	2.019328	22.57731	2.447059	16.31261	16.03277	23.10588	59.17899
None of the Above	24.66924	18.14407	2.307388	26.14665	12.95885	6.088746	3.58256	2.32311	2.461942	0.629553	36.72062	39.65842	22.93522	53.43694	1.835825	20.38668	1.893643	28.78471	0.299227	20.59175	7.044244	18.07595	74.19081

Highway Buffer	Tapwater T	Tapwater t	Covered W	Uncovered	Hand Pum	Tubewell	Spring	River	Tank Pond	Other	Drinking w	Drinking Ni	Drinking Ai	Total Hous	Piped Sews	Septic tank	Other Syst	Improved f	Open Pit				
2KM	31.19	17.82	2.21	24.30	10.52	8.45	1.49	1.30	0.90	0.75	47.18	35.54	16.20	60.87	3.47	28.49	1.59	26.54	0.44	16.71	12.69	22.90	63.34
4KM	27.33	19.67	2.56	24.45	12.05	7.61	1.62	1.82	1.45	0.52	41.11	34.38	23.59	56.11	2.01	23.81	2.55	27.27	0.17	21.68	8.26	17.96	72.85
None of the Above	24.67	18.14	2.31	26.15	12.96	6.09	3.58	2.32	2.46	0.63	36.72	39.66	22.94	53.44	1.84	20.39	1.89	28.78	0.30	20.59	7.04	18.08	74.19

Megacity Buffer																							
[Change] 2KM - 4KM	18.27	-14.48	-1.76	-11.36	-4.77	-17.04	-0.21	-0.23	-0.26	-0.04	11.35	-17.75	-8.14	13.27	11.75	-29.73	-0.94	-14.65	-0.19	-4.78	17.38	-13.93	-18.43
[Change] 2KM - Rural	14.21	-2.99	-0.45	-14.48	-4.09	15.64	-3.27	-1.99	-2.01	1.01	20.26	-12.11	-12.19	15.54	10.18	17.98	-0.61	-13.82	-0.01	-13.18	23.38	4.84	-42.14
Class 1 [>100000]	97.23	0.73	0.10	0.10	0.10	0.70	0.30	0.10	0.20	0.70	89.03		9.80	1.00	81.85	69.80	8.50	0.35	1.55	0.10	2.50	87.60	8.80	3.60
10KM	38.98	15.15	1.86	11.46	6.87	17.73	0.31	0.33	0.46	1.64	57.10		27.55	10.34	68.58	12.02	38.29	1.29	15.76	0.29	9.26	30.22	22.73	42.03

Blocktown Buffer	Tapwater T	Tapwater t	Covered W	Uncovered	Hand Pum	Tubewell	Spring	River	Tank Pond	Other	Drinking w	Drinking Ni	Drinking Ai	Total Hous	Piped Sews	Septic tank	Other Syst	Improved f	Open Pit				
2 KM	40.53	13.99	1.83	17.76	9.12	11.03	0.80	2.97	1.37	0.59	55.23	29.99	14.79	62.86	5.56	34.02	2.20	20.41	0.20	15.26	18.15	27.86	54.00
4KM	36.54	14.86	1.65	21.74	9.05	9.51	0.44	3.40	1.01	1.12	50.43	33.37	15.55	61.32	3.40	25.27	2.00	30.34	0.09	17.41	13.14	27.53	59.32
None of the Above	24.67	18.14	2.31	26.15	12.96	6.09	3.58	2.32	2.46	0.63	36.72	39.66	22.94	53.44	1.84	20.39	1.89	28.78	0.30	20.59	7.04	18.08	74.19

Table 7. Amenities provisions based on proximity of influence

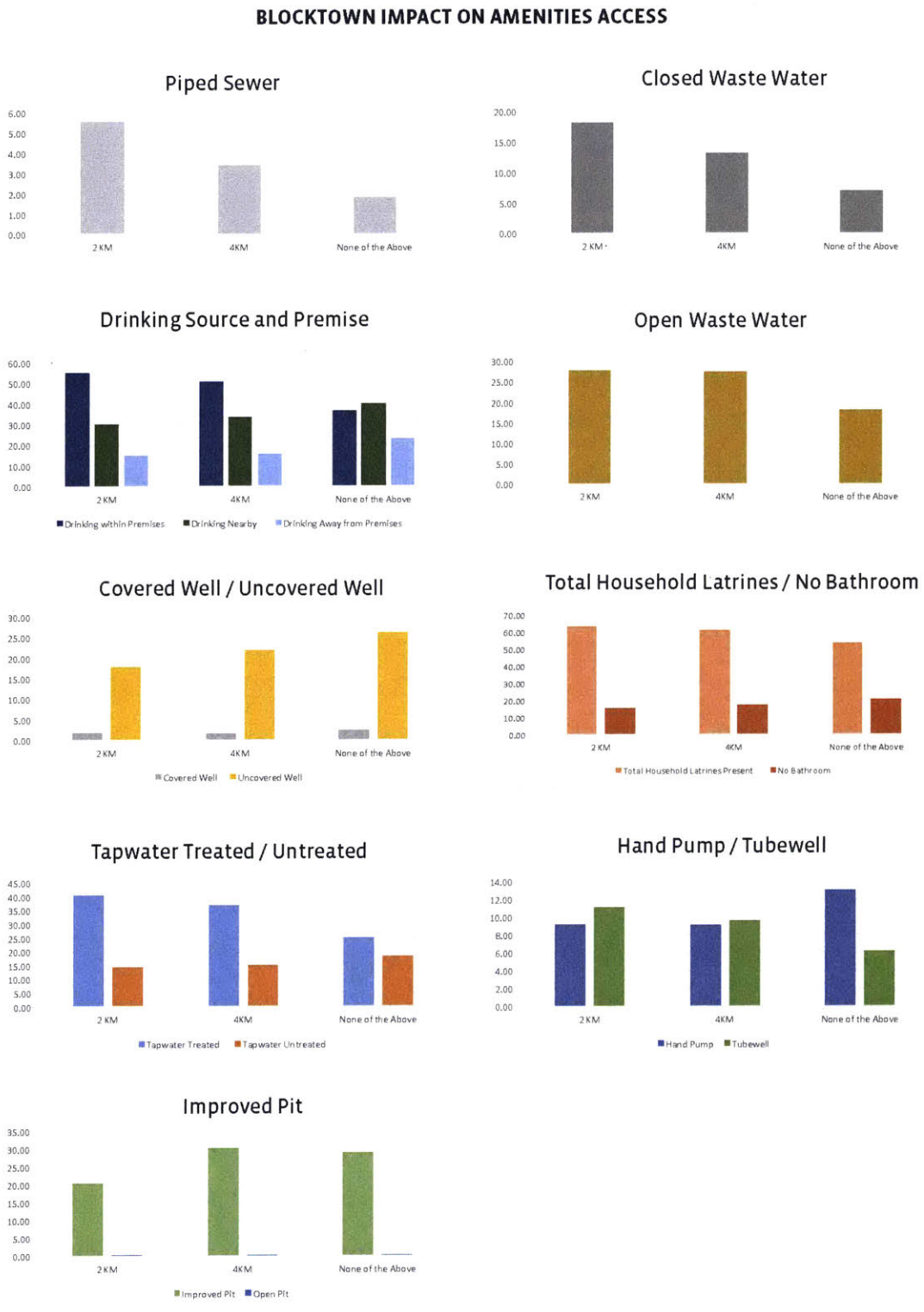


Figure 29. Access to an amenity and distance

3. Geographic Weighted Regression Analysis - Total Population and Amenity

In order to confirm the relationship between settlement size and amenity provision, geographic weighted spatial regressions were conducted in GIS to test correlation strength (Figure 28). The maps confirm that Urban amenity provision and settlement size do in fact follow the 4 Peri-Urban corridor outlays. When regressing urban amenities across population size, there are several emerging patterns. In Figure 28, the Closed Waste Water and Pipe Water Provisions follow the 4 Peri Urban Corridor outlays. Septic Tanks, a transitional amenity, creates an "inverted" patterning, where provision is present not where urban corridor outlays are, but instead around them. This observation and analysis for where "Transitional Amenities" are present will be fleshed out in the following section. Moreover, there are high contrasts in provisions amongst settlements within and outside an urban municipality. It shows that despite adjacencies and consistent growth trends, settlements not within the boundaries of a governing body are ineligible for urban amenity funding and therefore suffer significantly in having their needs met. Field interviews from informants have revealed sharp discrepancies for villages at the border of cities which have not been annexed. One such case discussed in Chapter 4.2 is the village Fursungi. Part of the village has been annexed into Pune city, but the remaining village - with over 50,000 people in population - is still ineligible for permanent urban amenities such as piped water systems.

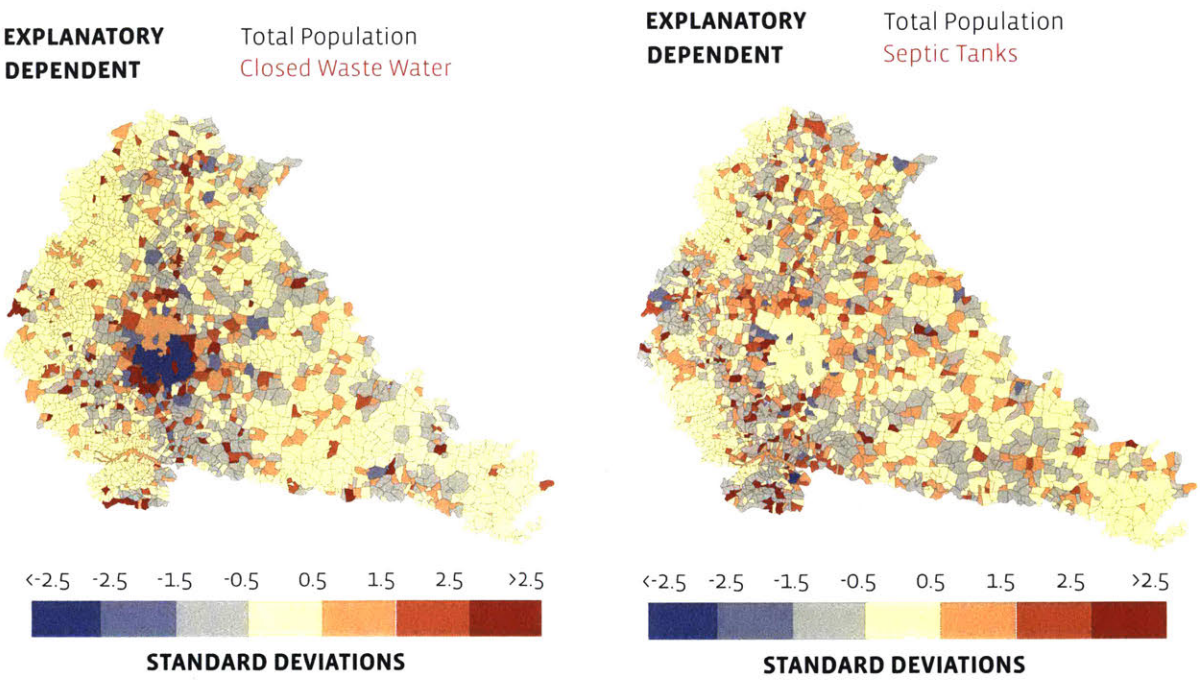


Figure 30. Left: Closed Waste Water regressed against Total Population, Right: Septic Tanks regressed against Total Population

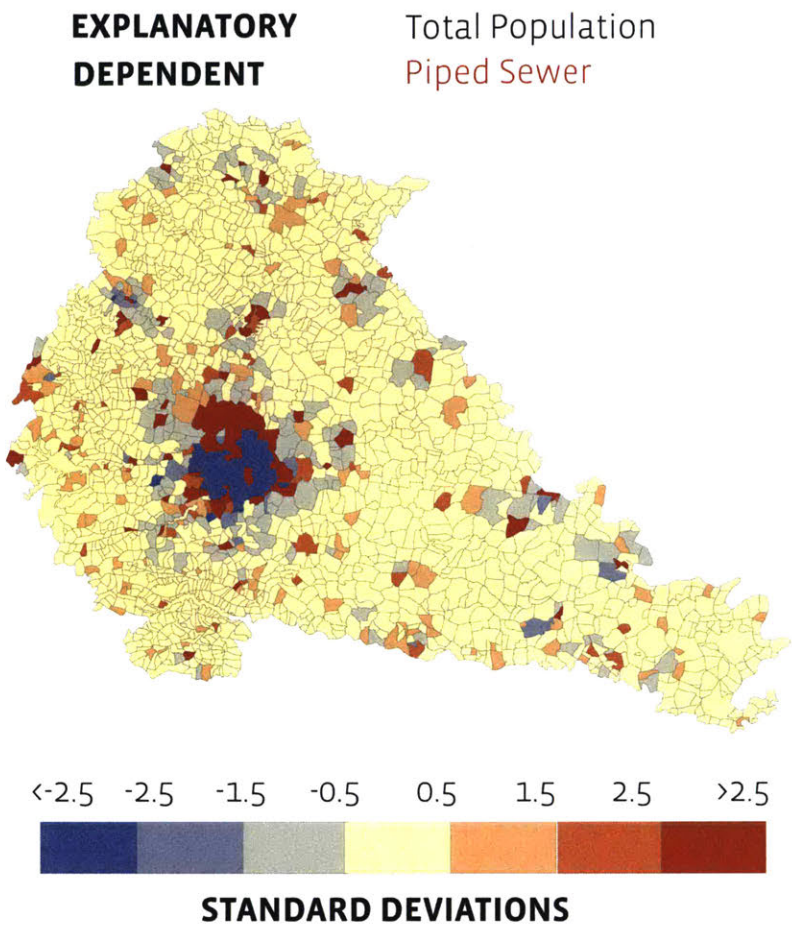


Figure 31. Piped Sewer regressed against total population

3. Construction of Peri-Urban WSS Composite Indices and Maps

The final section of this study combines insights from field interviews, transect reconnaissance, statistical analysis, GIS mapping, and our 4-Peri Urban framework to produce

3 composites. These composites are designed to support decision making for the Government of Maharashtra to prioritize and identify where urgent need in Peri-Urban Corridors. We created three indices to help visualize peri-urban conditions: first, an Urban Drinking Water and Sanitation Index; second, a Transitional Sanitation Amenities Index; and third, a Dire Conditions Index. The first is an index of improved conditions, the second is an index of transitional conditions, and the third is an index of degraded conditions.

The visual hierarchy of the map enables decision-makers to focus on need within the Peri-Urban Corridors. A second table, breaks down the total number of villages in Pune District that fall under each category by an equal distribution of 5 quintiles. It also includes a column, "PU Corridor," that isolates the number of villages in the Peri Urban Corridors under each quintile.

1. Urban Drinking Water and Sanitation Index.

The Urban Drinking Water and Sanitation Index combines six urban amenities that frequently surface as planning metrics, and were highlighted in village interviews. Six urban amenities variables taken from Sanitation and Drinking Water Categories (Figure 30), were averaged into a composite percentage 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 by quintiles and labels (Grave Needs, Basic Needs, Watching, Mostly Sufficient, and Sufficient). These normative terms were adopted to argue for systematic investigation of the 6.25% of villages in the lowest quintile and 52.63% in the "Basic Need". These normative terms were adopted to argue for systematic investigation of the 6.25% of villages in the lowest quintile and 52.63% in the "Basic Need".

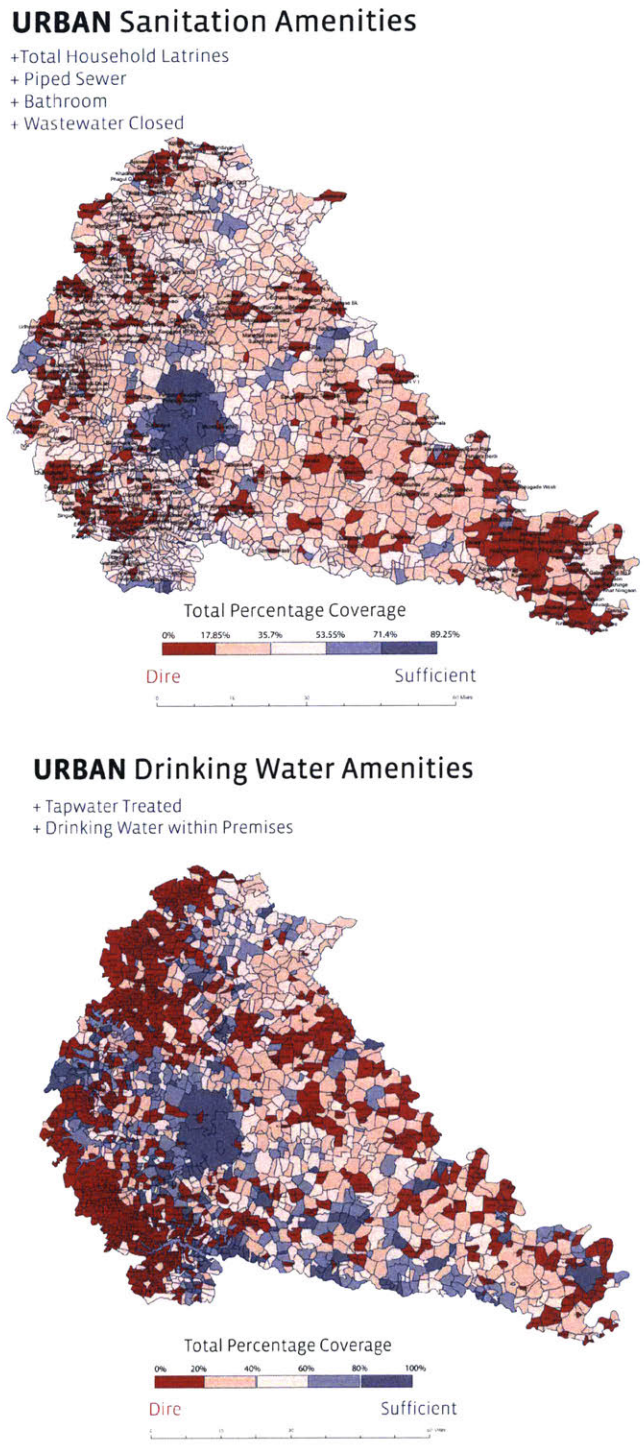


Figure 32. Top: Urban Sanitation Amenities Composite, Bottom: Urban Drinking Water Amenities Composite

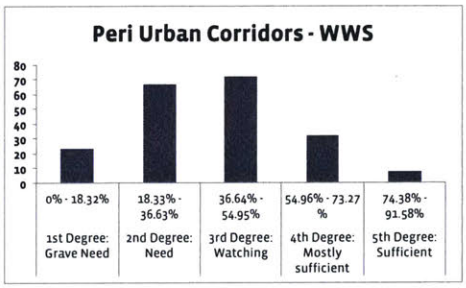
WATER SUPPLY & SANITATION

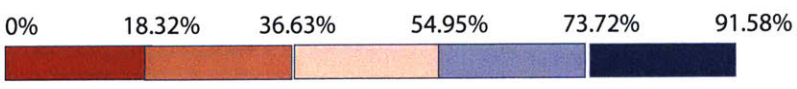
+Total Household Latrines
+ Piped Sewer
+ Bathroom
+ Wastewater Closed

+ Tapwater Treated
+ Drinking Water within Premises

Drinking Water and Waste Composite

Severity	Brackets	Villages	% in Pune	PU Corridors
1st Degree: Grave Need	0% - 18.32%	363	18.92%	23
2nd Degree: Need	18.33% - 36.63%	835	43.51%	67
3rd Degree: Watching	36.64% - 54.95%	509	26.52%	72
4th Degree: Mostly sufficient	54.96% - 73.27 %	189	9.85%	32
5th Degree: Sufficient	74.38% - 91.58%	23	1.20%	8
	TOTAL	**1919**		**202**





Grave Need — Sufficient

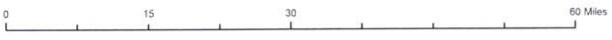


Figure 33. Drinking Water and Sanitation Index

There is great growth and need, in the western block towns and in Indapur block in the south east region. The maps indicate a few villages in the lowest quintile in the Pune City area, and great need for drinking water access along the small settlements in the western Ghats, highway corridors in western Maharashtra, and around the block towns in eastern Pune District.

2. Transitional Sanitation Amenities Index

The Transitional Sanitation Amenities Index is based on water infrastructure elements that are characteristic of improving peri-urban conditions, but not improved urban conditions (e.g., improved pit latrines, septic tanks, and open waste water drainage, as discussed in the previous section). These are good proxies for settlements that fend well for themselves with what Allen (2016) calls "Needs-Based practices". As settlement sizes grow, the need to transition to higher provisions is necessary. They are prominent in mid-sized villages.

Transitional amenities include:

Septic Tank - A septic tank us an underground tank in which sewage collects underground and decomposes through bacterial activity

Improved pit - Instead of a pit slab, an improved pit could could be ventilated or connected to a pour slab

Open Drain Water - No formal system for water drainage, mixed use between drinking and sewage water

Transitional Amenities Composite was defined by the following variables:

Transitional Composite = (Septic Tank + Improved Pit + Open Waste Water) / 3

TRANSITIONAL Amenities

- Septic Tank
- Improved Pit
- Open Drain

Transitional Amenities

Severity	**Brackets**	**Villages**	**% in Pune**
Very Low	0% - 13.33%	408	21.26%
Low	13.33% - 26.67%	706	36.79%
Medium	26.67% - 40.01%	589	30.69%
High	40.01-53.3%	168	8.75%
Very High	53.3% - 66.67%	47	2.45%
	TOTAL	1918	

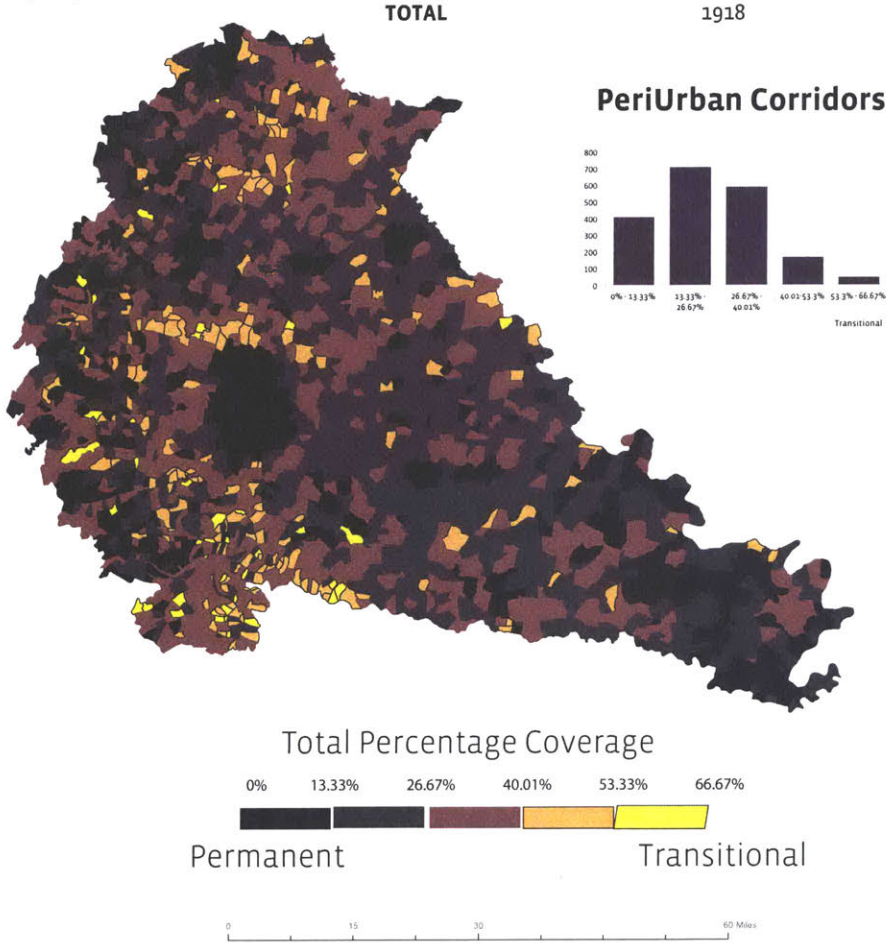


Figure 34. Transitional Sanitation Amenities Index

Figure 32 maps this index to help visualize spatial patterns of peri-urbanization. Interestingly, some villages with transitional sanitation systems are located along highway corridors in western Maharashtra, near to villages that have low Drinking Water and Sanitation scores. The Transitional Amenities map reveals a second interesting anomaly: villages with higher transitional amenities often border megacities and block town headquarters. They are flush against cities that *should* have higher sanitation amenities. Despite having urban-like growth pains, these villages are unable to build permanent infrastructure due to lack of funding. If they are annexed into megacity or block town governance, transitional amenities may be replaced by improved amenities, but recall that sanitation improvements are weakly correlated with settlement size. Knowing that the peripheral settlements of megacities and block towns will experience rapid rates of growth, policies to upgrade drinking water and sanitation amenities of the expanding urban-peri-urban border should be a priority.

3. Dire Situations Index

This category label may seem histrionic, but it embodies the lowest levels of water and sanitation conditions in the Census. It identifies villages in peri-urban spaces that have the harshest conditions which need immediate attention, especially if they are in any of the Peri-Urban corridors. The Dire Situations Index was created by averaging "No Latrine," "No Bathroom," "Drinking Water Away from Premises," and "No Wastewater Drainage." The majority of the villages in Pune fall under the "mostly sufficient category." Some 1.3% of villages are identified as being in grave need (80- 100% of their households are unserved), and 7.82 % are have basic needs (60-80% of their households are unserved). Figure 9 shows that they are concentrated along highway corridors in central and eastern Pune District. The Pune Zilla Parishad should focus attention on these places of grave and basic need.

DIRE SITUATIONS

-No Latrine
-No Bathroom
-Drinking Sources Away from Premises
-No Waste Water Drainage

Dire Situations

Severity	**Brackets**	**Villages**	**Percentage in Pune**
1st Degree: Grave Need	0% - 20%	25	1.30%
2nd Degree: Need	20.01% - 40%	150	7.82%
3rd Degree: Watching	40.01% - 60%	175	9.11%
4th Degree: Mostly sufficient	60.01% - 80%	823	42.89%
5th Degree: Sufficient	80.01% - 100%	347	18.08%

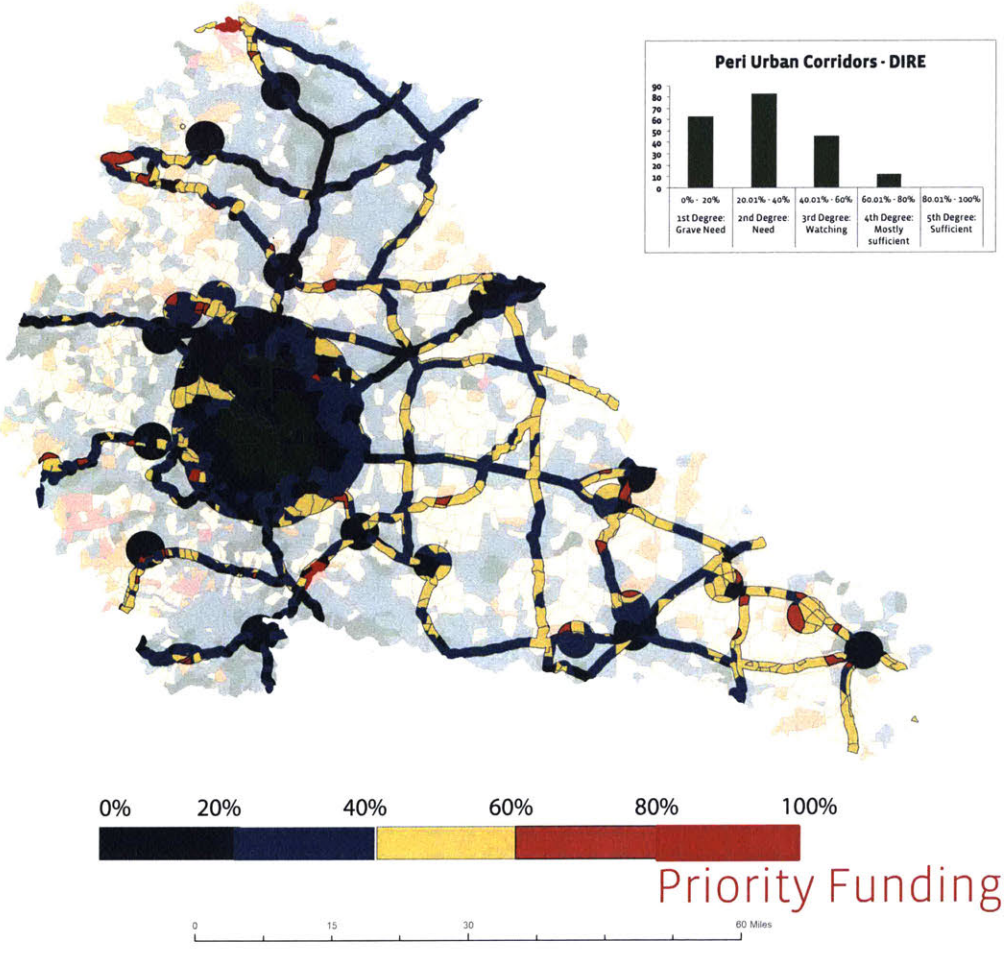


Figure 35. Dire Situations Index

4. Conclusion

This study helps visualize the purportedly undisciplined environments of peri-urban villages and disciplined environments of Peri-Urban villages in a rapidly urbanizing district of Maharashtra.

Building on previous bodies of research we linked field methods with Census mapping to visualize relationships among population, water supply, and sanitation conditions in peri- urbanizing regions. As underscored in the introduction, mapping alone cannot characterize peri-urban and rurban conditions, but it can help extend the insights critical social research.

In accord with recent research on rapid urban growth outside major cities, we showed that peri-urbanization is far more spatially extensive than is often perceived. It surrounds small towns, highways, and industrial areas, as well as large cities like Pune. Discerning these four major processes of peri-urbanization was a major finding of this research, and it was supported by field observation, interviews, and aggregate spatial data analysis. The buffer zone map of these four peri-urban processes provides a useful vehicle for visualizing where peri-urbanization has occurred, in the case of the 2011 Census data, and where it may occur as new annual data collected at the village level become available through the Government of India and states like Maharashtra. Historical and time series analysis will help shift from the limited static perspective a dynamic understanding of processes that are transforming peri-urban and rurban regions.

As a step in that direction, the maps and interviews generated here indicate diverse socio-spatial patterns of peri-urban population and water-related conditions. 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 smaller villages, but they because they are no different in drainage infrastructure their overall sanitation conditions will likely worsen. Census data indicated lower levels of service in towns of around 5,000. Villages that fall between urban and rural categories do not appear to be well served by either sector. We observed transitional sanitation amenities in mid-size settlements adjacent to cities and towns that call for attention on both sides of the rural-urban boundary.

This research showed that in addition to the district Zilla Parishad, various governing entities have responsibility for supporting village water and sanitation improvement. Even when far removed from a municipal body, 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. 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 (Lerner and Eakin, 2011).

In our research with local officials and villages, maps were mentioned as 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, like Participatory Rural Appraisal methods, groundwater reports, and Detailed Project Reports, they are not used in community meetings or Annual Action Plans for drinking water and sanitation investment.

VI. PLANNING IMPLICATIONS

1.Introduction

After 2 years of analysis evolving into our Peri-Urban conceptual framework, we brought our indices and frameworks to the Government of Maharashtra for feedback on how it can be implemented as a government resolution for peri-urban planning. Through our analysis, we have accomplished the following key results:

1. Identification of 4 major types of Peri-Urban Development: Highway Development, Block Corridor, Industrial-Driven, and Megacity Growth.
2. Empirically confirming the effect of the 4 Peri-Urban drivers based on settlement size, spatial autocorrelation, and distance.
3. Identification of the most relevant WSS Census variables for peri-urban planning
4. Development of 2 major indices of peri-urban WSS conditions & Needs (WSS Amenities Index & Dire Needs Index)
5. Identification of Class VI towns (>5,000) as settlements with low WSS amenities

The Planning Implications are several fold:

1. MIDC and Corporations have important influences on village, block, and district development whether they intend to or not

2. Village access to MIDC pipelines increase water coverage and reliability substantially (120 - 135 LPCDs)

3. Drainage: All settlement sizes with the exception of Metropolises have open drainage problems. Z.Ps should focus on drainage, liquid, and solid waste problems

4. Stakeholder Collaboration: Because rapid urbanization has no clear boundaries, various governing entities need to see beyond their own mandates. Z.P.s should coordinate with PMC, PMRDA, MIDC, State Highways, and Taluka Officers to allocate responsibilities and define extents of Peri-Urban Planning.

2. Next Steps

Our recommendations to the Pune Zilla Parishad and MIDC is broadly summarized below:

Prioritization of villages based on need level: We have created a way for the Zilla Parishad to systematically determine which villages should be prioritized above others based on need. After isolating out places not affected by peri-urban corridors, villages in peri-urban corridors yet sorely lacking in resources should be focused on first. In our research with local officials and villages, maps were mentioned as 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 22 planning processes, like Participatory Rural Appraisal methods, groundwater reports, and Detailed Project Reports, they are not used in community meetings or Annual Action Plans for drinking water and sanitation investment. The Zilla Parishad asked for further clarity on how variables were selected in our

indices. A more thorough training and explanation of relevant variables is necessary. We plan on sharing all data files and excel analysis with Government of Maharashtra

Accurate Population Count and Floating Population Count: The Pune Zilla Parishad and MJP both reported that current methods to determine population projections were inadequate for scheme implementation. Geometric and arithmetic methods sorely under counted population growth and floating populations. We recommended two ways to mitigate these inaccurate counts are 1) Consumer surveys through a population app implemented in Haveli Block 2) Creating precise rates with specific driving factors and growth.

Joint Planning: Policy-making is currently conducted on a state and district level, yet the current resource flow of information between the State Government and Zilla Parishad is limited once it reaches Village Gram Panchayats (Figure 34). Interviews with NGOs and grassroots mobilization groups such as Pune-based STAPI revealed sharp discrepancies between on-the-ground scheme implementations and government-enforced deadlines. This research showed that in addition to the district Zilla Parishad, various governing entities have responsibility for supporting village water and sanitation improvement. 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. 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 The extent to which corporations and MIDC have emerged in conversations with villages demonstrated a large influence that MIDC has on villagers. We recommend greater joint collaboration moving forwards, such as Corporations' burden on providing water supplies be factored into the ZP's funding deliberations.

MIDC as a model for inclusive planning: While MIDC's involvement should not be purely a function of villagers' sentiments, defining their sphere of influence and upholding them as a model could elevate villagers' needs. MIDC delineated what is their mandate to provide water supply versus what they are not required to do. Their funding is strictly through corporations and they see their operations to be private. However, we suggest that MIDC adopt a more inclusive perspective on how their activities affect nearby settlements.

Better yet, MIDC can serve as a model to Pune Zilla Parishad from a planning and operational level. Firstly, the way in which MIDC plans multi-phase infrastructure and water projects can take 10 years. When MIDC engineers assess which land to buy, they are also considering how the land can be connected infrastructurally to future plots over several decades. This forecasted planning ensures gridded systems. Moreover, MIDC's pricing model and water policies fosters villager accountability and ownership. For instance, if villagers do not pay their water on time, water supply is cut off after 40 hours. MJP has reported having a hard time penalizing and discontinuing water for defaulting villages due to political reasons. Whereas, MIDC operates solely as a private entity and therefore do not have political incentives getting in the way. Moreover, MIDC has projects that could serve as models for operations and maintenance. MIDC has net meters on all their pipes to keep track of flow rates. MIDC also has extensive GIS mapping for industrial development to forecast demand via SCADA to map out a local and large scale water supply map. The real-time and holistic mapping dashboard serves as an excellent example to other governing entities.

These exemplary operations can serve as planning examples. We also advise MIDC and corporations to think how their involvement to villages can be extended through corporate social responsibility initiatives. We encourage MIDC to understand how their influence reaches beyond mandate boundaries. This is particularly evident for downstream villages near Talegaon and Chakan MIDC, who experience industry pollution in river water. MIDC also influences the

influx of floating populations substantially, as migrants move into peripheral villages in order to be employed. We recommend MIDC to interact with villages within a 4 kilometer buffer catchment to better understand the extent of their influence.

Extend field research methods to Taluka and participatory G.P. Planning approaches: We also hope to integrate Gram Panchayats to submit their own inputs on scheme needs. Interviews with NGOs and grassroots mobilization groups such as Pune-based STAPI revealed sharp discrepancies between on-the-ground scheme implementations and government-enforced deadlines. We also believe that dividing field research by Taluka (Figure 36) will more evenly distribute the accountability and offset burden. Moreover, government data on a habitation level remain limited and sparse. We hope to disseminate our questionnaire structure to acquire data that can rectify floating population counts. Our hope is that our mapping dashboard can relay local-level needs to ensure more accurate data reporting alongside increased transparency and accountability between villagers and government officials.

Move from static analysis to dynamic forecasting tools (using M&E): Many of the frameworks and lessons are transferrable to other districts experiencing peri-urban symptoms. In collaboration with MASTEK, a monitoring and evaluation system implemented by JS2, we hope to offer training distilling the analytical methods used in the 2011 census for integration into their database.

We also hope to create a real-time, mapping dashboard tool that enables the government to have a more holistic and data-driven view of villages to increase informed investment and planning decisions. As laying down water infrastructure is sticky and costly, we believe that having a data-driven dashboard that is multi-year in nature will enable more informed longer-term investments. We seek to simulate the four processes of urbanization and its effects on nearby villages in Pune, Maharashtra (Figure 35). We propose to simulate the relationship

between peri-urbanization based on growth patterns between 2001 and 2011 Indian census data. We have begun creating rules and a software based in Processing, a Javascript-based script for our dynamic simulation. Users of this simulation will begin be national, district, and block level governance, wastewater management groups, infrastructure planning, and academia. They will also include the Tata Water Mission and Maharashtra Industrial Development Corporation. Scaling up, these methods could be potentially used as a model for other governments to learn from that have analogous data resources and peri-urban symptoms.

More broadly, we continue to seek to answer is to also implement our dashboards on a community level: Are peri-urban villages the anomalous accomplishments of charismatic leaders, community action, technological diffusion, or strategic investment patterns; or do they have a socio-spatial logic as well?

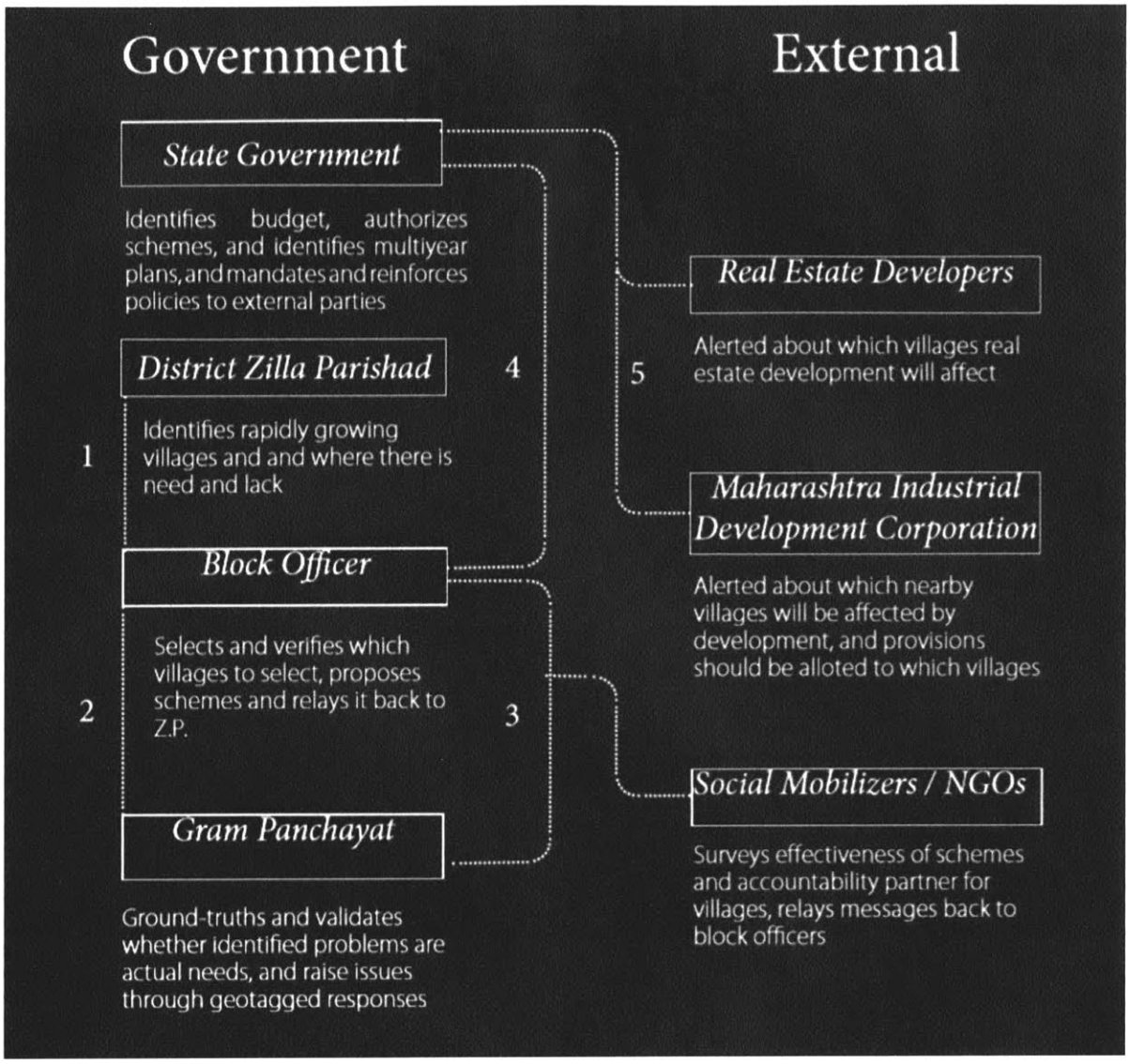


Figure 36. Stakeholder groups within external and government parties

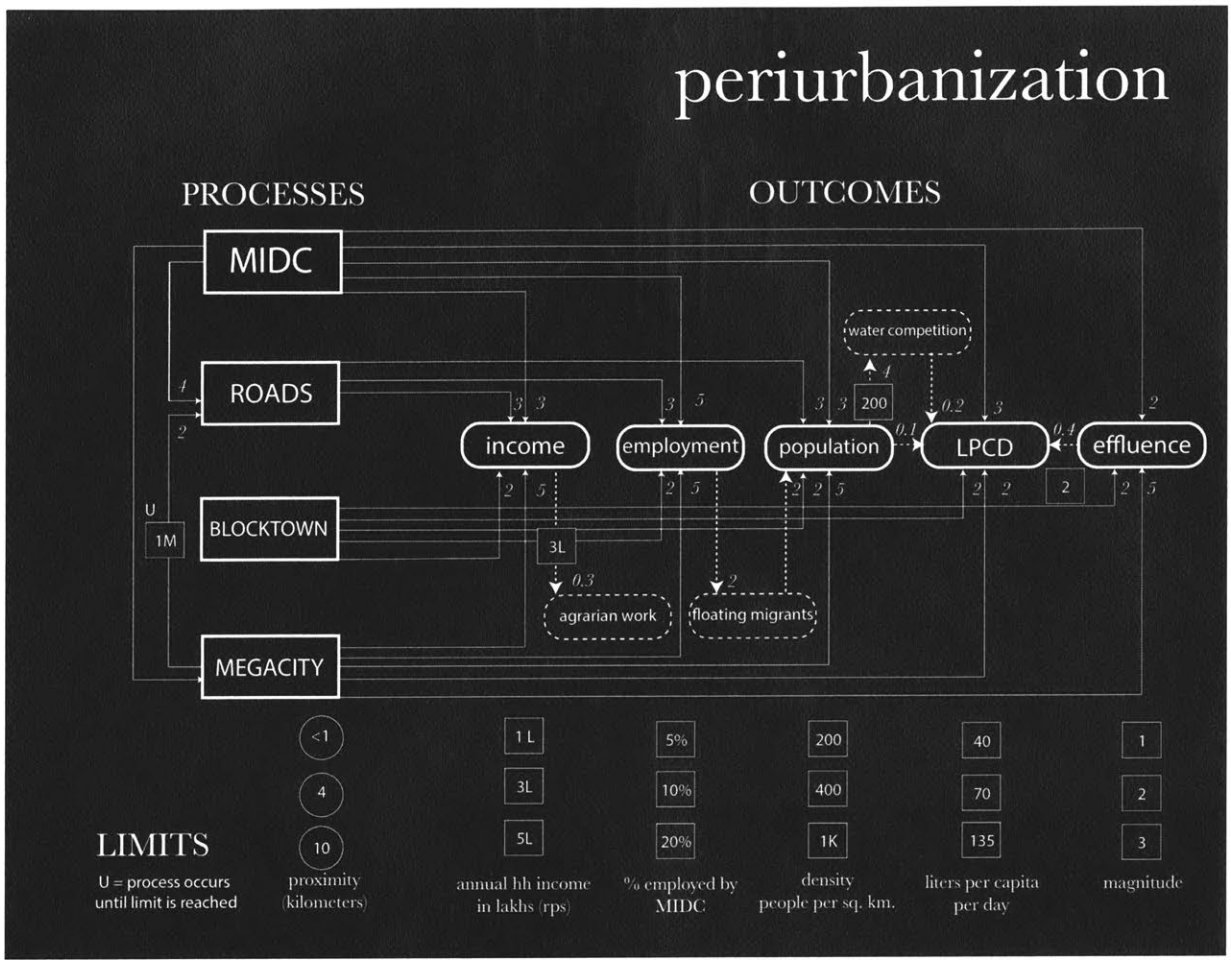


Figure 37. Rules and feedback loop for Peri-Urbanization simulation

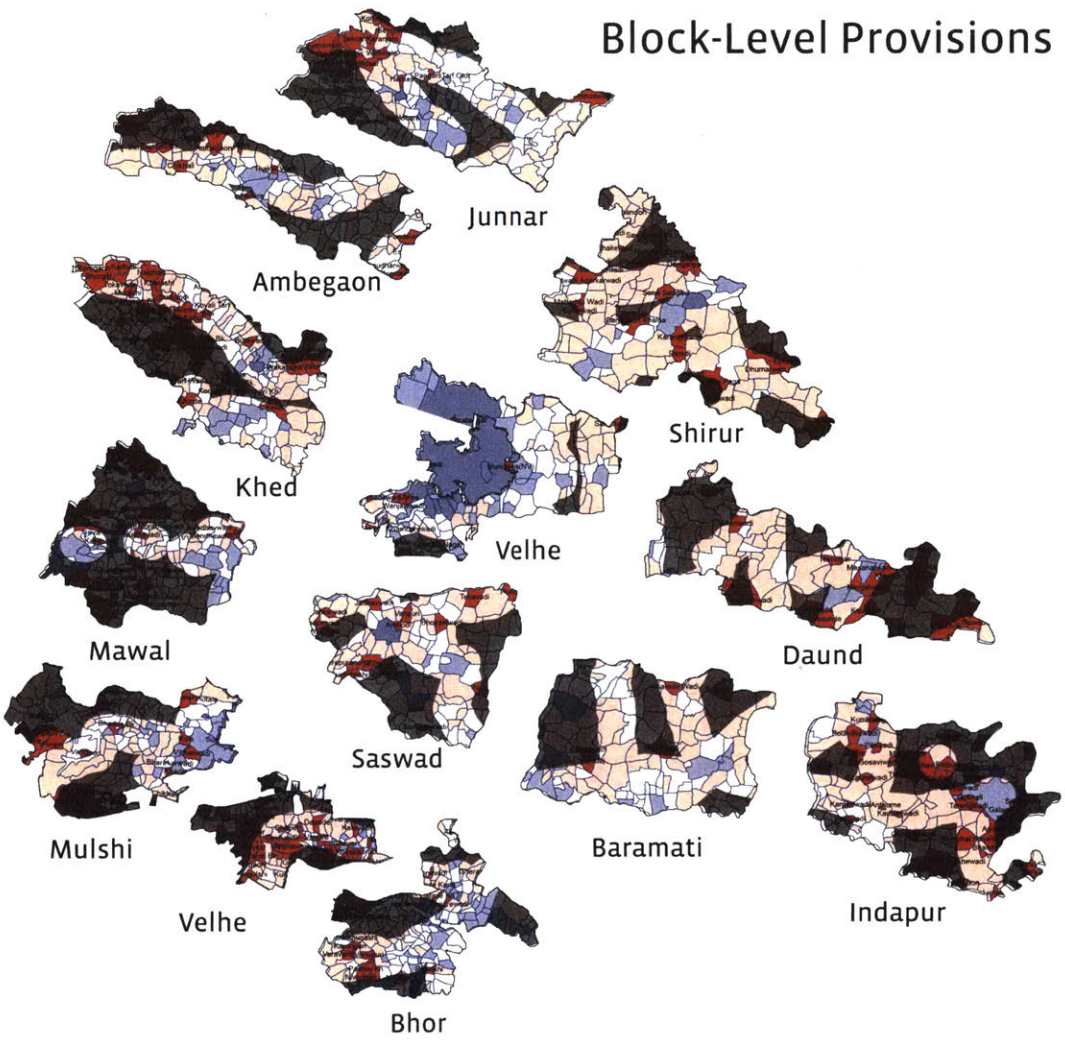


Figure 38. Taluka level divisions and prioritizations for water and sanitation planning

ACKNOWLEDGEMENTS

I would like to thank my advisor for the past 2 years, Professor James Wescoat for his generous devotion of time, guidance, and inspiration. I would like to acknowledge generous support from the Tata Center for Technology and Design, its director Dr. Robert Stoner, Dr. Chintan Vaishnav, and our colleagues Marianna Novellino, Paige Midstokke, and Sabah Usmani. I am grateful for collaboration with the Maharashtra Water Supply and Sanitation Department, officials in the Pune Zilla Parishad, Groundwater Survey and Development Agency, the World Bank India office, Mr. J.V.R. Murty, the Tata Water Mission, the Government of India National Informatics Centre, Rotch librarians and Aga Khan Documentation Center, and the many villagers who shared their time and knowledge with us.

About the Author

Rebecca has spent over 7 years working and living in India and other rapidly urbanizing areas in the world. Rebecca envisions the "Rurban," a project in which villagers strengthen skills and assets that they can use in their villages rather than having to migrate into cities.

She is the founder of Roots Studio, a social enterprise that digitizes the work and stories of traditional artists from remote corners of the globe with a marketplace built for the modern era. Rebecca is an Echoing Green Global Fellow and is affiliated with MIT D-Lab Scale ups Fellowship, MIT Delta V, MIT Global Ideas Competition, MIT Legatum Center, and MIT Sandbox. Previous to that, Rebecca was a Fulbright Scholar and National Geographic Young Explorer who followed cows in urbanizing Indian cities.

APPENDIX

Appendix I: In-Depth Questionnaire

Category	PERIURBAN PROBLEMS Water Competition	Waste Water Effluents	Exurban Slums
Description	Due to an increase in population, corporations, and industrial use, water resources are tight and villagers have to negotiate water access	Villages experience mix contamination of drinking water and waste water not delineated, where environmental damage and pollution are acute	Squatters sitting on public land that gets rented out mostly serving floating population
Likert 4 Qs	Is monsoon water scarcity: increasing, decreasing, about the same? Is water scarcity the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?	Is water pollution the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present? Is monsoon drainage the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?	Are slums the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?
Questions	is water scarcity increasing, decreasing, about the same?	-Where is waste dumped?	-What year did th exurban slum emerge? -What vocation do they have? -How does their culture differ?

Category	Overcrowding	Poor Access to Ameniti	Unemployment	Sanitation
Description	Increased population means less permeable land, storm water issues, crowding, creating difficulties in infrastructure planning	Many villages are geographically inaccessible to basic needs (schools, hospitals, banks, etc.).	The switch from rural to urban laborers is prominent as opportunities in the city and cost of living increase, and dwindling of cultivable land	How many households of toilets? Compulsory from the Gram Panchayat, 100% have toilets
Likert 4 Qs	Is overcrowding the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?	Is improved solid waste management the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present? Is access to closed sewers the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?	Is unemployment the: 4) most important issue; 3) important; 2) somewaht important; 1) not too important at present?	
Questions		-Where is the closest hospital? -Where is the closest elementary / secondary / college?	-What percentage of population is unemployed?	Wastewater Discharge? They have septic tanks, and a vehicle that takes it away and is supplied to farmers for manure

Village Name Interviewees Date				
Category	**Floating Population**	**Industrialization**	**Higher Water Demand**	**Water Source Questions**
Description	Increased temporal and migrant communities	Peripheral areas are often prime areas for industrial settlements and growth given its proximity to the city but expansive area, giving way to new dynamics	A need for more formalized water systems to accommodate growth and increased demand	
likert 4Qs	Are migrants settling here: 4 very fast; 3 somewhat fast; 2 slowly; 1 not at all	Is industry in this block growing 4 very fast; 3 fast; 2 not so fast; not at all? MIDC Beneficial to the community? 4. Very Beneficial 3. Beneficial 2. Not Benefcial 1. Harmful	Is water use increasing: 4 very fast; 3 somewhat fast; 2 slowly; 1 not at all	Does anyone in the households not have meters? Do any of the families not pay? BPL?
Questions	-Percentage of floating population (and what they come for)	-Who are the nearby industries / corporations? When did they come in? What schemes / programs have companies created? Are they effective?	Are villagers drilling more wells? Is the village seeking increased surface water from pipelines, reservoirs?	Is water quality excellent, medium, poor? Who operates the water system for the village?

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