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Metabolic Urbanism and Environmental Justice: The Water Conundrum in Bangalore, India

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ABSTRACT

Anthropologists, sociologists, geographers, and urban studies scholars have recorded the causes and consequences of inequities that underscore rapidly burgeoning cities in the global South. We argue here that such accounts of urbanism are incomplete without accounting for the inequities in metabolic flows of matter and energy that physically sustains the city. Using the example of domestic household water consumption patterns in Bangalore, we demonstrate how the city's hydrology is shaped by social, political, and economic variables. We present a simple coupled social-ecological framework that allows us to sketch the broad contours of this social hydrology of Bangalore. Our analysis provides evidence for why questions of environmental justice cannot be separated from questions of biophysical sustainability. We show that anthropogenic drivers of groundwater hydrology in Bangalore dominate background biophysical drivers. Unequal spatial distribution of piped water infrastructure is the principal driver of groundwater hydrology in Bangalore, leading us to hypothesize that all urban hydrology is social hydrology.

1. INTRODUCTION

Globally, more people now live in urban than in rural settings.[1] Although India's urban population proportion at 31% is still below the global average, it has been urbanizing rapidly. The population growth rate in urban India is more than two-and-half times that of rural India, and the 2011 census records how ''for the first time since Independence, the absolute increase in population'' has been greater in urban areas than in rural areas.[2] Indeed, India's current urban population alone, of over 370 million people, exceeds that of the total population of every other country on the planet with the exception of China. The urban share of India's gross domestic product (GDP) has grown from 38% in the 1970's to the current levels of approximately 60%.[3] Even as India is on a trajectory to double its current urban population within the next two decades, the ecological conundrums underlying this prodigal expansion of urban India are only beginning to register. Ecological conflicts in India have always pitted the industrial economy of its urban centers against the agrarian society. With rapid urbanization, however, conflicts over ecological distribution and environmental justice within the city have taken on a new salience. Inequities within the city are intimately linked to the conflicts between town and country.

The multiple conflicts surrounding urban domestic water provisioning in India (used for drinking and other non-commercial household activities) exemplifies how inequities at multiple scales ranging from the neighborhood to international river basins intersect with each other, and with the biophysical system. Even while the policy literature increasingly reduces the urban water

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[1]United Nations (UN), *World Population Projections: The 2007 Revision* (UN Department of Economic and Social Affairs, 2007).

[2]Census of India, *Rural Urban Distribution of Population: Provisional Population* (New Delhi: Registrar General and Census Commissioner of India, Government of India, 2011).

[3]Government of India, *12th Five Year Plan (2012–2017)*, vol. II (New Delhi: Sage Publications, 2013).

conundrum to a techno-managerial or at best an economics rooted missing market problem, there is now incontrovertible evidence that such reductionist approaches completely miss the political and social underbelly of urbanism in India.[4] Even while the emerging literature on urbanism has critically engaged with the engineering and economics landscape surrounding urban water, it has not paid adequate attention to underlying biophysical processes. Similarly, the more technical literature that takes into account both engineering interventions as well as underlying hydrological factors has shied away from explicitly modeling political and social variables.[5] Using the case study of Bangalore, a burgeoning metropolis and the third largest city in India, we address this lacuna by developing a framework for combining social, political, economic, and hydrological variables underlying urbanism.

The remainder of the article is organized as follows. Section 2 shows how a social metabolism framework can be used to combine social, political, economic, and ecological variables that characterize emerging urbanism in India. Section 3 provides a snapshot of water metabolism in Bangalore. Section 4 combines data from the local water utility, qualitative data from fieldwork in Bangalore, distributed groundwater modeling, and demographic data to make the case for a ''metabolic urbanism.'' We conclude in Section 5.

2. SOCIAL METABOLISM

Metabolism describes the conversion of matter and energy by living organisms and even entire ecosystems. As anthropogenic drivers came to dominate material and energy cycles, social scientists adapted the metabolism framework to describe flows of matter and energy through societies.[6,7] Modern cities are best understood as large metabolic centers that import prodigal amounts of matter and energy from their surroundings. Studying these metabolic flows is crucial to understanding the political economy and political ecology of biophysical sustainability.[8,9] The central feature of any social metabolism framework is that it allows for an integrated study of both flow of low entropy matter and energy on the source-side and degraded high-entropy matter and energy on the sink-side. Problems of ecological distribution and biophysical sustainability are often more pronounced on the sink-side. Indeed, the central feature of any conflict over environmental justice is the unequal distribution of resource flows and waste flows—in particular the fact that sections of the society that least benefit from resource flows bear the brunt of waste flows.[10,11,12] In the urban context, the flows of water and sewerage is a social metabolism problem that is fraught with vexed problems surrounding environmental justice as well as biophysical sustainability. Communities that least benefit from piped water often suffer from wastewater and sewerage discharge.[13]

3. BANGALORE'S WATER METABOLISM

The evolution of piped water infrastructure is well documented.[14] The principal source of surface water is the river Kaveri that is approximately 100 kilometers from the city and 500 meters below the city. Currently the city imports about 1,400 million liters a day (MLD) from Kaveri. To motivate the water metabolism framework that we develop here, consider the background water cycle. Bangalore is a sprawling city and covers an area of 800 square kilometers, and receives an average annual rainfall of 850 mm (millimeters). This translates to approximately 1,850 MLD. The river water imported by Bangalore represents over 75% of the rainfall that the city receives; or anthropogenic variables account for 43% of the total water throughput into Bangalore. If groundwater extraction is included, anthropogenic drivers dominate background rainfall driven hydrology.[15] This domination is complete once we consider water throughput from a metabolic perspective and include wastewater flows.

The water metabolism in Bangalore is not only driven by the aggregate throughput attributable to anthropogenic

[4]See for example, M. Ranganathan, ''Paying for Pipes, Claiming Citizenship: Political Agency and Water Reforms at the Urban Periphery,'' *International Journal of Urban and Regional Research* 38 (2014): 590–6.

[5]See for example V. Srinivasan, S.M. Gorelick, and L. Goulder, ''A Hydrologic-Economic Modeling Approach for Analysis of Urban Water Supply Dynamics in Chennai, India,'' *Water Resources Research* 46 (2010): W07540.

[6]M. Fischer-Kowalski and W. Hüttler, ''Society's Metabolism: The Intellectual History of Materials Flow Analysis, Part-1: 1860-1970,'' *Journal of Industrial Ecology* 2 (1998): 61–78.

[7]M. Fischer-Kowalski and W. Hüttler, ''Society's Metabolism: The Intellectual History of Materials.''

[8]P.W.G. Newman, ''Sustainability and Cities: Extending the Metabolism Model,'' *Landscape and Urban Planning* 44 (1999): 219–226.

[9]D. Malghan, ''On the Relationship Between Scale, Allocation, and Distribution,'' *Ecological Economics* 69 (2010): 2261–2270.

[10]J. Martinez-Alier, ''Social Metabolism and Environmental Conflicts,'' *Socialist Register* 43 (2007).

[11]J. Martinez-Alier, ''Social Metabolism, Ecological Distribution Conflicts, and Languages of Valuation,'' *Capitalism Nature Socialism* 20 (2009): 58–87.

[12]D. Malghan, ''A Dimensionally Consistent Aggregation Framework for Biophysical Metrics,'' *Ecological Economics* 70 (2011): 900–909.

[13]V. Mehta, R. Goswami, E. Kemp Benedict, S. Muddu, and D. Malghan, ''Social Ecology of Domestic Water Use in Bangalore,'' *Economic and Political Weekly* 48 (2013): 40–50.

[14]S. Narain and P. Pandey, *Excreta Matters: How Urban India Is Soaking up Water, Polluting Rivers and Drowning in Its Own Waste*, State of India's Environment 7 (New Delhi: Centre for Science and Environment, 2012). Also see V. Mehta, R. Goswami, E. Kemp Benedict, S. Muddu, and D. Malghan, ''Social Ecology of Domestic Water Use in Bangalore,'' *Economic and Political Weekly* 48 (2013): 40–50.

[15]*Cf.* Section 4 for estimates on groundwater extraction. No reliable data exists for groundwater. The official municipal boundaries of the city spans approximately 700 sq km, and the short-term average rainfall in Bangalore is 900 mm. We use these numbers in our analysis in Section 4.

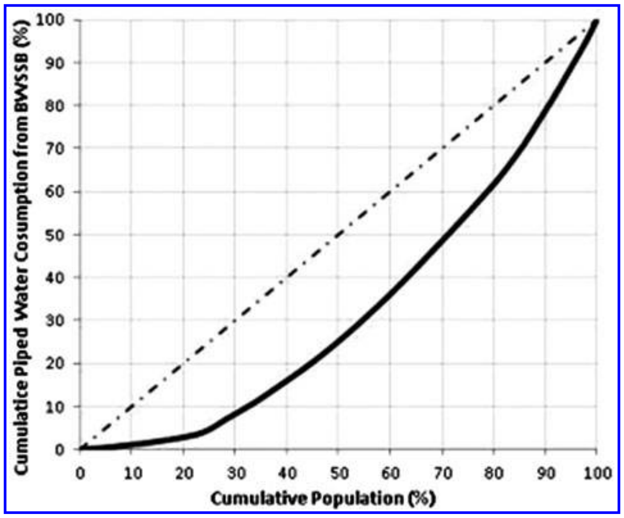

FIG. 1. Lorenz curve for domestic piped water supplied by the public utility, Bangalore Water Supply and Sewage Board (BWSSB). The Lorenz curve was calculated using administrative boundaries of the utility (27 subdivisions that lie within the jurisdiction of Bangalore; snapshot from March 2012). *Cf.* V. Mehta, R. Goswami, E. Kemp Benedict, S. Muddu, and D. Malghan, ''Social Ecology of Domestic Water Use in Bangalore,'' *Economic and Political Weekly* 48 (2013): 40–50, for computational details.

factors but also the (unequal) distribution of water flows between its over 8.5 million residents. In Figure 1 we sketch out the Lorenz curve for piped water availability in Bangalore using aggregate data from the public utility. The Lorenz curve in Figure 1 grossly understates the actual inequality in availability of piped water, as it does not take into account inequality within each of the 27 administrative subdivisions that make up the public utility.

A significant factor underlying the Lorenz curve in Figure 1 is the spatial distribution of piped water infrastructure. As the city expanded, the water infrastructure has not managed to keep pace despite periodic augmentation in supplies, especially in the rapidly growing periphery.[16] Figure 2 shows monthly data for total water withdrawal from river Kaveri between April 2008 and March 2014, along with historical augmentations of supply capacities since the 1970s. The data since 2013 show the latest and final Kaveri water augmentation—Phase 2 of Stage Four. The top panel in Figure 2 presents data as gross million liters per month (not accounting for leakage losses. The dotted lines in the top panel show the successive additions to piped water supply infrastructure. The bottom panel contextualizes the data by presenting data as gross water availability per person (measured as liters per capita per day, or LPCD). Despite withdrawing all the water allocated to urban drinking water use from the river (leaving nothing for other towns within the state that are located in the Kaveri basin), imported river water availability is currently at the 1970s level, and below 1990s, just before the economic and population boom of the last fifteen years (historical per capita water availability are once again shown as dotted lines in the bottom panel).

A central feature of water metabolism in Bangalore is the spatial variation in piped water availability. We describe this in Figure 3 and Figure 4. Between 2001 and 2011, much of the population growth has been driven by rapid rise of the periphery where water infrastructure is the least developed. Figure 4 shows the per capita consumption of piped water supplied by the public utility for the month of March 2011. As seen from the figure, there is a gross mismatch between population centers and piped water availability. Figure 3 adds a snapshot from March 2013 and helps illustrate the engineering and political economy constraints that renders utility supplied piped water a distant dream for a significant proportion of households in Bangalore. In 2013, the public utility shrunk its administrative boundaries such that it no longer covers the entire city. Despite significant supply augmentation, several peripheral areas of the city do not yet receive any piped water. The new administrative boundary represents an acknowledgement of the fact that with no more supply augmentation possible peripheral areas of Bangalore remain beyond the pale of piped water supply. Even in areas that are serviced by the public utility, the maximum average availability of water is little over 100 LPCD, well below estimated per capita consumption in Bangalore of about 150 LPCD. Thus, the central fact of water metabolism in Bangalore is that there is no part of Bangalore that is able to meet its entire domestic water needs through water supplied by the public utility.

Bangalore's experience is not atypical and consistent with numerous studies that describe the diversity of formal and informal, surface and groundwater sources used in Indian cities. These include utility piped supply, private wells and borewells, tanker supplies of groundwater from sources within and outside the city, bottled water, untreated water bodies, as well as neighborhood-scale micro utilities supplying groundwater.[17,18,19] Data on groundwater extraction in Indian cities is not systematically collected and even government sources acknowledge this as the key missing link in urban water accounting.[20] Indeed, there is not a single Indian city with quantitative extraction or aquifer depth data even as

[16]On the political economy of extending water supply to periphery of Bangalore, see M. Ranganathan, L. Kamath, and V. Baindur, ''Piped Water Supply to Greater Bangalore: Putting the Cart Before the Horse?'' *Economic and Political Weekly* 44 (2009): 53–62.

[17]V. Srinivasan, S.M. Gorelick, and L. Goulder, ''A Hydrologic-Economic Modeling Approach for Analysis of Urban Water Supply Dynamics in Chennai, India,'' *Water Resources Research* 46 (2010): W07540.

[18]V. Srinivasan, S. M Gorelick, and L. Goulder, ''Factors Determining Informal Tanker Water Markets in Chennai, India,'' *Water International* 35 (2010): 254–69.

[19]S. Misra and B. Goldar, ''Likely Impact of Reforming Water Supply and Sewerage Services in Delhi,'' *Economic and Political Weekly* 2008: 57–66.

[20]Government of India, Planning Commission, *12th Five Year Plan (2012–2017), Volume I* (2013), 162.

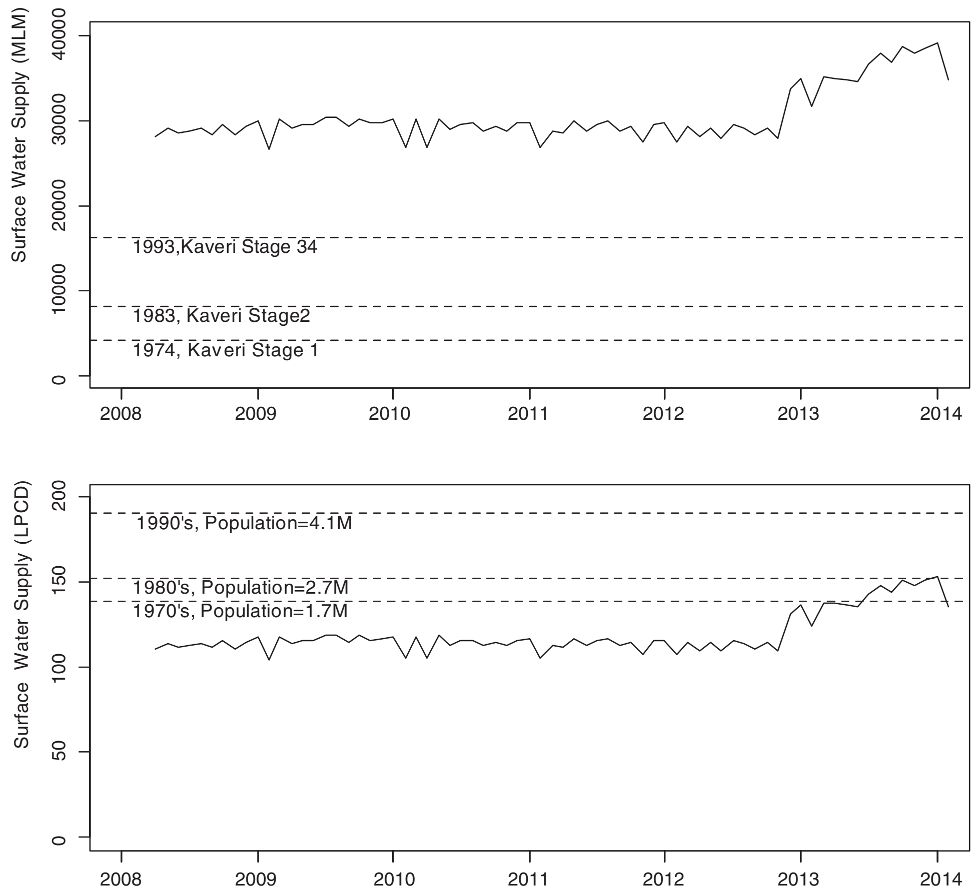

FIG. 2. Total surface water withdrawals from R. Kaveri (2008–2014). Dotted lines represent historical data. See text for further explanation.

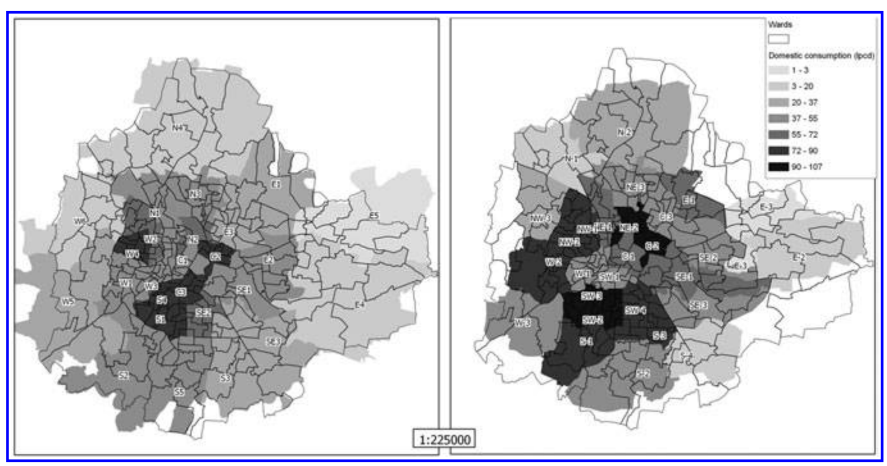

FIG. 3. Spatial variation in domestic piped water consumption. The left panel is a snapshot from March 2011 and the right panel is from March 2013. Ward boundaries are overlaid in black outline. See text for explanation. Note that the utility administrative boundaries have changed between 2011 and 2013.

qualitative and anecdotal evidence mounts on cities' increasing reliance on groundwater sources.

From a metabolic perspective that looks at energy and material flows on both the source-side as well as the sink-side, the wastewater and sewerage picture in Indian cities is alarming. Nationally the installed wastewater treatment capacity is only 30% of the excreta it generates. The Government of India officially recognizes that ‘‘even if the entire available capacity was utilized, 70% of wastewater would be released untreated.’’[21] Bangalore like many other Indian cities currently does not fully utilize its installed capacity for wastewater treatment.

[21]Government of India, Planning Commission, *12th Five Year Plan (2012–2017), Volume I* (2013), 163.

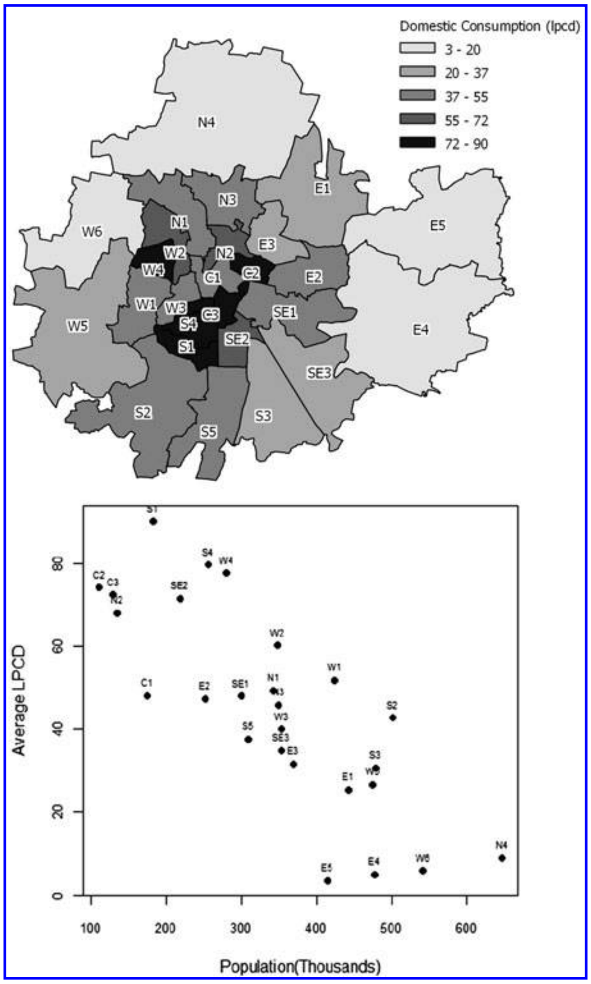

FIG. 4. Per capita Bangalore Water Supply and Sewage Board (BWSSB) domestic water consumption. The top figure shows the spatial pattern of domestic consumption of piped surface water supplied by BWSSB in the month of March 2011 (data from BWSSB). The same data is plotted against subdivision population in the bottom figure where the X-axis represents subdivision population in 1,000s. Charts reproduced from V. Mehta, R. Goswami, E. Kemp Benedict, S. Muddu, and D. Malghan, ''Social Ecology of Domestic Water Use in Bangalore,'' *Economic and Political Weekly* 48 (2013): 40–50.

4. SOCIAL HYDROLOGY OF BANGALORE

In this section, we show how a metabolic framework helps characterize Bangalore's hydrology as a tightly coupled social-ecological system.[22] We first demonstrate using a simple ''thought experiment'' lumped model of Bangalore that the city's groundwater hydrology is dominated by anthropological variables. In Figure 5, the basic water balance for Bangalore is depicted under both a hypothetical condition with no anthropogenic perturbation (left panel); and the altered state with groundwater pumping, surface water imports, pipe leakage, and return flows. In the ''natural'' state, 10% of rainfall ends up as groundwater recharge (computed as 63 mm/y in the first column of Table 1). In the right-panel of Figure 5, we depict the water balance altered by water imports (drawn to scale as it is of the same order of magnitude as rainfall); leakage from utility pipes, groundwater pumping, and return flows. To estimate the new water balance, we assume the overall leakage to be 30% and 80% return flows.[23] We further assume a per capita consumption of 150 LPCD to be met by a combination of utility supplied surface water and groundwater pumping. The results in Table 1 show how anthropogenic factors dominate water balance in Bangalore. First, groundwater recharge from leaking pipes is more than twice the rainfall recharge in 2011; and more than three times the rainfall recharge in 2014—the prima facie evidence for why all urban hydrology is social hydrology. When we include sink-side return flows, the background rainfall recharge is completely dwarfed by anthropogenic drivers. The simple lumped model is very sensitive to assumptions made about return flows. In Table 1 we have assumed that return flows recharge aquifers. With this assumption, in 2014, we end up with a positive state of elevated recharge (without considering pumping for non-domestic uses that constitute at least 60% of all groundwater pumping in Bangalore).

While the simple lumped model demonstrates how the city alters background groundwater hydrology, the city is not one homogenous box even from a hydrological standpoint (given Bangalore's hard-rock, low-yielding aquifer hydraulics). The spatial variation in social, economic, and political variables is even more pronounced. We also developed a spatially distributed groundwater flow model running under steady state conditions (using 2011 data from Table 1). The dynamics of water supply and domestic water use combined with groundwater hydrology points to significant spatial variations in groundwater head (depth) across the city. Our analysis shows that the domestic sector alone could cause elevated groundwater levels in the central

[22]See for example: L.A. House-Peters and H. Chang, ''Urban Water Demand Modeling: Review of Concepts, Methods, and Organizing Principles,'' *Water Resources Research* 47 (2011): W05401; S. Kenway, A. Gregory, and J. McMahon, ''Urban Water Mass Balance Analysis,'' *Journal of Industrial Ecology* 15 (2011): 693–706; and V Mehta, R. Goswami, E. Kemp Benedict, S. Muddu, and D. Malghan, ''Social Ecology of Domestic Water Use in Bangalore,'' *Economic and Political Weekly* 48 (2013): 40–50.

[23]See V. Mehta, R. Goswami, E. Kemp Benedict, S. Muddu, and D. Malghan, ''Social Ecology of Domestic Water Use in Bangalore,'' *Economic and Political Weekly* 48 (2013): 40–50 for for details on the lumped model assumptions. In 2011, the overall impact on recharge remained negative with and without including recharge from return flows. In 2014, however, artificial recharge with or without including return flows impacts the sign of the overall recharge. Without including return flow recharge, net recharge is negative; including return flow recharge makes net recharge positive. This demonstrates the sensitivity of the coupled system and how it can tip from one direction to another. Uncertainties about anthropogenic drivers of artificial recharge from return flows and pipe leakage are high—and our lumped model demonstrates how important these terms are to the overall water balance. The conceptual lumped model highlights the need to fill in this knowledge gap in urban water balance.

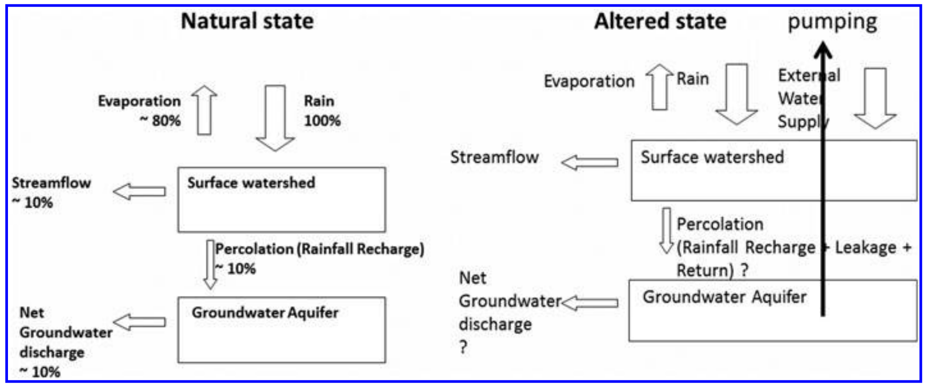

FIG. 5. Conceptual ''lumped'' model of urban water balance for Bangalore. See text for explanation.

parts of the city, and dropping levels in outer areas of the city, consistent with qualitative trends reported by the Central Ground Water Board.[24]

While the lack of high-resolution spatiotemporal data on well dynamics do not allow for a city-scale verification of our model results that strongly supports the social hydrology hypothesis, we present here data and evidence from more localized field studies to corroborate our findings. As part of the ongoing construction of a partially underground metro system in Bangalore, a careful study that combined dense sampling of well depth measurements from 400 locations in the central 20 square-kilometers of Bangalore with household water consumption surveys in a groundwater model provided evidence for the dominant role played by leakage from utility pipes.[25] This work showed how in the central parts of the city (where the public utility piped network is the densest) groundwater levels were shallow and affected by recharge from leaking pipes. Central Groundwater Board (CGWB) also reports a rise in groundwater wells in areas where Bangalore Water Supply and Sewage Board (BWSSB, the public utility) supply is available and where no significant development has taken place; whereas in a number of outlying areas without piped water supply, monitoring stations have dried up.[26]

Further corroboration of the social hydrology hypothesis comes from well depth data from wells monitored by the Department of Mines and Geology (DMG). In Figure 6, we consider three monitoring stations of DMG to illustrate how social hydrology drives groundwater dynamics in the city. The top panel in Figure 6 shows the location of these three monitoring stations in relation to two principal anthropological drivers—piped water infrastructure and population growth. Byadarahalli is a monitoring station in the western part of the city, and location in a ward where the population grew approximately 2.5 times between 2001 and 2011. The well hydrograph shows a downward trend since year 2000, consistent with the fact that groundwater pumping is the primary driver here. In the case of High Court monitoring station that is located in an area that is well served by piped water and also saw a modest decline in population, the expected upward trend in the well hydrograph is observed (pumping is less than total recharge). Finally, in Nagarvapalya, an area that is served well by piped water and where population has seen only modest increase, we see how background hydrology is not dominated by social hydrology.

TABLE 1. A LUMPED WATER BALANCE FOR BANGALORE DOMESTIC WATER

mm/yr	*Natural*	*2011 Estimate*	*2014 Estimate*
Rainfall recharge	63	63	63
Piped supply leakage	0	141	219
Net pumping	0	368	292
Return Flow	0	139	220
Net recharge (without return flow)	63	−164	−10
Net recharge (with return flow)	63	−25	210

All numbers are in mm/y change in groundwater levels. The first column is the water balance in the absence of any anthropogenic perturbations. The second column uses data from March 2011 and the last column used data from February 2014. See text for further explanation.

5. TOWARD METABOLIC URBANISM

At the heart of any environmental justice conundrum is the tight coupling between questions surrounding distribution and biophysical sustainability. Nowhere is this more evident that in the rapidly growing urban centers of the global South.[27] In this article, we demonstrated the

[24]Ministry of Water Resources, *Ground Water Scenario in Major Cities of India*, Technical report, Central Ground Water Board (2011). *Cf.* V. Mehta, R. Goswami, E. Kemp Benedict, S. Muddu, and D. Malghan, ''Social Ecology of Domestic Water Use in Bangalore,'' *Economic and Political Weekly* 48 (2013): 40–50 for details of the distributed model used.

[25]M. Sekhar and M.S.M Kumar, *Geo-hydrological Studies along the Metro Rail Alignment in Bangalore*, Technical report, Bangalore: Department of Civil Engineering, Indian Institute of Science (2009).

[26]Ministry of Water Resources, *Ground Water Scenario in Major Cities of India*, Technical report, Central Ground Water Board (2011).

[27]P.W.G. Newman, ''Sustainability and Cities: Extending the Metabolism Model,'' *Landscape and Urban Planning* 44(1999): 219–226.

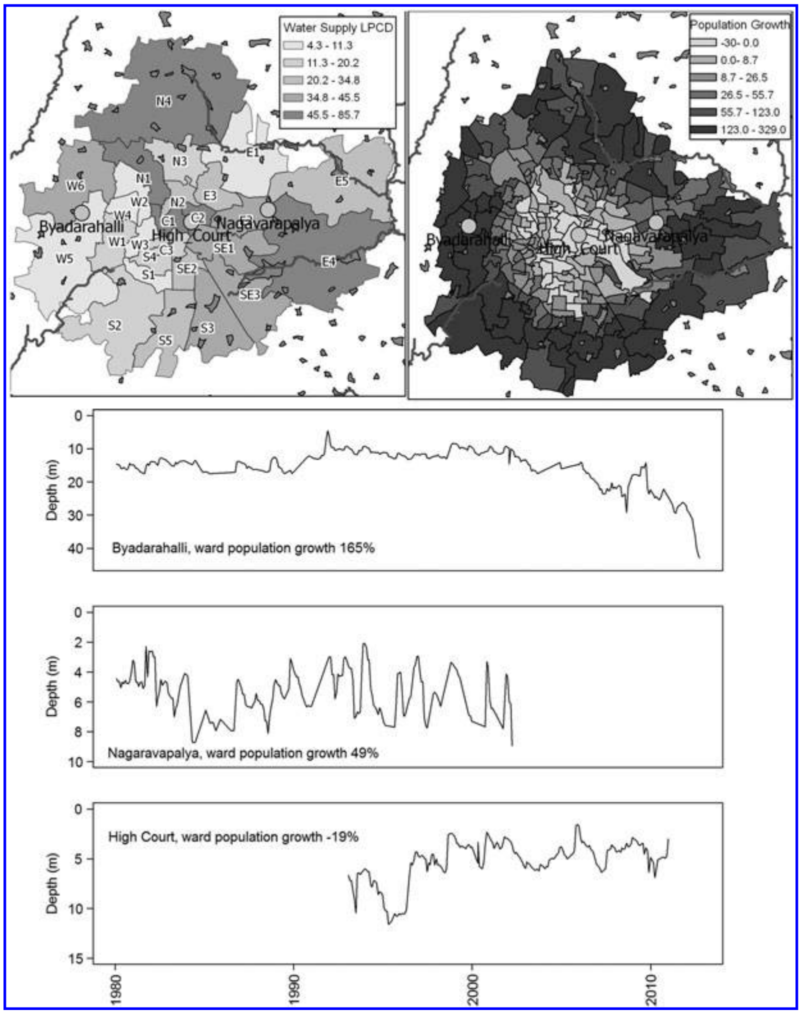

FIG. 6. Evidence for social hydrology. The bottom panel is well hydrographs from three stations monitored by Department of Mines and Geology (DMG). The top left map overlays water features in the city on top of piped domestic water consumption (March 2011 data, liters per capita per day [LPCD]). The top right map records ward level percentage population growth between 2001 and 2011. The three DMG stations were selected to illustrate differing outcomes form social hydrology. In both Bydarahalli and High Court, anthropogenic signals dominate water balance albeit producing outcomes in opposite directions. In Nagarvapalya, the water balance is not dominated by social hydrology. See text for further explanation.

usefulness of the metabolic framework to describe and analyze the complex relationship between social, political, economic, and ecological variables in an urban context. The social hydrology of Bangalore demonstrates how questions of justice are inseparable from even the technical characterization of urban water balance.

Between 2011 and 2013, the public utility increased its withdrawal from river Kaveri, going from 900 MLD to 1,400 MLD. During this period, the administrative boundaries of the utility shrunk so that it does not cover peripheral parts of the city even while Electronics City, the ground zero of India's information technology revolution and home to its fabled software export powerhouses, was brought under the ambit of the utility. From an engineering perspective the infrastructure needed to pipe water to Electronics City (that lies outside the administrative boundaries of the city) is no different from supplying piped water to other peripheral areas. Thus between 2011 and 2013, Bangalore not only appropriated *all* the remaining water from the river basin allocated to urban centers in the state of Karanataka but also effected a change in the distribution of water within the city.

The technical relationship between piped water transmission and distribution is well characterized.[28,29,30] Integrating social hydrology models within a social metabolism framework helps clarify the linkages between biophysical sustainability, distributive justice, and economic efficiency. India is already the world's largest consumer of groundwater, accounting for 25% of global extraction[31] (that grew ten-fold between 1950 and 2010, from 25 km^3 to 250 km^3). The biophysical pressures on further withdrawals provide the larger context for conflicts

[28] S. Kenway, A. Gregory, and J. McMahon, ''Urban Water Mass Balance Analysis,'' *Journal of Industrial Ecology* 15(2011): 693–706.

[29] T. Hayashi et al., ''Effects of Human Activities and Urbanization on Groundwater Environments: An Example from the Aquifer System of Tokyo and the Surrounding Area,'' *Science of the Total Environment* 407 (2009): 3165–72.

[30] Y.Y. Kim, K.K. Lee, and I. Sung, ''Urbanization and the Groundwater Budget, Metropolitan Seoul Area, Korea,'' *Hydrogeology Journal* 9 (2001): 401–12.

[31] N. Gilbert. ''Water under Pressure,'' *Nature* 483 (2012): 256–257.

between different sections of the society. In the urban context, import of vast quantities of surface water further modifies the environment (especially when one includes the enormous energy costs of pumping water). Policy measures that reduce a complex problem with equity and biophysical sustainability dimensions to the question of economic efficiency and full cost pricing have usually overlooked questions of justice.[32] The metabolic framework helps uncover how urban relations are shaped by access to basic domestic water as well as by impact of wastewater discharge.[33] Ongoing fieldwork in Bangalore indicates that access to water and sanitation services are likely an important driver of social mobility—especially among slum dwellers in the city.[34] The case study of water metabolism in Bangalore suggests that social scientists, ecologists, and urban studies scholars will do well to consider ''metabolic urbanism'' as one of the primary portraits of relationship between society and environment in rapidly burgeoning cities of the global South.

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AUTHOR DISCLOSURE STATEMENT

The authors have no conflicts of interest or financial ties to disclose. VKM and DM designed the study. RG assisted with data collection and analysis. VKM performed the geographic information systems (GIS) analysis. VKM and DM performed the statistical analysis. EKB contributed scenarios data, and SM contributed groundwater data. VKM and DM wrote the final paper that was reviewed and approved by all authors. This research has been approved by the Institute Ethics Committee at the Indian Institute of Management Bangalore.

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[32] M. Ranganathan, L. Kamath, and V. Baindur, ''Piped Water Supply to Greater Bangalore: Putting the Cart Before the Horse?'' *Economic and Political Weekly* 44 (2009): 53–62.

[33] M. Ranganathan, ''Paying for Pipes, Claiming Citizenship: Political Agency and Water Reforms at the Urban Periphery,'' *International Journal of Urban and Regional Research* 38 (2014): 590–6.

[34] On the evolution of slums in Bangalore *cf.* A. Krishna, M.S. Sriram, P. Prakash, ''Slum Types and Adaptation Strategies: Identifying Policy-relevant Differences in Bangalore,'' *Environment and Urbanization* 26 (2014): 1–18.