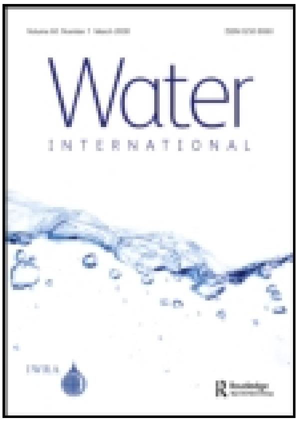

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Examining the emerging role of groundwater in water inequity in India

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Examining the emerging role of groundwater in water inequity in India

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This article addresses a gap in the water equity literature arising from the simultaneous use of surface water and groundwater in India. Using two diverse case studies – one agricultural (Kukdi) and one urban (Chennai) – we demonstrate how gaps in planning, design and policy exacerbate inequity. Groundwater abstraction from user wells allows wealthier users to both free-ride and capture a greater share of the resource. By converting a public resource to a private one, it worsens inequity and jeopardizes the sustainability of water projects. The article suggests that better monitoring, inter-agency coordination and rethinking water entitlements and norms are needed for going forward.

Keywords: water; groundwater; conjunctive; equity; entitlements; India

Introduction: equity in water issues in India

There is a rich database of case-study research on water conflicts and equity issues in India. These cover a wide range of issues, ranging from equitable allocation of inter-state rivers to debates over large dams, where civil engineers' claims of 'efficiency' of large dams have been shown to mask the fact that there are winners and losers in the beneficiary and displaced communities (Duflo & Pande, 2007; Mehta, 2007; Thakkar, 2004), as well as inequities between head-end and tail-end users in surface-water canal-irrigated projects (Kulkarni, Sinha, Belsare, & Tejawat, 2011; Mollinga, 2008; Patil, 1995). Reviews of watershed development projects, promoted as a benign alternative to large dams, have also argued that farmers are not passive observers of watershed projects; they wield their power to influence the location and size of watershed structures and they may generate inequities between upstream and downstream users of water (Batchelor, Rama Mohan Rao, & Manohar Rao, 2003; Glendenning, van Ogtrop, Mishra, & Vervoort, 2012; Kerr, 2002; Narayana, 1987). Similarly, within the groundwater literature there is ample evidence that richer farmers are able to drill deeper (Shah, 1988) and thus capture much of the available groundwater resource. Most previous analyses of equity in the water sector are confined to specific scales and contexts. The problem is that unlike other natural resources like land or forests, water is a mobile resource that exists in multiple interconnected forms – e.g. groundwater and surface water – often with differential systems of rights and regulations. Few studies have analyzed the equity dimensions arising from the multi-dimensional, multi-scalar nature of water.

This article addresses a particular gap in the water equity literature arising from the simultaneous use of multiple forms of the resource: surface water and groundwater. The

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existence of water as a visible surface-water component and an invisible groundwater component produces unique challenges in the management of water systems. Water policies in India continue to be divided along groundwater–surface water lines, resulting in "hydroschizophrenia" (Llamas & Martínez-Santos, 2005). While hydrologists have long pointed out interconnections between surface water and groundwater, for example that groundwater pumping often occurs at the expense of surface-water flows (Bredehoeft, 2002; Sophocleous, 2000), such analyses are largely missing from Indian case-study research (Ranade, 2005). Pumping technologies are becoming cheaper, and electricity more accessible; this has led to an explosive growth of groundwater use in India. While the resulting declines in groundwater levels in India have been widely discussed (Moench, 1992; Rodell, Velicogna, & Famiglietti, 2009; Shah, Roy, Qureshi, & Wang, 2003), studies that link groundwater pumping to declining flows in rivers due to loss of baseflow remain scarce. To our knowledge, the social dimensions of conjunctive use of groundwater and surface-water resources have not received any attention.

This article is organized as follows. First we explore two case studies – one involving rural agricultural water use, and the other urban water use. In the next section, we discuss the lessons learned from the two case studies. In the following section we discuss the implications for policy and in the final section we propose a way forward to examine water governance issues in the context of the current expansion in groundwater use.

Case studies

Agricultural groundwater use: the Kukdi Major Irrigation Project

Public-sector irrigation is rapidly changing in India, and the state of Maharashtra is no exception to this. Surface projects that were designed independently of groundwater are increasingly being used to harness groundwater. This has been a gradual ongoing process which has shifted benefits from public to private. There is enough evidence across the country that shows expansion of groundwater irrigation and reduction in the area under surface irrigation (Janakarajan & Moench, 2006). Public water sourced through gravity flows is increasingly being sourced through pump irrigation, either through lifts on canals or through groundwater in command areas (Shah 2011).

Poor cost recovery; centralized management and political interference; weak administration; overemphasis on repair and rehabilitation rather than reforming irrigation bureaucracy; lack of participation of users, etc., have contributed to poor performance of public-sector irrigation. However, what is insufficiently discussed is the burgeoning groundwater economy in the canal commands, which has changed the face of public-sector irrigation. Increasing use of groundwater in canal commands has huge implications for equity, both in terms of direct access to water and decision making in its use and allocation, but also indirectly in terms of changing land and labour relations. Figure 1 shows the increasing penetration of groundwater into canal commands in Maharashtra. Of the total irrigated area in canal commands, that irrigated by wells increased from 26% in 2000–01 to 37% in 2010–11, while that irrigated by canals decreased from 73% to 62% in the same period.

This section discusses the case of the Kukdi Major Irrigation Project in Maharashtra to show how the benefits of canal commands are increasingly accumulated in the hands of the few, with an increasing number of wells in command areas, and potentially serious implications for equity. The Society for Promoting Participative Ecosystem Management (SOPPECOM, 2012) carried out a study to understand whether the water entitlement

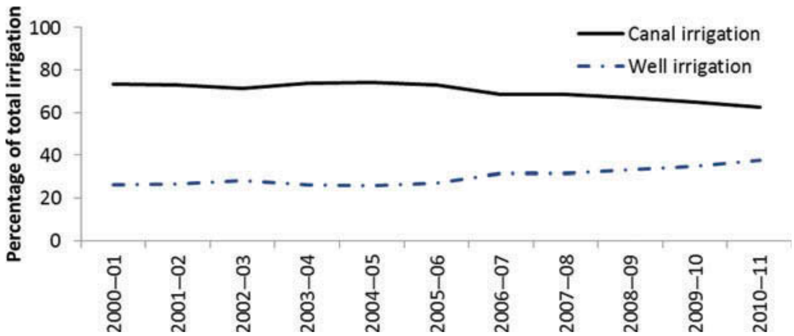

Figure 1. Surface-water and groundwater irrigation in canal command areas in Maharashtra show a decline in canal irrigation and an increase in well irrigation. Source: Irrigation Status Report 2010–11, Water Resources Department, Government of Maharashtra.

programme – a part of the reform process in the irrigation sector in Maharashtra – was in fact promoting the much-promised equity in water distribution. A water entitlement is defined as an authorization to use water and is issued by the water regulatory authority or the river-basin agency. It is relevant for surface storages and evolved through a set of parameters that include designed utilization in three seasons, land within command areas, river losses and gains, and evaporation. Water entitlements for agriculture are worked out after allocations for the other two categories, industry and domestic use, are worked out. Importantly, use of groundwater in canal commands is not taken into account while working out entitlements. Thus, the key finding was that the programme was completely misplaced in the current context of canal irrigation in Maharashtra, which was characterized by the infiltration of groundwater abstraction. The study was done in two irrigation projects in Maharashtra; one of these, the Kukdi Major Irrigation Project, is discussed here.

The Kukdi Major Irrigation Project

The Kukdi project is a multi-river, multi-reservoir and multi-canal project. Its 156,000 ha command area cuts across three districts of north (Ahmednagar) and west (Pune and Solapur) Maharashtra. It has five dams and a dense network of right- and left-bank canals, distributaries, and finally the command areas at the minor level. In short, it has several levels at which water is distributed, and these levels cut across the political and physical boundaries of the region, making it a complex project to govern.

This discussion draws from a study by SOPPECOM (2012) that looked at the command areas of several water user association (WUAs), including insights from two WUAs which are located on a single distributary of the Kukdi project in Ahmednagar District. They are located at the middle and the tail end of the distributary and give a fair understanding of how water distribution is affected by location and how people at different locations cope with their locational advantages and disadvantages.

The Sahakari Pani Vapar Sanstha (Sahakari Co-operative WUA) is a tail-end WUA and currently does not receive any water from the Kukdi project despite being in its command. The WUA was formed 10 years ago, and although it does not receive any water from the system, it continues to function as a co-operative. Its command area is 200 ha, and its membership is 100–150 farmers. Despite the lack of surface water, the command area was lush green. Further probing revealed that the command area of this WUA has a large number of wells, which benefit about 90% of the farmers in the winter season. However, summer crops are grown by only the 20% of farmers who are able to pump water from the adjacent river. Drip irrigation is practised in about 50% of the area; the major crops are onion and pomegranate.

The Dharmanath Pani Vapar Sanstha (Dharmanath Co-operative WUA) is a middle-reach WUA with a command area of 465 ha and a membership of 324 farmers. This middle-reach WUA is better off than the tail-end one. However, not more than 100 ha of it is covered by flow irrigation. Only about 15–20 of the 324 farmers benefit from flow irrigation. Like the tail-end WUA, this one had several wells in its command area: bore-wells that were below 300 ft., and numerous dug wells. There were also a series of pipelines from the streams to the farms. The command areas were green, despite the low demand recorded for flow irrigation. Bananas, pomegranates, onions and sugar-cane were grown, mostly irrigated through a drip network. Low water demand for flow irrigation also meant low recovery of water charges. The complaint from the farmers was that in the last 10 years or so the command area has received water for not more than 12–15 days each year, which amounts to about 2–3 rotations in the entire year, where ideally there should be a minimum of 4–6 in each of the seasons of winter and summer.

In both the WUA commands there were similar responses to the uncertainties associated with flow irrigation, although there were some variations due to the locational advantage in the middle-reach WUA. In the tail-end WUA, there was no hope that the flow-irrigation system would ever work for them. The head and the middle-reach WUAs were drawing most of the water, depriving their own tail-end users in the process. As a result of this, many farmers opted out of the system and started setting up their own systems, either building river lifts, digging wells or going for bore-wells. This provided them some amount of assured water supply and the much-needed control over water.

The middle-reach WUA benefitted some of the head-end farmers and thus did not opt out of the system completely but innovated and improvised by shifting to pump irrigation either through ground or the closest surface source like the river or streams. Most of the wells in the command of this WUA are located in these streams, where water is freely lifted from canals or delivered through channels or pipelines made by the landowners. Consider the case of Sandeep Salke, a prosperous farmer who harnesses canal water from a stream nearby. He owns 40 acres of land, and is a member of two WUAs, but pays no water bill to either since he does not directly benefit from flow irrigation. Instead, he chose to lay a pipeline from a stream 4–5 km away to irrigate his 40 acres. He depends on the canal flows to recharge the stream from which he draws water. This is how he ensures his water security and control – the public resource becomes a private one for those who can afford to harness it. This is largely the story of the few prosperous farmers on this system. Others are direct beneficiaries in the sense that they take the canal water either into their wells directly or soak their land with water to recharge their wells. Both the WUAs – one better located in the distributory and the other very unfavourably located – have shifted over to groundwater and/or lift irrigation, both of which are in the private domain, offering better water control for the farmers. However, we have seen in the cases of both WUAs that the shift to the private domain was made possible by a large public investment in the form of a surface irrigation project.

The reasons for these shifts are manifold, and the most evident one expressed by the farmers is the poor functioning of surface systems, which do not offer any water security to most farmers, thus forcing some farmers – mostly small farmers with no wells in the command areas – to move out of the system, or those with wells and better resources to innovate and improvise, converting the public resource into a private one. There has been a general discontent about the number of rotations and about water not released per the demands of the WUA. The canal inspectors and section officers we spoke to in Kukdi agreed with this observation and said that expansion of the command area without due attention paid to the increase in river, canal and reservoir lifts means that command-area entitlements are low and frequent rotations are not feasible.

Many of the older farmers narrated how the situation was far better 20 years ago, with more than 70–80% of the commands being irrigated by surface flows. Then, well irrigation was seen as a more expensive option, and people preferred the gravity flows. However, according to an irrigation officer, demands on the water gradually increased from other non-irrigation uses, particularly domestic water for the growing urban areas and also industries. Political pressure in the head reaches of the Kukdi project also led to construction of a series of weirs on the river where dam waters were released and later lifted by the farmers in those locations. In another section, the officer informed us that 50% of the command under his jurisdiction draws water from river lifts. Thus, the landscapes of the command areas were changing rapidly.

Cropping patterns changed with better markets, infrastructural supports, and subsidies offered to horticulture, floriculture, etc. Cereals were thus replaced by crops that promised better 'value' and required very high control over water. Drip irrigation thus became a favoured form of irrigation in these areas. Most farmers within the commands have a well or a bore-well.

We see that the whole nature of flow irrigation is changing. These systems were designed to operate independently of groundwater interactions. Today, groundwater has become an important element in the system, with potentially far-reaching implications. Earlier, only a small number of farmers had wells. Now almost all farmers in the command have wells. More and more farmers are relying on wells and looking at flow irrigation as a supplement, mainly as a means of recharging their wells. The uncertainty created by lack of information, and inability to provide sufficient number of rotations due to over-extended commands, has exacerbated these trends in Kukdi. The turnover to WUAs has in fact led to an increased informalization of the system, which has also led to concentration of irrigation and increasing exclusion of farmers.

Insights from the Kukdi case study

The study provides insights not only about the concentration of water but also about the deep-seated changes that are underway in command-area irrigation. These changes are a result of changing irrigation policies but also of shifts in agricultural and land-use policies. Crop patterns have been changing, and more efficient methods of irrigation such as drip and sprinkler have also meant that farmers prefer to receive much of their water as groundwater recharge, which is recharge as a result of canal flows, rather than direct flow application. This has made for sharpening inequalities between head and tail, within the system at all levels. The study shows that the pump-irrigation economy has in fact taken over the surface-irrigation systems, with serious implications for equity within the command areas of canals but also across sectors: domestic, agriculture, and industrial users. The head reaches of canals are able to extract both surface water and groundwater, forcing the tail-enders to gradually opt out of the public system. Flow canals are increasingly being used as recharge canals by those who have the ability to combine groundwater and surface water, thereby increasing their water security and control. Tail-enders are increasingly being thrown out of the system. Small landholders within commands with no wells are increasingly moving out of agriculture, and those at the tail end with proximity to rivers are going in for lift irrigation, for which the recurrent costs of electricity are very high. Apart from the inequities that are directly linked to access to water, shifts in cropping patterns, or alternatively reallocations in water from subsistence crops to commodity crops, alter the arrangement in land, water and labour relations.

Urban groundwater use: Chennai

As India urbanizes, one of the major challenges will be that of supplying water to its burgeoning urban population. Traditionally, urban water supply has been conceived to be about centralized piped water schemes. Most water supplied to large metropolitan areas is sourced from surface-water reservoirs (though some smaller towns have piped schemes sourced from bore-wells). Self-supplied groundwater sourced from private wells has hitherto played a very small role in formal government policy on urban water supply, although this is changing. For the purposes of this article, the main distinction drawn is between centralized, public, surface-water-based supply and decentralized, private, groundwater abstraction.

Official norms on how much water urban dwellers *ought* to get are typically developed from the perspective of designing and financing piped supply infrastructure. Several organizations and expert committees, such as the Central Public Health and Environmental Engineering Organisation, National Master Plan India – International Drinking Water Supply and Sanitation Decade, and the National Institute of Urban Affairs, have proposed norms for basic infrastructure and services. These norms vary by size and class of urban settlement and approach to urban water supply. The norms are based on a per capita estimate of the water needs of a 'typical' urban dweller, with provisions to account for industry and commercial water use and for pipeline leakage.

Recent surveys of water users, however, reveal a very different picture. Groundwater is playing an increasingly important role in urban water supply. Several studies of Indian megacities (Shaban & Sharma, 2007; Zérah, 2000) have shown that between 25% and 80% of households rely on private wells for some portion of their water needs. The implications of this expansion of urban groundwater use and piped supply–groundwater linkage and consequent implications for revision of urban supply norms have yet to be understood.

Most government documents do not formally acknowledge the role of groundwater in meeting urban water demand, although recently there have been some indirect references. The limits to meeting urban water demand through water imported through massive inter-basin transfer schemes are increasingly being recognized. The recent 12th Five Year Plan calls for a greater reliance on "local sources" (Shah, 2013), including groundwater. The high-level Zakaria Committee (1963) recognizes that urban supply comes at a cost and makes provisions for differential abilities to finance urban infrastructure as well as the feasibility of augmenting supply with local groundwater. The committee notes that in small towns it would be possible to meet certain water uses such as gardening or washing of clothes from local sources such as wells, lakes and rivers, which would not be possible in bigger towns. The committee acknowledges the role of self-supplied groundwater mainly to justify differences in infrastructure investments in small towns versus large cities. Beyond this, there is little mention of the role of groundwater in providing urban water security. Importantly, none of the recent policy documents examine the implications of the increased reliance on local sources or the institutional changes needed.

Similarly, the urban rainwater harvesting movement in India is about recharging local aquifers. Many cities such as Chennai and Bangalore now have rainwater harvesting laws which require households and commercial and institutional establishments to capture rainwater collected on the roof and direct it to infiltration pits on the property. In most cases, the urban water utility or the urban development authority is charged with enforcement of the law. The enthusiasm for rainwater harvesting is an implicit acknowledgement that a portion of urban water needs will be met from groundwater via private wells. However, despite the passage of such laws there are no noticeable changes in design of urban water norms or institutions monitoring groundwater. Urban water utilities continue to plan and build projects to import, treat and distribute 135 litres per capita per day to households with piped connections.

Case study of Chennai, India

The role of groundwater in increasing inequity is analyzed in an urban context using a case study of Chennai (formerly Madras), India's fourth-largest city. According to the 2011 census, about 7 million people reside in the urban agglomeration, which includes peri-urban areas, towns and villages. The water utility, Metrowater, supplies mainly the municipal area; supply is currently being expanded to outlying suburbs. The water utility supplies water from rain-fed reservoirs and well-fields outside the city (Metrowater website, http://chennaimetrowater.gov.in/departments/operation/developwss.htm) as well as from inter-basin transfer projects – the inter-state Telugu Ganga Project and the intra-state Veeranam project – and more recently from desalination plants.

Although only 5–10% of the city's centralized piped water is sourced from groundwater (from well fields to the north), private well supply is much larger. A large fraction of households have private wells. Two large household surveys, conducted in 2004 and 2006, respectively, suggest that 60–70% of Chennai's households use private wells to supplement water. Similarly, ward-level 2001 Housing Census data from Chennai show 46% of households depending on groundwater as their primary source of drinking water, although this fraction varied spatially throughout the city. Households access groundwater directly through their own private wells as well as indirectly through the private tanker market. The conflicts between tankers and peri-urban villages are well documented and well addressed elsewhere (Janakarajan, 1999; Ruet, Gambiez, & Lacour, 2007). However, because tanker water is expensive, it typically accounts for only a small fraction of the urban water demand. Therefore, this article focuses only on the component of groundwater use arising from direct abstraction of groundwater via private wells.

Groundwater plays a critical role in Chennai's overall water supply. It is an important supplementary source of water in dry months and drought years. For instance, when Chennai suffered from a severe multi-year drought in 2003–2005, Chennai's reservoir system dried up completely. This occurred both because of the lack of inflows due to the failed monsoon as well as the failure of the inter-state Telugu Ganga project to deliver water. As reservoir levels dropped, piped supply was curtailed and then completely halted for a period of almost 12 months (Srinivasan, Gorelick, & Goulder, 2010a). Households turned to their own wells to augment supply. This curtailment of piped supply had a dual effect on the aquifer: extraction increased, and recharge from leaky pipelines dropped; the water table fell approximately 8–10 m. Many wells went dry. As households lost access to both of their lowest-cost sources of water, wells and piped supply, they were forced to purchase expensive water from private tankers and suffered losses in well-being.

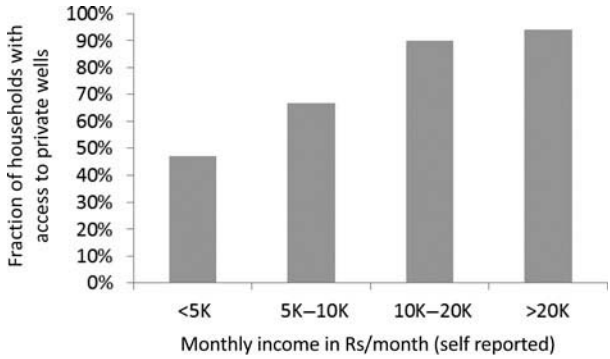

Figure 2. Private well ownership correlated with income per a household survey of ~1500 households in Chennai conducted in 2006 (Srinivasan, 2008).
Note: 1 Rupee ~ 0.022 USD in 2005.

Everyone lost access to piped supply during the 2003–2004 drought, but the households that suffered the most were the ones whose wells also went dry (Srinivasan et al., 2010a).

The Chennai case study demonstrates the welfare implications of this massive exploitation of groundwater. But these welfare implications were not uniform: middle- and upper-income households were more able to invest in private water systems of increasing complexity, particularly deep bore-wells. The Chennai household survey data (Figure 2) corroborate this: unsurprisingly, well ownership is correlated with household income. A significant fraction of household water was sourced from groundwater, and richer households were able to consume more because they had better access to *both* groundwater and piped water. Indeed, even in a wet year like 2006, household survey data show that people with private wells used significantly more water than people without wells (Table 1). A previous household survey conducted during the severe 2003–2004 drought showed that the poorer households lacking piped connections were the hardest hit as water tables fell and they lost access to shallow bore-wells (accessed via hand pumps), which went dry (Vaidyanathan & Saravanan, 2004). The only households that were able to access water cheaply were those with deep, productive bore-wells. Overall, wealthier households were more able to diversify and sustain consumption levels in all periods, but especially during droughts.

Although Chennai Metrowater was proactive in supplying water via tankers to slum areas, slum households were completely dependent on the vagaries of tanker supply. Interviews with local residents suggest they developed mechanisms of collective action to lobby Metrowater officials to secure a lifeline supply of tanker water, but at considerable expense of time and money. As a result, water use tended to be inequitable across income classes. One insight from this is that private well abstraction is not something that a water

Table 1. Differential consumption by well-owning versus non-well-owning households in 2006 (a wet year).

	Water use (litres per capita per day)
Households with piped supply and wells	133
Households with no piped supply, only private wells	78
Households with no piped supply or wells	35

Source: Srinivasan et al. (2013).

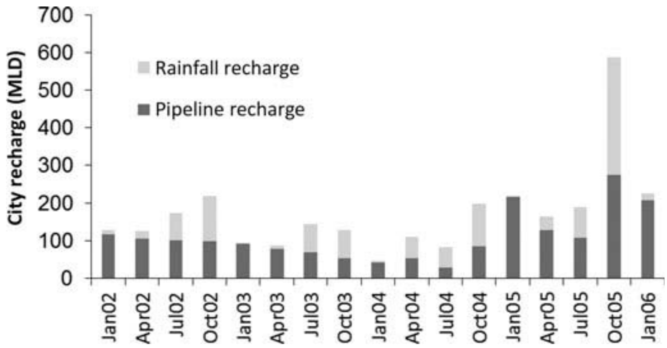

Figure 3. Leakages from the public delivery system constitute about half of the total recharge into the aquifer. Based on a groundwater model; model development and calibration are described in Srinivasan (2008).
Note: MLD, milliion litres per day.

utility can control for. It cannot be addressed easily by 'managing' the resource differently, since the utility cannot control who abstracts groundwater, when, or how much.

Furthermore, analysis shows that access to groundwater worsened existing inequities in public supply. Overall, groundwater played an important role in 'buffering' consumption during dry seasons and multi-year droughts, but groundwater availability was biased by piped supply availability. A groundwater model of Chennai (Srinivasan et al., 2010a) showed that leakage from pipelines was a significant contributor to groundwater recharge and availability, contributing almost 50% of the urban recharge (Figure 3). As a result, the neighbourhoods that receive plentiful piped supply are also the ones with shallow groundwater levels. In other words, the use of groundwater amplifies existing inequities in piped water distribution.

The case study showed that the groundwater aquifer essentially functioned as a substitute for surface-water storage, but with very different legal and institutional controls. Chennai has not been able to increase its surface-water storage capacity to keep pace with population growth. Analysis of Chennai's water reservoir system indicates that reservoir storage is extremely constrained. The city does not really have the capacity to store either the peak monsoon flows or the Telugu Ganga project imports. The result is that in wet periods, the Metrowater utility expands its hours of supply; much of this water leaks out from the ageing piped network and recharges the aquifer. In dry periods, piped supply is cut back, and users turn to their private wells to meet their needs. Thus, the water is abstracted back via private wells. In effect, the aquifer plays the function of a balancing surface-water reservoir. The net result of this is an unintentional switch from public to private supply during droughts. The water which was meant to be supplied to all consumers through the public supply system is now only available to users who have invested in bore-wells.

The Chennai case study also raises questions about the long-term sustainability of public water utilities. Private wells constrain how much a water utility can charge for water, with implications for its financial sustainability. The marginal cost of extracting water from a bore-well works out to INR 5 to 7 per kL. In contrast, the long-run marginal cost of water from new sources could be as high as INR 45/kL (e.g. in the case of Chennai's desalination plants). Metering water and charging more to recover a portion of the cost of piped water delivery has long been suggested to control demand and to ensure the long-term financial sustainability of the public water supply. However, if the water utility were to greatly increase water charges, the wealthier households with bore-wells could opt out of the system altogether, choosing to rely partly or entirely on privately abstracted and treated groundwater. Only the poorer users would be dependent on public supply, severely straining the financial viability of the water utility. It should be pointed out that this is not intended to imply that private wells are undesirable. Indeed, previous studies show that rainwater harvesting and dependence on local water sources is desirable. However, private groundwater abstraction needs to be accounted for in planning, designing and managing urban water systems (Srinivasan, Gorelick, & Goulder, 2010b).

Insights from the Chennai case study

The Chennai case study highlights the critical role that groundwater plays in buffering urban consumers against drought and dry seasons. There is an increasing reliance on private wells as public supply remains unreliable. The problem is that this expansion in groundwater use via private wells has exacerbated existing inequities in access to water for domestic needs – partly through differential well ownership rates and partly because leaky pipelines recharge groundwater more in wealthier neighbourhoods, which also get more hours of piped supply. However, existing government regulations take a rather contradictory approach to self-supplied groundwater. On the one hand, rainwater-harvesting mandates implicitly assume that self-supplied groundwater will play a major role in achieving urban water security. On the other hand, design standards and urban water supply norms largely ignore this. To ensure equitable and sustainable access to urban water, it is critical that policy makers acknowledge the role of self-supply.

Discussion

The two case studies presented in this article highlight a trend that is being observed throughout India: the substitution of publicly supplied surface water by privately abstracted groundwater. The case studies bring to light problems with current policies arising from this.

First, groundwater expansion *complicates water entitlements*. Current policies on water entitlements and norms on water allocation – both within and across sectors – fail to consider conjunctive water use. In the agricultural sector, many states are considering creating water entitlements based on surface-water storages, assuming a particular pattern of surface-water use as independent of groundwater. This is problematic because rights to groundwater and surface water are treated very differently. While entitlements are created to surface-water resources, groundwater remains open access and unregulated. Landowners are entitled to abstract as much groundwater as they can – the abstraction is unmetered – and at the same time, electricity is free for farmers. The equity implications arising from this expansion of groundwater use apply not only to other groundwater users but to surface-water entitlements as well. Similarly, in urban areas, current urban supply norms continue to focus exclusively on public piped water delivery, completely ignoring the large component of urban water use that is groundwater-based.

Second, current policies fail to acknowledge the interconnectivity of groundwater and surface water that *exacerbates inequitable allocation of water*. Both case studies show how losses from the public delivery system result in recharging wells. In the Kukdi case study, private wells allow head-end farmers to further consolidate their capture of the resource. In the Chennai case, wealthy households can augment unreliable piped supply with self-supply from their own wells, while poorer users cannot. Drawdowns by users with deep bore-wells cause the water table to drop, depriving the nearby slums that are dependent on shallow bore-wells and hand pumps.

Third, groundwater expansion necessitates *different forms of monitoring and regulation*. Much of the formal policy addressing equity – both in urban and rural areas – is focused on centralized surface-water schemes, which are easier to track, monitor and regulate. Whereas centralized piped supply schemes are planned, financed and controlled by government agencies, private wells are planned, financed and controlled by individual households. The problem is that groundwater is difficult to quantify because it is extracted by the users based on their ability to invest in extraction mechanisms. It is virtually impossible to track or regulate, and current institutions are poorly equipped for this task.

Finally, however, none of these policies have looked at the present use of surface water and its substitution by groundwater and how this is impacting the *financial sustainability of these systems*. Recent reforms in the water sector have included regulation, repair and maintenance and participatory management of public water. Emphasis on policies around improving performance of the public surface systems has changed over time. In the initial period, the bulk of the investment went into infrastructure improvement, and repair and maintenance of the canal systems. This was followed by policies geared towards institutional restructuring and economic reforms. Since groundwater use is unregulated, it does not generate any revenue for the state. In fact, it leads to creation of a perverse subsidy for those with adequate means to abstract water without paying for it. This is a kind of free riding that does not promote efficiency, revenue generation or equity. The Kukdi study clearly brings out the need to bring the wells in the commands under the jurisdiction of the WUAs. The Chennai study brings out the need to bring groundwater use from urban wells under the jurisdiction of the water utility.

Implications for contemporary water policy

In recent years, there have been several new legislative and policy initiatives at the state and national levels. In India, water is a state subject; national framework laws must be passed or ratified by the states. The central government has jurisdiction only over the sharing of inter-state rivers. A few of these initiatives, as well as the recent draft national water framework law, were re-examined based on how they approach the issue of conjunctive use of groundwater and surface water.

First, many of the recent initiatives acknowledge in principle the need to account for the interconnected nature of surface water and groundwater. For instance, the Maharashtra State Water Policy (GOM, 2003) states that the "isolated and fragmented approach to surface and groundwater development and management" has resulted in deteriorating quality of surface and groundwater and calls for "integrated and coordinated development of surface and ground water and their conjunctive use" at all stages of project planning and development. Similarly, the draft national water framework bill by the Alagh Committee (MoWR, 2013) advocates river-basin management and requires states to "manage groundwater conjunctively with surface water of any basin of which it is a part, taking into account any interconnections between aquifers or between an aquifer and a body of surface water". However, in both cases, the prescribed approach to water entitlements and WUAs focuses only on surface-water deliveries to the offtake point; command-area wells are not mentioned.

Similarly, inter-state water-dispute tribunals are either inconsistent or silent on groundwater extraction and the possible impacts on streamflows. The Krishna and Godavari

Water Disputes Tribunal conceded the interconnectivity between surface and groundwater but noted that groundwater flow is not fully calculable from the technical point of view, and therefore "not fully cognizable" from the legal point of view (as reported in Cauvery Water Disputes Tribunal, 2007). In the Narmada Water Disputes Tribunal, while it is not categorically stated that the allocation refers only to surface water, this can be inferred based on the inter-sectoral allocations of water proposed by the states (Ranade, 2005).

Overall, while the principle of integrated management of surface water and groundwater in the design and planning of projects is mentioned in many contemporary policies, there is very little concrete guidance on how to operationalize this. Often, the implementation rules contradict the principle of conjunctive management. Integration of surface water and groundwater cannot occur without a major realignment of how groundwater and surface-water organizations function on the ground. As written, existing policies would merely perpetuate the status quo.

The way forward

Several researchers have investigated case studies of groundwater governance across the world (Faysse, Petit, Bouarfa, & Kuper, 2012) and attempted to explain why groundwater is effectively governed in some places. The studies show that participation of local groundwater users in framing the rules is critical. For groundwater governance to be effective, top-down rules must be enforced by bottom-up local institutions, because local users have a "comparative advantage" over government in having the relevant information and potentially being able to monitor resource use, provided they have an incentive to manage the resource sustainably, especially when their long-term livelihoods depend on groundwater (Rica, López-Gunn, Llamas, Bouarfa, & Kuper, 2012). However, the likelihood and success of collective action around groundwater have been found to be influenced by several factors, including a shared understanding of the problem (Faysse et al., 2012), the nature and extent of the aquifer (Ostrom, 2009), the level of dependence on the aquifer for livelihoods (Mukherji & Shah, 2005), the transaction costs of regulating a large number of small rural users (Shah, 2009), the presence or absence of farmer lobbies (Mukherji, 2007), the homogeneity of groundwater users (Shah, 2009), and the ability to enforce restrictions effectively (Rica et al., 2012). However, the present authors are not aware of any successful cases of groundwater governance in India. The widely cited Andhra Pradesh Farmer Managed Groundwater Systems experiment was an informational, not regulatory intervention (FAO & BIRDS, 2010). The objective was to give farmers information on the level of recharge in a given monsoon so they could reduce the risk of second crop failure if they knew the rains had failed. Thus, the project was designed to protect farmers from incurring losses, not necessarily to control groundwater depletion.

This article has used two very different case studies to illustrate equity issues arising from the massive groundwater exploitation underway in India. The access and equity implications of this development have been poorly studied, and current policies have failed to take account of them. For instance, the recent 12th Five Year Plan of the Planning Commission of India rightly emphasizes local sources but does not quite address the institutional structure needed to ensure equitable access to water resources – particularly in light of the conjunctive use of surface water and groundwater. Based on these case studies, a series of actions that recognize water as a multi-dimensional, multi-scalar resource are recommended.

Recognize water as a common-pool resource

The interconnectivity between surface water and groundwater implies that the present "hydroschizophrenia" of creating entitlements to surface water while allowing groundwater to remain open access cannot continue. In reality, there is only one, interconnected resource, which is a common-pool resource. Any reforms of water rights must take cognizance of this. Creation of entitlements to just surface water, leaving groundwater as an open-access resource, is likely to exacerbate inequity.

Create institutions to manage the water resources of the region

At the moment, surface-water and groundwater monitoring agencies at the national and state levels are separate (e.g. the Central Water Commission versus the Central Ground Water Board). Very little coordination or exchange of data occurs between them. Indeed, the very conceptual framework for quantifying and allocating water resources allows for 'double counting'. If the long-term equity and sustainability of public water delivery are to be ensured, there is an urgent need for better inter-agency coordination. Moreover, scientific research on how surface water and groundwater are connected will be needed. Although most water professionals verbally acknowledge the interconnectivity, there is very little guidance on how to operationalize this knowledge in ways that can be used to manage a specific project or water utility.

Track overall water use, not just water delivered by centralized supply schemes

There is a need for monitoring mechanisms to track total water use, not just water delivered by centralized piped or canal schemes. At present, to our knowledge, groundwater use is not being formally tracked by any monitoring agency in any canal irrigation project or in any urban area. Although the number of wells may be tracked, water use is not. It is true that monitoring groundwater is not easy, because groundwater use is controlled by the end user, who has little incentive to disclose how much is abstracted. However, modern technologies – feeder-level electricity data in agricultural areas; tracking divisional sewage collection in the case of urban settlements – suggest the possibility of tracking groundwater use, at least by groups of users, if not individual users. Only if all water use in all seasons is considered can equitable access to water be ensured.

Create norms based on overall water use

Finally, to ensure equitable access to water, water entitlement reforms and water delivery norms must consider conjunctive use of surface-water and groundwater resources. Norms and entitlements dealing with only centralized water supply are inherently flawed and open to exploitation by the privileged few who can afford deep bore-wells and opt out of (or free ride on) the public delivery system.

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