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Socio-Environmental Dynamics and Emerging Groundwater Dependencies in Peri-Urban Kathmandu Valley, Nepal

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ABSTRACT: Groundwater is an increasingly important source of water supply in Kathmandu Valley, one of the fastest-growing South-Asian urban agglomerations. A groundwater policy drafted in 2012 was partly an outcome of an institutional restructuring of water management in Kathmandu Valley. Our findings in this article show that this policy lacks attention to peri-urban dynamics of change and growth and does little to address the unplanned and unregulated groundwater use in peri-urban locations in the valley, which urbanises at a faster rate than the main city. This article discusses the growing use of, and dependence on, groundwater in these rapidly evolving peri-urban spaces. Groundwater use continues to increase, despite growing protests and worries about its consequences. Our findings show that the polarised views and local conflicts around groundwater exploitation are the outcome of multiple entanglements: sectoral divides and overlapping responsibilities in water institutions, governance and management; social and economic transformations in peri-urban spaces; the invisibility of groundwater; and ambiguity in the hydrological dynamics of conjunctive water use. While we see no easy solutions to these problems, the policy-relevant recommendations we derive from our analysis of the drivers and the dynamics of using, governing and managing groundwater draw attention to the complex on-the-ground realities that need to be better understood for addressing macro-micro gaps in (ground)water management.

KEYWORDS: Groundwater, institutions, peri-urbanisation, policy, Kathmandu Valley, Nepal

INTRODUCTION

Groundwater is an important source of water globally, increasingly relied upon for multiple water needs, as surface water supplies diminish or become polluted (Jones, 2011; FAO, 2016). The global groundwater extraction rate has almost tripled between 1960 and 2010 and continued to increase between 1 and 2% annually (van der Gun, 2012). Unprecedented pressures on the resource have often resulted in reduced quantity and deteriorated quality of groundwater, coupled with secondary impacts like land subsidence, damage to vegetation, and depletion of surface water hydraulically connected to the exploited aquifers (Jones, 2011; FAO, 2016). Conjunctive use – simultaneous use of surface water and groundwater sources – can, without supporting hydrological and technical know-how, result in competition and conflicts, which are intensified by weak socioeconomic, legal, institutional and political conditions (Howard, 2013; van Steenbergen et al., 2015a; Kurki and Katko, 2015).

The need to manage groundwater sustainably and to understand the dynamics of integrated water resources management is recognised worldwide (Shah et al., 2003; Jones, 2011; van der Gun, 2012). Groundwater policies and regulatory frameworks to control exploitation have been formulated worldwide (Foster et al., 2011). However, the invisibility and variability of groundwater, exacerbated by highly variable precipitation, hydrogeological conditions and climatic uncertainties (Mukherjee et al., 2015), create a significant challenge in putting into practice policy initiatives, even when formal institutions for groundwater development and regulation have been established (Mukherji and Shah, 2005; van Steenbergen et al., 2015a; Howard, 2013). These challenges are compounded by socio-natural processes and inter-relationships, including the diversity of actors, interests, incentives, rights, practices and constraints. Clearly, there is a strong case for localising groundwater development, management and governance (FAO, 2016).

The important question is: how can the technical and managerial capacity of local institutional actors be developed as socio-economic and political factors vary widely? And how can regulatory instruments and institutional arrangements be made to work in situations where water governance is far from predictably organised? Solutions that have worked in one place are not necessarily a viable option for other places. Van Steenbergen et al. (2015b) show that the ban on groundwater use in Baluchistan Province in Pakistan to address depletion has triggered an informal groundwater market rather than bringing about intended managerial improvements. Shah (2009) argues that groundwater exploitation in South Asia has occurred in a chaotic, unregulated manner by myriads of small-scale informal water users. He adds that formal authorities lack political support, institutional capacity and interest in fighting groundwater over-exploitation and degradation, and labels the situation as 'anarchy'.

In South Asia, industrial, drinking and domestic water uses are rapidly restricting the highest user of groundwater, irrigation, which accounts for over 85% of total groundwater extraction in the region (FAO, 2013, cited in Mukherjee et al., 2015). In the absence of sufficiently strong public policies, control and regulation, groundwater exploitation has grown far beyond sustainable use (Shah et al., 2003; Shah, 2009). The problems are particularly acute in peri-urban spaces. On the one hand, peri-urbanisation adds to water-users and uses as agricultural land is rapidly converted to non-agricultural uses and agricultural water is redirected and appropriated by competing claimants. On the other hand, most South Asian cities rely on groundwater extracted from peri-urban areas (e.g. Ruet et al., 2007; Janakarajan, 2008; Shrestha, 2011). Groundwater extraction frequently happens in a haphazard and unregulated manner (Ruet et al., 2007; Janakarajan, 2008; Howard, 2013). Furthermore, uncontrolled urban activities degrade peri-urban groundwater quality (Karpouzoglou et al., 2018). Such dynamics involving multiple actors and institutions make peri-urban water security complex and uncertain (Narain and Prakash, 2016; Shrestha et al., 2018). As our case studies will show, peri-urban water management challenges are aggravated by the erosion of pre-existing water management institutions and emergence of new institutional arrangements, which are not (fully) in place or dysfunctional. This creates socio-institutional voids, multiplicity and complexity in these rural-urban interface locations (see van Steenbergen et al., 2015b).

In this article, we argue the need to contextualise groundwater use, management and governance, recognising specific socio-ecological nuances. However, location-specific and locally agreed rules and practices may not always bring the envisaged improvement in groundwater governance, for lack of, for example, local-level awareness, interest and leadership. Understanding local realities and integrating scientific, socioeconomic and policy aspects are thus crucial for any groundwater management initiative (Reddy et al., 2014; FAO, 2016). In the face of these challenges, devising, implementing and sustaining 'collective' groundwater management is certainly complex, but as Kulkarni et al. (2015) note, not necessarily 'utopia'. Several studies on groundwater governance emphasise the need to engage with local actors and understand local processes, political capacities and interests, and accordingly to innovate and mobilise political and institutional actions for feasible and effective contributions towards sustainable groundwater management (van Steenbergen, 2006; van Steenbergen et al., 2015a; FAO, 2016).

This paper illustrates the changing nature of groundwater use in two peri-urban villages in one of the fastest urbanising South Asian urban agglomerations: Kathmandu[1] Valley in Nepal (Muzzini and Gabriela, 2013), where groundwater use is rapidly increasing (Shrestha et al., 2012). Although the government has formulated a groundwater policy for Kathmandu Valley, extraction continues against the policy directive. In fast-growing peri-urban areas, the demand for water puts a stress not just on groundwater and its users, but on various water sources, users and those making efforts for water management. In situations of high need and demand, groundwater use has become both a 'solution' and a 'problem' for water management. The groundwater policy aims to restrict the use of shallow groundwater for domestic uses. The groundwater licensing guidelines categorise[2] deep groundwater uses, which it aims to formalise and regulate. However, changing land and water uses and challenges of managing water for multiple water needs and demands of the growing peri-urban population in the valley have received little attention. Addressing this policy gap, we use two case studies to illustrate the macro-micro gaps in groundwater management.

Following this introduction, we present the focus and methods of our research presented in this article. Next, we briefly summarise the socio-ecological and institutional context of groundwater management in Kathmandu Valley. We then elaborate on the cases, showing trends in groundwater use, related conflicts and management efforts and challenges experienced by water users, community-level service providers, resource managers and government authorities responsible for water management. This is followed by a discussion on how peri-urban socio-environmental and institutional changes influence water securities, thereby shaping groundwater use, management, and related conflicts. We conclude that groundwater management is a complexly entangled socio-environmental issue that requires looking beyond reforms in water-related formal institutions, to consider both formal and informal practices and institutions around changing land and water uses.

RESEARCH QUESTIONS, METHODOLOGY AND CASE SELECTION

In this article, we answer the following questions: (1) What changes are driving groundwater exploitation in peri-urban Kathmandu Valley? (2) How and why do different water users frame groundwater exploitation either as 'solution' or as 'problem'? (3) How are peri-urban water management challenges dealt with socially, politically and institutionally, or are decisions evaded, resulting in mounting conflicts? Both locations selected as cases for this article have an increasing groundwater dependency. Dadhikot, the first site, has been undergoing rapid urbanisation. Surface water was historically earmarked for irrigation, and stone spouts and traditional shallow wells (*kuwa*) for drinking water needs. In view of the few sources, managing drinking water was particularly difficult in Dadhikot. In the second site, Lamatar, urbanisation has been more gradual. Although multiple spring water sources made Lamatar a water-rich village, water sources are declining and demands increasing with urbanisation. Together, these sites provide an in-depth insight into the socio-environmental changes in peri-urban context and how these shape – and are shaped by – groundwater extraction, and related conflicts and management challenges.

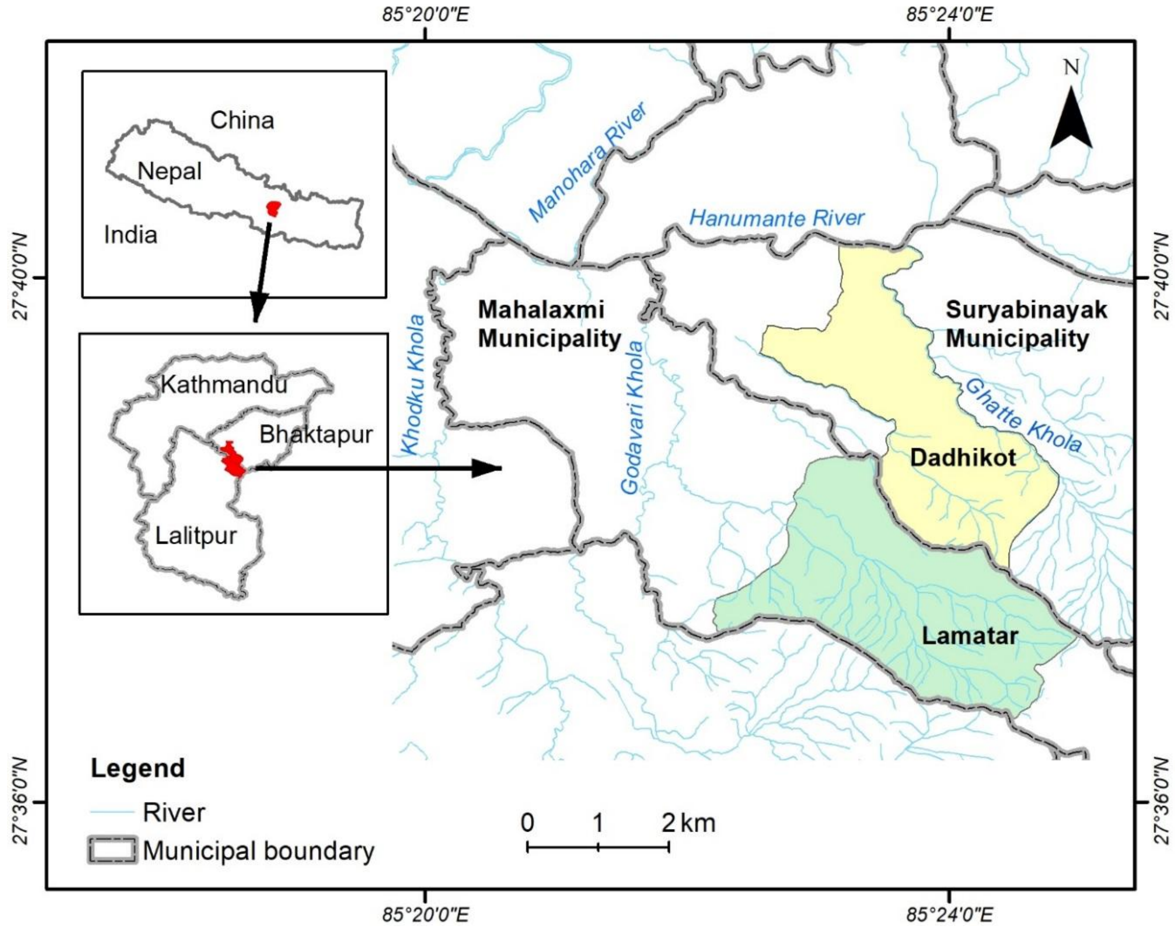
Field research was carried out by the first author between 2015 and 2018. The research was designed as an ethnographic case study (LeCompte and Schensul, 2010), using qualitative research

[1] The capital of Nepal, Kathmandu, is located in Kathmandu District of Kathmandu Valley.

[2] Categories are: (i) personal, (ii) industrial, (iii) commercial (iv) communal (v) others.

methods. Case studies are most appropriate for developing concrete, practical, contextualised knowledge (Yin, 2003) pertaining to specific issues. Data were gathered by mapping and following the various actors and their linkages to changing water and land use practices and analysing how these changes relate to groundwater exploitation and management in Kathmandu Valley. Methods included literature review, study of policy documents, informal conversations, open and semi-structured in-depth interviews with actors and key informants and focus group discussions. Informal interaction during field visits to water-related infrastructure (intakes, wells, filter-systems, distribution tanks, etc) and observation of water-related activities (maintenance of an irrigation canal or drinking water supply systems; complaints at the water supply offices, meetings, etc) were crucial for understanding the complex peri-urban groundwater dynamics. In Dadhikot, 23 informal talks and interviews, 23 open and semi-structured interviews, and three focus group discussions were held with irrigators, male and female residents, in-migrants, farmers' group leaders, representatives from community-based organisations, water suppliers, managers, entrepreneurs, teachers, local politicians and other relevant informants. In Lamatar, 32 informal talks and interviews and 17 open and semi-structured interviews were held with similar persons. In addition, informal talks and interviews were held with 42 government officials, three officials from non-governmental organisations (NGOs) and one INGO working on changing land and water uses and water quantity and quality issues in Kathmandu Valley. Participation of the first author in several annual national groundwater symposiums has increased our understanding of the severity of groundwater exploitation, particularly in Kathmandu Valley.

Figure 1. Location of study sites in Kathmandu Valley.



Groundwater use, impacts and governance in Kathmandu Valley: A brief review of the context

The population of Kathmandu Valley is growing about 4.3% annually, with an increase by over 499% between 1955 and 2008 (Bhattarai and Conway, 2010). Kathmandu Valley is located in central Nepal. It has a sub-tropical climate with over 1,500 millimetres average annual rainfall, 80% of which occurs during the monsoon period (UN-Habitat, 2015).[3] Between 2001 and 2011, the population of Kathmandu Valley has increased from 1.6 million to over 2.5 million (CBS, 2001; 2012a). The built-up area increased from 2.94% in 1967 (Thapa and Murayama, 2009) to 24.7% in 2011 (JICA, 2012). Water demand has reached 377 MLD,[4] while supply is 120 MLD (wet season) and 73 MLD (dry season) (KUKL, 2017). Water sources in Kathmandu Valley include both groundwater and surface sources. With the increasing pressure on surface water, groundwater use is also increasing (Pandey et al., 2012; Shrestha et al., 2012; Shrestha et al., 2017).

Administratively, Kathmandu Valley encloses three districts: Kathmandu, Lalitpur, and Bhaktapur. Together, these cover an area of 899 km^2, whereas the area of the valley as a whole is 665 km^2 (Shukla et al., 2010). The groundwater basin in the valley has an area of 327 km^2 (Shrestha et al., 2017). It is considered a closed and isolated groundwater basin, with irregular and discontinuous aquifers (Shrestha, 2012a). From a hydrogeological perspective, there are two major aquifers: shallow and deep, both within the consolidated sediments of Kathmandu Valley. These two vertical layers are separated by an impermeable clay layer that acts as a barrier for direct recharge of the deep aquifer layer (Pandey and Kazama, 2012; Pradhanang et al., 2012). The estimated thickness of the shallow aquifer varies from 0 to 85 m, that of the clay layer varies from less than 10 to more than 200 m, and that of the deep aquifer from 25 to 285 m (Pandey and Kazama, 2011). The traditional sources of groundwater, such as stone spouts and dug-wells, are based on shallow aquifers. These water sources were recharged via ponds and canals, traditionally used for irrigation and other sociocultural activities (UN-Habitat, 2007).

A piped water distribution system for the ruling elites was established in 1891, while water supply to the general public started in the late 1920s (Dongol et al., 2012). This modern water supply system has gradually replaced traditional supply and recharge systems. The rapid urban growth in the valley since the 1970s has increased water demands for the growing population and expanding industrial activities. This has led to increasing exploitation of the available water resources, groundwater being withdrawn by means of shallow and deep tube wells. Mechanised groundwater extraction started in the early 1970s. Extraction from deep aquifers increased mainly after the Nepal Water Supply Corporation (NWSC), the formal water supply utility, introduced groundwater as a major component of its supply system since the mid-1980s (Pandey and Kazama, 2011). Degradation of surface and shallow groundwater quality has boosted extraction of deep groundwater as an alternative, safe, and reliable source (Chapagain et al., 2010; Pandey et al., 2012; Shrestha et al., 2016). Over the decades, urban expansion, increasing gaps between water demand and supply, and ineffective rules and regulations have resulted in unregulated use of groundwater for community, public, private and commercial purposes (Creswell et al., 2001; IDC, 2009; Dongol et al., 2012; Pandey and Kazama, 2014). In our cases, we show how unregulated use has continued even after the formulation of regulatory mechanisms.[5] Total groundwater extraction was less than 0.04 million m^3/year in the early 1970s, but went up to 12.2 million m^3/year in the late 1980s, and over 25.5 million m^3/year by 2009 (Pandey et al., 2012). Groundwater extraction in Kathmandu Valley exceeds recharge since the mid-1980s, and the gap is

[3] From June through September.

[4] Million litres per day.

[5] The guidelines for licensing the extraction and use of groundwater specify the need for a permit, except for domestic uses of shallow groundwater. It also specifies how to obtain a licence and the volume that can be extracted in different areas of the valley (see KVWSMB, 2015).

widening (Shrestha et al., 2012; Pandey et al., 2012). In 2001, the extraction rate was 20 times as high as the recharge rate. At the 2001 rate, the groundwater reserve will be used up within 100 years (Cresswell et al., 2001). A study of groundwater balance in Kathmandu Valley has shown a deficit of 29.52 million m^3 (Chhinnamasta Consultancy, 2014). Studies have reported a drastic decline of the groundwater level in the deep aquifers, ranging from 1 to 4 m per year since 1984. Decline up to 80 m has been observed in NWSC well fields (ibid). However, there are discrepancies in such estimates, due to the complexity of geological formations and lack of adequate and reliable datasets (Pradhanang et al., 2012).

Since the early 1960s, studies have been undertaken to understand the geological formations, groundwater environment, recharge and hydrogeology of Kathmandu Valley. JICA (1990) has divided the groundwater basin in the valley into three districts: the northern, central and southern groundwater districts. The first is composed of permeable sediments, while the others have a low permeability (JICA, 1990 in Shrestha et al., 2012). Depletion of the groundwater level has been reported from the northern and central groundwater districts (Shrestha, 2012a; Pandey and Kazama, 2014). Although groundwater extraction started relatively late in the southern groundwater district, it has grown rapidly and is likely to increase tremendously (IDC, 2009). In addition, the high rate of urbanisation has tremendously increased the impervious surface, thereby radically reducing groundwater recharge (IDC, 2009; Shrestha et al., 2012).

Studies have shown that groundwater in the valley is already over-exploited. Its decreasing quantity and degrading quality are leading to serious problems (Cresswell et al., 2001; Pandey et al., 2012; Pandey and Kazama, 2014). The Government of Nepal (GoN), owner of water resources, has made a number of formal institutional attempts at the development and conservation of groundwater since the late 1960s. The Groundwater Resources Development Board (GWRDB) was established in 1976 under the Ministry of Water Resources (now: Ministry of Energy, Water Resources and Irrigation), for the enhancement of groundwater study and resource management. However, its effectiveness was limited to groundwater development for irrigation in the southern plains (Pandey and Kazama, 2014).[6] Moreover, groundwater extraction rights and ownership issues have never been taken seriously (Shrestha et al., 2012), making groundwater a near-'open access' resource (Pandey and Kazama, 2014). In 2006, the government established the Kathmandu Valley Water Supply Management Board (KVWSMB), aiming to improve drinking water supply services in the valley and replacing NWSC for water supply there. KVWSMB handed over its responsibility for water supply to Kathmandu Upatyaka Khanepani Limited (KUKL)[7] under a 30-year lease. KUKL services are largely limited to the urban areas of the valley. The District Water Supply and Sanitation Division (DWSSD), under the Department of Water Supply and Sewerage (DWSS),[8] supplies water in peri-urban Kathmandu Valley. Interviews with DWSSD officials revealed that these services are increasingly shifting to groundwater, to avoid use of increasingly polluted surface sources and conflicts with prior rights-holders, and meet rapidly increasing water demands. DWSSD[9] supplies financial and technical supports through community-managed drinking water supply projects, completion of which is a major basis on which performances of DWSSD and its officials are evaluated, both officially and socially. Hence, it is under growing pressure to extract (ground)water. Additionally, other governmental and non-governmental organisations are working to

[6] This region is called Terai.

[7] A public company registered under the Nepal Government’s Company Act 2006 and operating under the Public Private Partnership modality.

[8] DWSS is the lead agency for the drinking water supply and sanitation sector of Nepal (Rural Water Supply and Sanitation Sector Policy, 2004). www.dwss.gov.np/?lang=en

[9] DWSSD supports water infrastructure, while the community is responsible for managing the land needed for such infrastructure.

deliver drinking, domestic and irrigation[10] services in the peri-urban areas, also increasingly based on groundwater.

On the other hand, KVWSMB has the sole authority for groundwater regulation and management in the entire valley (Dhakal, 2012). In December 2009, the Supreme Court of Nepal issued an order to follow the provisions of the Water Resources Act (1992), enforce a licensing system, and control the illegal exploitation of groundwater. This was in response to a writ filed by Pro Public[11], a forum for protection of the public interest, in June 2003, to issue an order for regulating groundwater use in the valley. Following the order, the KVWSMB recruited a consulting company to prepare a draft groundwater management and regulation policy for the valley (Pandey et al., 2012; Pandey and Kazama, 2014). KVWSMB finalised the draft policy and submitted it to the line ministry in December 2010. The involvement of national and international organisations in studying groundwater issues in Kathmandu Valley, as well as compiling and analysing the scattered information, has increased the number of studies and publications on groundwater-related issues (e.g. Shrestha et al., 2012; Pandey and Kazama, 2014). Such initiatives have stimulated debates about rainwater harvesting[12], recharge and groundwater management. Under the influence of growing concerns about groundwater degradation and its potential consequences, the Groundwater Policy for Kathmandu Valley was approved by the cabinet in June 2012. However, its implementation has remained weak and largely limited to issuing licences and legalising deep groundwater extractors. KVWSMB estimated there are around 1000 deep tube wells, only 414 of which are licensed (interview, 03/02/2016). Due to unclear roles and responsibilities for groundwater regulation and management, this has remained "nobody's responsibility" (Pandey et al., 2012). In addition, a lack of scientific knowledge on groundwater has adversely affected its development, management and protection (Dhakal, 2012).

The Melamchi Water supply Project (MWSP) is underway since the 1990s to augment water supply in Kathmandu Valley (Domènech et al., 2013). Five hundred and ten (510) MLD of water are expected into the valley from external sources in three phases, each adding 170 MLD to the supply system. The first phase is expected to get completed soon and to improve water supply, thereby decreasing groundwater extraction (Shrestha, 2012b). However, this supply is limited to urban areas (Domènech et al., 2013; GoN, 2016)[13], while groundwater extraction is also increasing for the growing peri-urban population. In this context, it is relevant to understand how urbanisation shapes peri-urban hydro-social dynamics in relation to groundwater, and the existing institutional mechanisms for groundwater management. In the next section, we discuss two cases of contestations and conflicts between surface water and groundwater uses and users in two peri-urban locations. We note how increasing urbanisation has resulted in a prioritisation of institutional support and investments for groundwater extraction for drinking and domestic supplies over irrigation needs and demands. In part, this happens because irrigation and agriculture are on the decline, while urbanisation and in-migration are increasing demand for drinking and domestic water. Nonetheless, these developments pitch different groups of peri-urban communities against one another, leading to an increase of conflicts about water security.

[10] During our fieldwork, we found GWRDB has started supporting formally registered farmer groups in Kathmandu Valley to drill and use deep groundwater for irrigation. Governmental organisations and NGOs also support well construction for irrigation to economically empower women.

[11] See http://propublic.org

[12] GoN prepared Rooftop Rainwater Harvesting Guidelines in 2009.

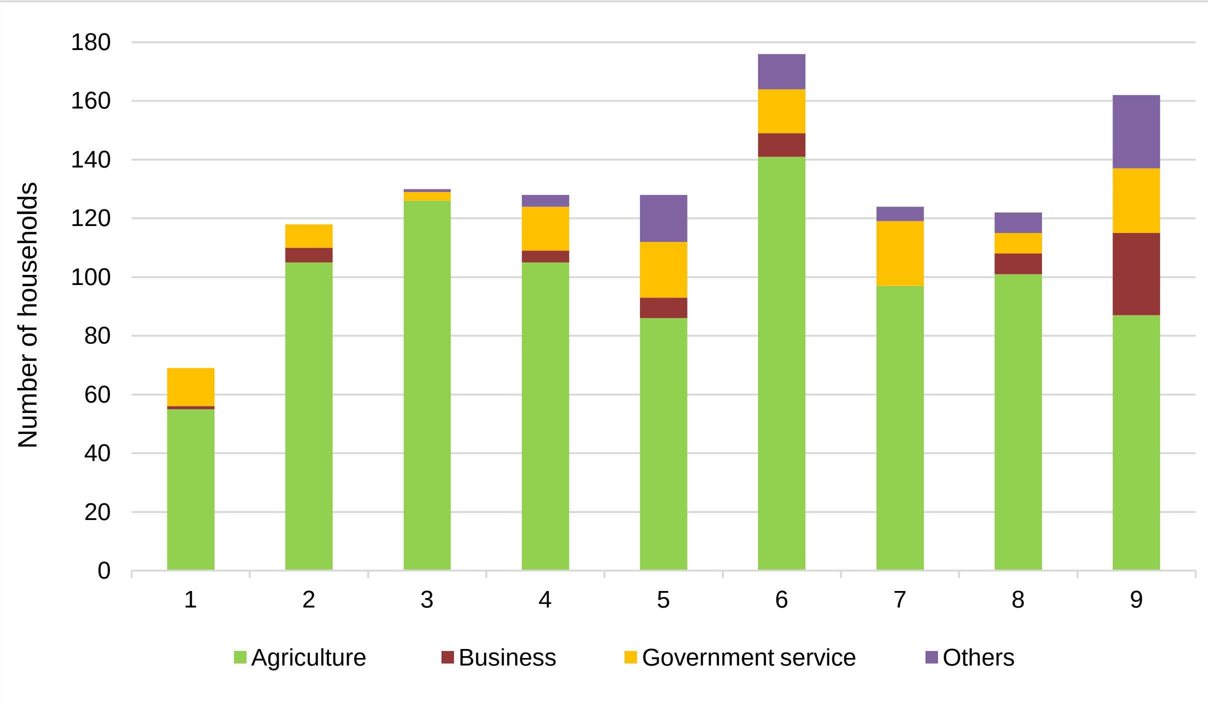
[13] Interview, Official, Ministry of Water Supply and Sanitation, 26/09/2016.

SOCIO-ENVIRONMENTAL DYNAMICS AND GROUNDWATER DEPENDENCIES IN PERI-URBAN KATHMANDU VALLEY

Dadhikot

Dadhikot VDC[14], spread over 6.27 km^2 is a rapidly evolving peri-urban area, located around 12 kilometres east of Kathmandu (Figure 1). With restructuring of the local government units in 2017, Dadhikot belongs to the new Suryabinayak[15] Municipality. The annual population growth rate in Dadhikot increased from 1.17 (1981-1991) to 6.05% (2011). While the population increased by over 60%, the number of houses increased by almost a hundredfold between 2001 and 2010 (CBS, 2001; 2012a). The built-up area has increased by over 250% between 1992 and 2010, and is expected to grow by about 110% between 2010 and 2030 (Sada et al., 2016). Nonetheless, agriculture is still a major livelihood for many inhabitants (see Figure 2). Agriculture depends on traditional surface irrigation sources from the Mahadev/Ghatte Khola, a stream in Dadhikot VDC. Mahadev Khola Rajkulo (royal canal) is the largest canal irrigation system in Dadhikot (Figure 4). The permanent intake (weir and sluice gate, located in Ward 4) of this historical irrigation canal was constructed in 1956 and served approximately 450 hectares (ha) of land (DIO, 1996). After road improvements in the 1980s, the farmers of Dadhikot started growing vegetables, and Dadhikot became a major vegetable producing area for Kathmandu Valley (Bhaktapur DDC, 2002).

Figure 2. Households according to major occupations in different wards of Dadhikot.

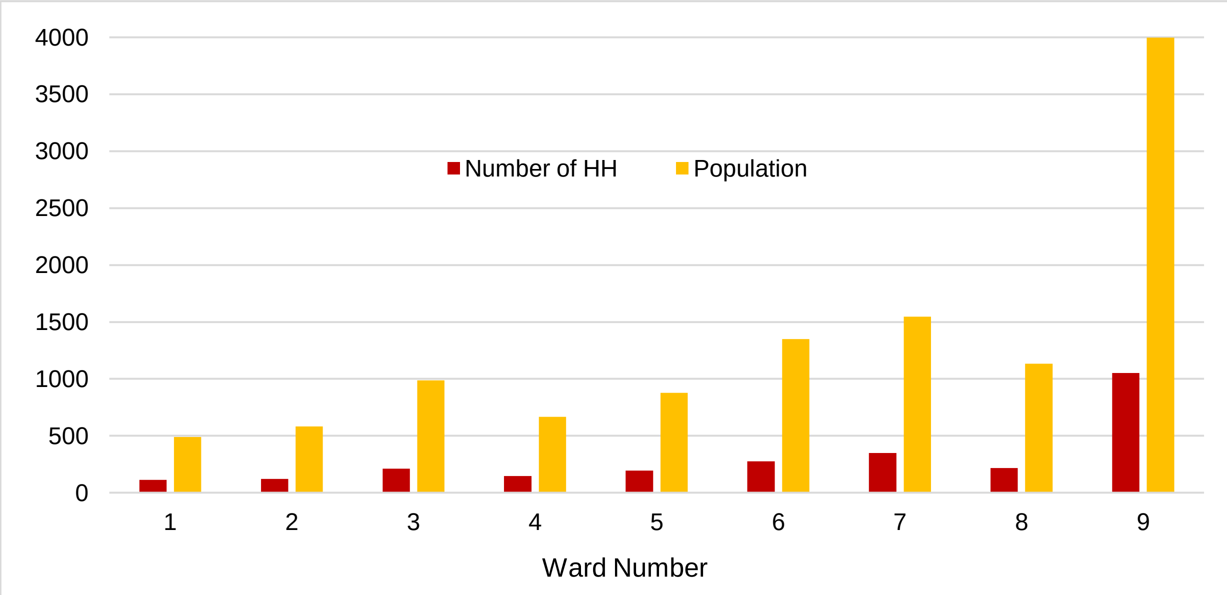


Note: Adapted from VDC Profile, 2006.

[14] Village Development Committee; this used to be the smallest local government unit in Nepal. Each VDC was administratively divided into 9 wards.

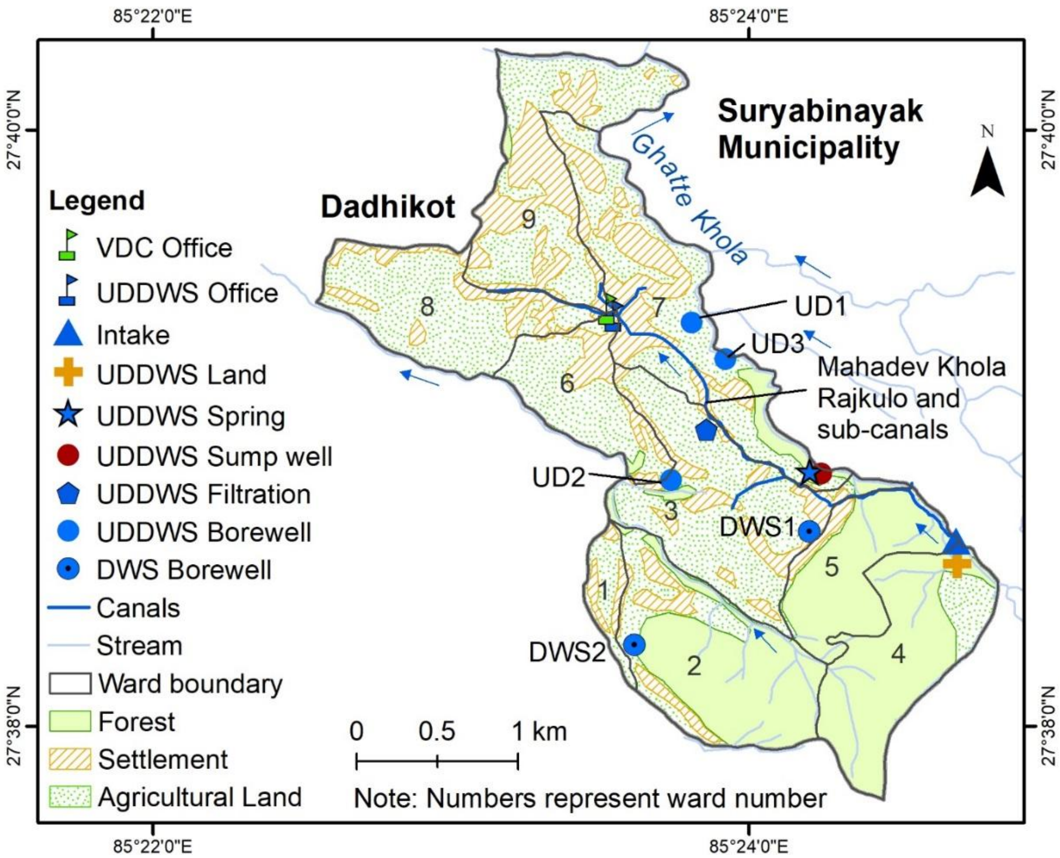
[15] Dadhikot and three other VDCs were merged to form Anantalingeswor Municipality in 2014, which was merged into the Suryabinayak Municipality in 2017.

Figure 3. Population and number of households (HH) in different wards of Dadhikot



Note: Adapted from CBS, 2012b.

Figure 4. Uttisghari/Brihat Dadhikot Water Supply and Sanitation and Mahadev Khola Rajkulo in Dadhikot.



Note: DWS refers to other drinking water supply systems in Dadhikot. Blue arrows show the direction of river and canal flow.

During the Maoist insurgency (1996-2006), Dadhikot changed rather quickly, becoming a peri-urban patchwork of agricultural fields, multi-storey buildings, and more diverse economic activities. Land transactions and buildings have been on the rise since then. Many new migrant farmers are leasing in land for commercial farming, while Dadhikot landowners rent out agricultural land to brick factories that cater to the building boom in Kathmandu Valley. These changes deeply affect water availability and quality, especially with the conversion of arable land into housing plots and the growing demand for domestic water. In the sections below, we discuss the development and functions of Uttisghari, the largest drinking water supply system in Dadhikot, which started in 1995. It supplies water to wards 3, 6, 7, 8 and 9, which include around 76% of the total population (Figures 3 and 4).

Eroding and emerging water management institutions

The historic Mahadev Khola Rajkulo originates in the hills in the south-eastern part of the Dadhikot VDC, sloping down to the flatter north regions of the VDC. This irrigation system is believed to have been developed around the 1670s (Adhikari, 2012). As in other areas in Nepal, this scheme, initially run by villagers, was managed by the irrigation department of the government until the 1980s, and then returned to a formally established water users' association (WUA) in the early 1990s. The WUA in Dadhikot had been formed to access institutional support for system rehabilitation after canal damage by a landslide. However, the WUA did not remain active very long, due to dissatisfaction among committee members with lack of transparency about rehabilitation expenses and their affiliations to different political parties. Nevertheless, this project introduced a tendency to look for governmental support for canal maintenance.

Although the rehabilitation improved irrigation services, covering drinking water needs from a few traditional sources remained a daily hardship in Dadhikot. A government-managed inter-VDC system supplying tap water to Dadhikot was started in the early-1980s but, with poor management and maintenance, it became almost dysfunctional by 1985. Aiming to reduce this daily hardship, the then elected local representatives initiated a drinking water supply system, named Uttisghari Drinking Water Supply, in the mid-1990s. This system, based on a local spring source, started regular services via public taps since 1999-2000, with funding and technical support from the DWSSD. In the early 2000s, the committee was formally registered at the District Water Resource Committee (DWRC) as Uttisghari Dadhikot Drinking Water and Sanitation Consumers' Committee (UDDWSCC). With formal registration, UDDWSCC gained a permit to use the water sources for its service area of five wards of Dadhikot. Currently, there are six such community-managed drinking water supply systems in Dadhikot, two of which (including UDDWSCC) are formally registered. Both started supply using local spring sources, but with increasing water demand have added deep borewells, funded by the DWSSD. Another community-managed system[16] in Dadhikot has also sunk a borewell, and is getting formally registered.

As population and water demand continued increasing, UDDWSC, in consultation with DWSSD, shifted to private (paid) tap water supply. Officially, such an approach to pipe and provide individual (paid for) household connections was considered to be efficient and sustainable. Supported by DWSSD, the UDDWSCC tapped an additional spring and sank a well[17] close to the bank of the Mahadev stream and started 250 private taps. Over the years, the UDDWSC committee established itself as an institutionally and financially secure water committee. In 2004, it was identified as the second-best functioning community-managed drinking water initiative in the country. This merit and its improving socio-political links have helped UDDWSCC in accessing regular financial and technical support from the

[16] For drinking water supply in Wards 1 and 2.

[17] Officials from DWSSD explained the well is based on groundwater and seepage water from the stream (Interview, 25/02/2016).

government. In 2007, UDDWSCC bought a plot of land, added a deep borewell[18] with support from DWSSD, and expanded its services. However, water quality of the borewell dropped within a few years, showing a high sediment load. Aiming to resolve the problem, the committee purchased land and, supported by DWSDD, it added a water treatment plant, but water quality of the borewell continued degrading. Additionally, the yield of its spring water sources and the water level in the well also declined, leading to increasing consumer complaints. While sources were declining, applications for new tap connections increased; by 2013, the committee supplied around 1500 taps (UDDWSCC, 2013). There were some 600 additional applications for new connections, adding pressure to arrange for additional water sources. In 2015, UDDWSC was dissolved, registering itself as Dadhikot *Brihat* (extensive) Drinking Water and Sanitation Consumers' Committee (DBDWSCC). This change was in part a strategy to continue accessing funding from the government for expanding and improving its services, demands for which further increased after transformation of Dadhikot from a rural to an urban administrative unit in 2014.

Groundwater exploitation, water (in)security issues and related conflicts

Following the restructuring, in 2016 DBDWSCC bought one more plot of land and added a new deep borewell[19] with the support of DWSSD, and added over 700 new taps. Nonetheless, after failure of the first deep borewell, the committee did not prefer a deep borewell for expanding its water supply services. In 2014, the Uttisghari committee had tried making a well in Ward 4 of Dadhikot, upstream to the intake of Mahadev Stream Irrigation Canal (Figure 4).[20] However, this was strongly resisted by farmers, especially those from the upper reach of the canal system.[21] Cultivating paddy, wheat, potatoes and commercial vegetables, they feared that well construction at the intake would reduce water availability for irrigation. The farmers had also opposed the UDDWSSCC in 2006. Then, the committee, in coordination with the local government, tried to make a well at the irrigation intake. A farmer recalled:

> In 2006, the UDDWSCC tried digging a well at the intake (of the irrigation canal) to take water for their water supply. This would stop all irrigation services for us. So we protested. I coordinated the informal struggle committee. [..] Over 400 people protested at the VDC office. Our slogan was: "we do not need drinking water, irrigation is a prerequisite for us". Almost each household sells cucumbers and pumpkins, with a value of at least NPR[22] 50,000 per year. If we lose this water, we will lose our livelihood source (Interview, Dadhikot, 03/08/2016).

These farmers complained that this plan was an indirect attempt to reallocate stream water for drinking water supply, while ignoring their livelihoods. After their protests, the UDDWSCC had sunk its first deep borewell. While in 2006 UDDWSCC had tried making a dugwell on public land, by 2014, it had bought a plot of land upstream to the canal intake and reattempted to make a well on it. This again led to overt farmer resistance and added water management challenges for the committee. The chairperson of the DBDWSCC:

> We started by tapping surface water sources. As this was inadequate to meet the demands, we started groundwater extraction. The problem is that water from our first borewell is turbid (…) so our consumers regularly complain about our services. [..] Furthermore, demands for water and new connections are

[18] Depth 72 m, located in ward 7 (of the VDC).

[19] Depth 179 m, located in Ward 3.

[20] Drinking water is supplied by a different community-managed water supply system.

[21] Drinking water in these areas (Wards 4, 5, figure 4) is supplied by another community-managed drinking water supply system.

[22] 1 USD = NPR 103.7 (2/03/2018).

> rapidly increasing with in-migration. These (…) have been a challenge for us. We applied for additional budget and have been following up regularly since two years. Finally, this new project under the DBDWS has been approved. It is crucial for our drinking water supply but we could not initiate it (…) due to the conflict between drinking water and irrigation interest groups (Interview, 08/06/2015).

After this resistance, DBDWSCC had the second (deep) borewell drilled and started water supply from this second borewell in 2016.[23] However, within a few months the yield of this second borewell also declined. With declining spring water sources, opposition from rights-holding farmers and need of an additional source to continue supply, DBDWSCC has recently added a third borewell on public land, approved by the newly elected local representative for management of drinking water services and with assurance of technical and financial support from DWSSD.[24] While DBDWSCC is struggling to supply water to its current users, the rising number of applicants for tap connections is increasing the pressure for accessing additional (ground)water sources.

Unlike the socio-economically and institutionally secure DBDWSCC, irrigation infrastructure in Dadhikot lacks a formally registered management institution, and also monitoring and maintenance. Over the years, canal irrigation has become limited to the upper reach, while downstream farmers only have canal water during the monsoon. This unreliability of canal irrigation has made farmers less concerned for the canal. Hence many farmers switch to the groundwater alternative. A farmer, also local government staff, said:

> In the past, we would take our agro-tools and clean the canal as needed.[..] Nowadays canal irrigation is limited to the monsoon. No one bothers about the canal unless they are funded for maintaining it. [..] Those who can afford it have made private wells for irrigating. Although well-water is not sufficient, its use as an alternative for canal water is increasing. [..] Irrigation is also affected by borewell construction and tapping of spring water sources for drinking water supply, so the amount of water flowing into the stream will obviously decrease. [..] It is not possible to keep people from using sources for drinking water supply. The situation is very complicated (Interview, Dadhikot, 26/06/2015).

Over the years, the water supply from community-managed drinking water systems in Dadhikot has been decreasing, while service charges are increasing, making groundwater the most reliable and economically viable source of water.[25] An unpublished survey conducted in 2012 (by the Nepal Engineering College) showed that 27% of the households in Dadhikot have private wells. Field observations showed that wells are rapidly increasing, while traditional recharge ponds in Dadhikot have vanished. A non-governmental initiative to restore traditional ponds was started in a community forest in 2013, but as funding decreased, the project was discontinued.

Lamatar

Lamatar VDC[26], some 16 km southeast of Kathmandu and covering 1365 ha, is part of Mahalaxmi Municipality (Figure 1). With an annual population growth of 0.8%, this formerly rural village, where the conversion of agricultural land into residential plots started in the 1990s is gradually urbanising. Currently, only half of the population practices agriculture as the main occupation, with inhabitants increasingly occupied in governmental and non-governmental services, small businesses, wage labour, construction and other work (Figure 5).

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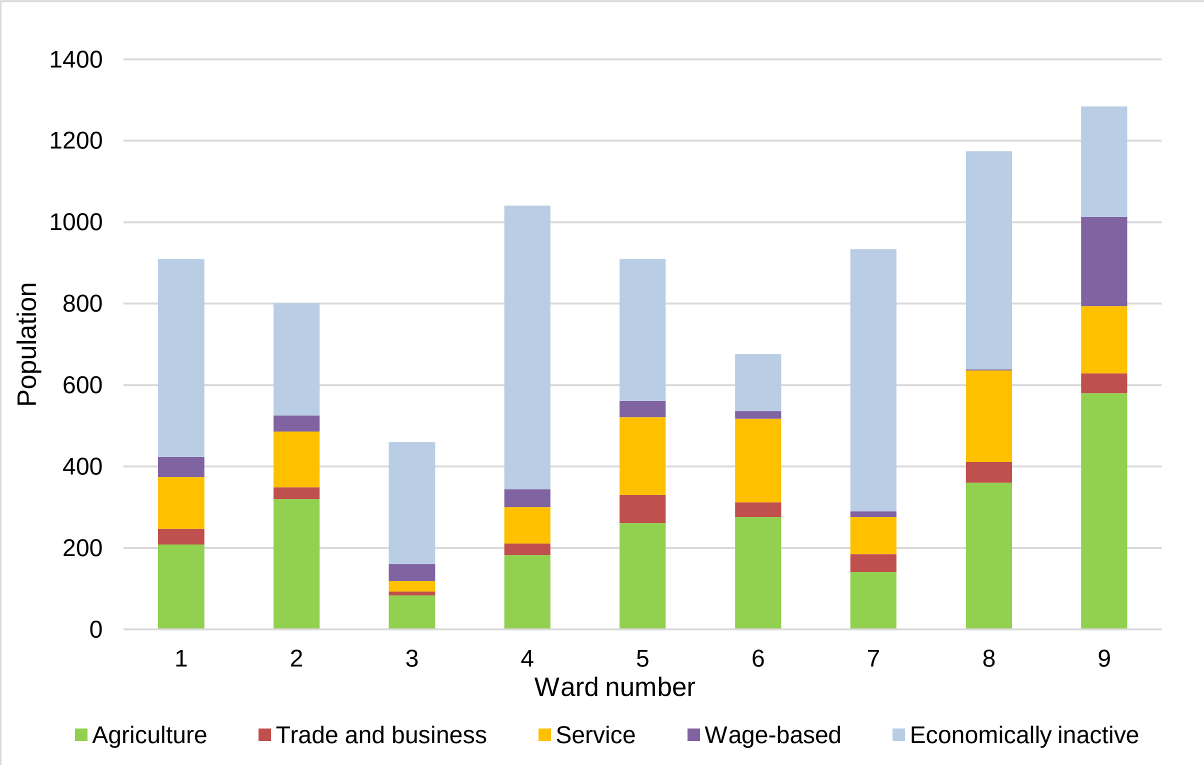
[23] The hydro-geological survey for the borewell was done prior to the 2015 earthquakes, which, according to DBDWSCC, may have impacted the aquifer.

[24] Depth 185 m, located in Ward 7.

[25] Until 2007, UDDWSC charged NPR 100 as the monthly minimal tariff per tap for 10,000 litres of water, which was reduced to 8000 litres in 2011. Since 2012 the minimal tariff is NPR 140 for 8000 litres of water.

[26] Lamatar VDC was clubbed with four other VDCs to form Mahalaxmi Municipality in 2014.

Figure 5. Population according to occupation in different wards of Lamatar



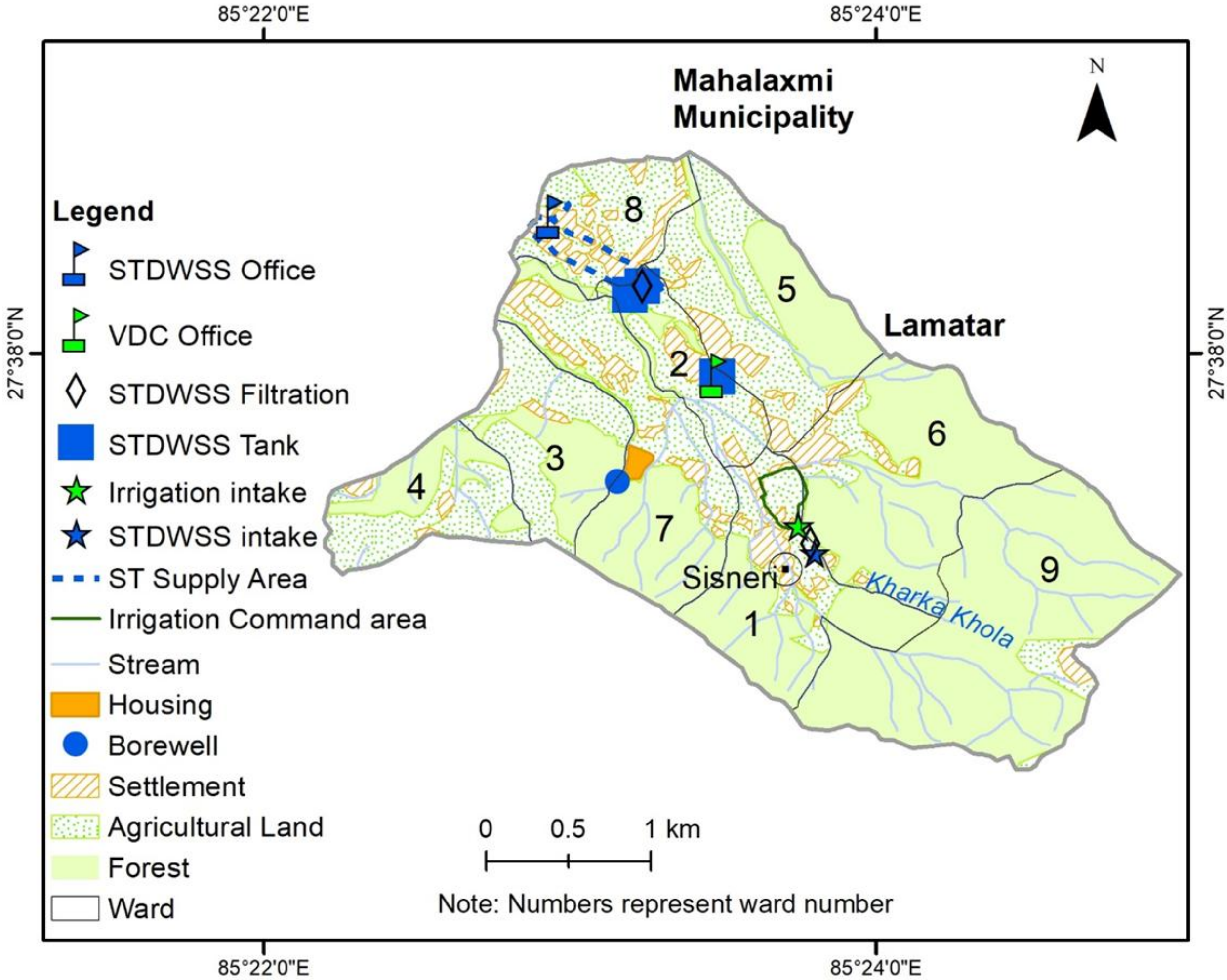
Note: Adapted from VDC Profile, 2013.

Peri-urban dynamics, strategies and insecurities concerning groundwater

Lamatar's hilly topography is covered with forests, managed by 11 community forest user groups.[27] Over 50 springs and streams originate in these forests, feeding into stone spouts, wells and canals (VDC Profile, 2013). These traditional sources for drinking, domestic and irrigation uses continue to be of major importance for daily water needs. Government-managed drinking water supply started in the early 1980s, using water from a spring in a neighbouring VDC to provide five different VDCs, including Lamatar. This started piped water supply via public taps in Lamatar. Tapping of springs in Lamatar for various community-managed piped water supply systems started in the 1990s. Most of these were supported by non-governmental organisations promoting safe water supply and sanitation, a sector highly prioritised by the government. One of them is the Shasambhu-Thulaghar Drinking Water Supply and Sanitation Consumers' Committee (STDWSSCC). Unlike most other such committees, it supplies water via private taps, and is trying to improve and expand its services by extracting groundwater through a deep borewell. Below, we discuss how this attempt to extract groundwater resulted in disputes between the residents, who are divided on the issue: some see groundwater extraction as a problem, others as a solution to their water insecurity.

[27] These groups are from the wards 1, 3, 5, 6, 7, and 9, that include the community forests.

Figure 6. Shasambhu-Thulaghar drinking water supply and sanitation and Kharka Khola irrigation in Lamatar.



STDWSSCC supplies water to part of Lamatar's Ward 8, a more rapidly urbanising settlement with an increase in non-agricultural livelihoods (see Figures 5 and 6).[28] Like most other community-managed committees in Lamatar, STDWSSCC is not formally registered. It started in 2005 by negotiating rights to use Kharka Khola, a seasonal stream in the community forest in Sisneri, a village in Ward 1 of the VDC (Figure 6). A verbal agreement was made that, while STDWSSC has a use right, farmers in Sisneri as prior users get priority and can divert water from the intake of STDWSS for irrigation during cropping seasons. Having obtained the use right from the Sisneri villagers, STDWSSCC mobilised its social connections with governmental and non-governmental organisations and successfully arranged financial and technical support. In the following years, through similar support it improved its intake and added a filtration system for water supply. A member of both STDWSSCC and the above-mentioned inter-VDC water supply management committee stated as follows:

> People used to drink stream water and water from traditional wells. This settlement was small, with sufficient water for all. After the government had started public taps in the early 1980s, people started using tap water for drinking, but water demands continued increasing. We started the Sashambhu-

[28] Note: Ward 8 does not have a community forest and its population is not involved in such a group.

> Thulaghar drinking water supply to meet growing demands for piped tap water. Although called a drinking water supply scheme (committee) to obtain support, water was actually used for domestic needs (washing, cleaning, etc) except drinking. Gradually, as the public tap supply continued decreasing and water demands increasing, we added a filter to make it potable (Interview, 09/06/2017).

The fact that STDWSSCC obtained approval and funding for the scheme without formal registration, illustrates its social and professional connections. STDWSSCC started with 40 private taps and free water for two users who provided land for the system's tanks. Currently (2017), it supplies 109 taps while demands for new connections are increasing. However, flow in the Kharka Khola has been declining. Water scarcity peaks during the dry seasons, when discharge is low while the farmers in Sisneri, who are upstream and prior users of the stream, start irrigating their crops. In the face of declining water supply, many households in the Sashambhu-Thulaghar settlement have dug private wells and use shallow groundwater.[29] The quality, however, is poor, making the settlement dependent on STDWSS despite the decreasing of the source and supply of its water. The earthquake in 2015 further reduced water flows in Kharka Khola. This led to the decision by the STDWSSCC to bore a deep borewell and access groundwater to improve and extend service. A member explained: "there is huge demand for new tap connections and we are in the process of drilling a deep borewell for our scheme. After this we will start supplying new taps" (04/02/2017, office of STDWSSCC). Arranging for new water sources puts additional pressures on the committee to arrange the needed investments; a STDWSSCC member explained: "drilling a deep borewell requires huge investment. [..] We cannot afford this on our own and will have to request finance from organisations supporting drinking water services".

In 2017, STDWSSCC tried to get registered at the District Water Resource Committee as a formal drinking water user committee, to gain the formal rights to the water source (Kharka Khola) and to access more funding for such initiatives. The committee publicly announced its decision to register and expand services through sinking of the borewell. However, drilling a deep borewell became a major factor of conflict. The Sisneri villagers were unwilling to agree because of the potential impacts on the availability of, and access to, water. While they had agreed to let STDWSSCC access the spring source, this new appropriation of water was not acceptable to them. They complained that registration without consulting them is a strategy of STDWSSCC to avoid prior water users and their claims, illicitly capture the water source, and drill a deep borewell by mobilising their social connections. Therefore, the villagers submitted a petition against STDWSSC at the District Water Resource Committee.

A villager from Sisneri stated: "If this water is given, there will not be enough for irrigation and drinking [.…]. If they try to take water from here, we will brutally cut their pipes. If there is not enough for us, how can we give water to outsiders!" He added:

> Deep boring takes water from everywhere, withdrawing water from adjoining sources. This will lead to the drying-up of our sources. STDWSSCC never consulted our political leaders or water users. We wonder how its decision came about! Our argument is that people have to be involved in conserving the forest to get water. We, villagers from Sisneri, have been protecting our forest. By doing so, we are also protecting our water sources. Now outsiders come and try to sink a borewell. Will we let them do so? STDWSSCC strategically posted a public notice giving us a limited time to organise and take action against their decision. They wanted to avoid us, the local people. We have already submitted a petition against them (Interview, Sisneri, 07/02/2017).

Groundwater exploitation: Problem or solution

Sisneri farmers grow paddy, wheat and commercial vegetables, which they irrigate by making a temporary dam at the Kharka Khola. The farmers, particularly those with lands located downstream of

[29] STDWSSCC started with NPR 75 as monthly tariff, with no restriction on the volume of water used. Currently the minimal monthly tariff is NPR 150 for 8000 litres.

the intake of STDWSS, have long been unhappy with this sharing of Kharka Khola. The irrigation intake lies downstream of the intake of STDWSS supply (Figure 6). The farmers complain that, despite agreed priority of their water rights over STDWSS supply, this has not been practically possible because of the concrete intake for drinking water supply. A farmer: "STDWSSCC had told us that we can open their intake and take water if needed. But how should we open and close their concrete intake? That is not possible in practice" (Sisneri, 19/07/2017).

Such contestations around water use were key factors in the local elections in May 2017. Following the elections, ward-level meetings were conducted to discuss these issues. The chairperson of the community forest in Sisneri, also a former elected local representative from Sisneri, elaborated:

> We agreed to registration of the water sources but we will not let a deep borewell be drilled (…) as this will damage our water sources. In our case all water sources are in the forest, so the forest committee is protecting them. But, as water flows down, it is crucial to make dams (…) to conserve water sources. [..] The current practice is that downhill villagers only use water flowing down, but nobody is concerned about preserving those sources. After the earthquake, water sources have further declined. STDWSSCC intends to get registered, drill a borewell and manage water only for their supply area. That will not work. The forest committee had let STDWSSCC use the water source as they are also villagers of our VDC, but our villagers here complain that we did not monitor their activities and let them take the source (Interview, Lamatar, 14/06/2017).

On the other hand, STDWSSCC, having invested in developing its water supply system Kharka Khola for a larger group, argues that deep borewells are the only solution to the growing demand:

> If there was water, investing in surface sources would have been useful. But now there is no water except in the peak monsoon, while water demands continue to increase. New houses are coming up and they demand tap connections. The only solution is a deep borewell. Everyone, including people in Sisneri, has realised that in the future we will have to use groundwater sources. We do not have a big stream source. [..] (Deep) borewells are being made everywhere (in Kathmandu Valley). In the neighbouring VDCs, there was no need to get approval, nor did they publish any public notice, they are simply drilling more borewells. The housing colony made a borewell, and who dared to oppose? But when the general public tries to get a borewell, then the people oppose. A resident in our settlement had tried to get a borewell drilled for his private use, but villagers opposed it. Without knowing the facts, people argue water sources will dry due to deep borewells. In this region, everywhere there is plotting. The roads are being widened. Settlement will continue increasing. Water scarcity will definitely increase. There is no option except going for deep borewells (Office Operator, STDWSS, 9/06/2017).

While the political (ward-level) decision was to prioritise surface water development, the villagers are deeply divided in their opinion on this issue. In 2017, another group of villagers (mainly from Ward 7 of the VDC) submitted a petition at the ward office requesting action against the deep borewell sunk in 2016 in the commercial housing project in Lamatar. The protesting villagers argue that this drilling resulted in the complete drying up of a spring located uphill. Its flow had been declining over the years, and further declined after the earthquake, to run completely dry by late 2016. The commercial housing had not obtained a KVWSMB licence, nor conducted a public hearing or obtained approval from the ward office, while all are required for licensing. Nonetheless, the ward secretary for Lamatar argued that the housing project had fulfilled all formal requirements for its construction. Moreover, neither the ward secretary nor other members of the ward-level committee were clear about the recently formulated formal requirements for drilling a deep borewell, and they assumed that the commercial housing owner had a licence. As there were no complaints, the ward office did not inquire and interfere in the water arrangements. The villagers explain that the political and economic power of the commercial housing owners enabled them to ignore formal requirements of approval, while this power reach compelled villagers to refrain from protesting until local representatives were elected in 2017.

Despite the protests and concerns over groundwater use, the campaigning strategy in the local elections of propagators of 'one-house-one-tap' provision helped the election of pro-groundwater ward committee members. During this time (also the fieldwork period) there were five applications for permits to bore deep borewells (for water supply in different parts of Mahalaxmi Municipality). Nonetheless, continued protests against groundwater development have resulted in the decision to engage technical experts for a detailed study on the possible impacts of conjunctive water use. It was decided that priority should be to develop springsheds and surface water streams. The ward chairperson clarified the position as follows:

> Drinking water was one of my priorities in (…) the local election. [..] The settlement is expanding. Considering the increasing water needs, our springs and streams are not going to be sufficient. People from Sisneri argue that making dams in gullies to collect and recharge rainwater will make our springs sustainable and sufficient for water supply. But with expanding settlement we have no option but making a deep borewell. The district drinking water division will soon be conducting a study to explore the possible ways to manage the water supply [..] We will of course, not be ignoring the need of upstream villagers to have reliable irrigation water. (…) (Interview, ward office, 24/08/2017).

As these debates continue, it is likely that groundwater extraction in Lamatar will continue. The ward chairperson clarified that, though the ward-office was trying to notify the commercial housing owners to obtain a licence, there was no plan to penalise or refrain from groundwater extraction; thus, local opposition was largely ignored. Meanwhile, the community forest in Sisneri, partly supported by the District Forest Office, has started making water capture and recharge ponds to increase sustainable availability of water. Nonetheless, attention is needed to ensure that such activities will not be short-lived or turn into a mere argument legitimising groundwater exploitation.

DISCUSSION: (PERI-)URBANISATION AND GROUNDWATER EXPLOITATION

The findings presented in this article draw from the investigation of the socio-environmental and institutional dynamics in relation to groundwater use in two peri-urban locations in Kathmandu Valley, Dadhikot and Lamatar. We have shown that the use of, and dependence on, groundwater are increasing, despite growing protests and societal divisions concerning its consequences. From the cases, we identify five complex interlinked factors and processes that have triggered increasing groundwater exploitation: (i) uncontrolled urban expansion and subsequently increasing water demands; (ii) poor management and the resulting decline of traditional water sources; (iii) increasing surface water insecurities and related conflicts with prior rights-holders; (iv) lack of coordination between different actors using and governing water (and land), and poor implementation of groundwater policy; (v) limited knowledge on the local hydro-geological complexities and how they are related to the wider socio-political and institutional environment.

With increasing in-migration and land conversion, drinking (and domestic) water demands are increasing in peri-urban Kathmandu Valley, as illustrated by the Dadhikot and Lamatar cases. In both areas, many water sources traditionally used for irrigation have been reallocated to meet ever-increasing drinking water demands. With changing land and water use and management practices, many traditional sources of water have declined, degraded or dried up. As these socio-environmental changes have increased competition for water, groundwater has emerged as the alternative water source. In addition to the shallow wells used at household level, groundwater extraction from deep aquifers by new and deeper wells has emerged and is still increasing. An example is the Uttisghari/Brihat community-managed water supply in Dadhikot discussed above. Although urbanisation in Lamatar has been relatively slow and population growth relatively low, these are increasing here as well. While use of groundwater from deep aquifers is still new in Lamatar, extraction of shallow groundwater for household uses is common.

Groundwater extraction in Kathmandu Valley ever more exceeds its recharge, with negative consequences like drying traditional water sources, decreasing yield of wells, and declining groundwater levels (Shrestha et al., 2012; Pandey et al., 2012). The threat of disturbances to the local hydro-geology and potential loss of water access and rights, thereby exacerbating water insecurities, united the prior rights holders to contest groundwater exploitation. On the other hand, decline of traditional water sources, growing opposition from prior rights-holders, and increasing water demands have stimulated drinking water suppliers to take recourse to groundwater, which is perceived to be a reliable water source free from prior rights issues. Thus, they use various strategies to strengthen and legitimise their rights to groundwater exploitation: for example, purchasing land at the irrigation intake, coordinating with local and central government, restructuring of UDDWSCC and making borewells in the wards served by them in Dadhikot, attempts to formalise STDWSSCC, and coordination with the elected government in Lamatar.

The 1992 Water Resources Act (WRA) of Nepal provides water use rights while it vests ownership of water resources in the state. WRA has set the priority order for different water uses, drinking water having first and irrigation second priority. Although drinking water supply has received much national[30] (and international[31]) attention, peri-urban areas of Kathmandu Valley (like elsewhere; see Janakarajan, 2008; Narain and Singh, 2017) continue to be largely excluded from services of the official provider, KUKL. As elaborated in the case studies, peri-urban areas depend on community-managed drinking water services, priority for which has grown in local development projects facilitated by governmental and non-governmental agencies.[32] The Groundwater Policy of 2012 has also encouraged such community-managed drinking water supply initiatives. The policy reserves shallow groundwater for domestic water uses, and requires obtaining a permit from KVWSMB for any deep aquifer use, including community water supply schemes. Accordingly, the borewells made for the community-managed water supply systems in peri-urban areas of the valley, developed with support of DWSSD, should have been registered, received a permit and regulated under KVWSMB. However, none of these systems in Dadhikot have such a permit.

Such increasing use of groundwater without obtaining a permit as required by the groundwater management policy (also for community-managed supplies) shows weak implementation of this policy. Furthermore, these community-managed drinking water supplies are financially and technically supported by DWSSD, a government body, whose responsibilities overlap with KVWSMB, the formal authority to regulate and manage groundwater use in the entire valley. These overlapping institutional arrangements, together with growing pressure to mobilise new water sources for the rapidly increasing population and to avoid more contestations around declining surface water sources have led to the emergence of water-mining practices that transgress the groundwater management policy. These socio-environmental and institutional dynamics illustrate poor coordination, not only between these government agencies responsible for drinking water supply in the valley, but also between and among different bodies responsible for planned land and water management. Lack of compliance with the existing groundwater management policy in case of community-managed drinking water supply systems is often justified by the need to provide basic water services for 'the community'. However, less attention is paid to how the sectoral focus on drinking-water supply augmentation is promoting in-migration into the peri-urban areas. Availability of drinking water services is a major factor in decision-

[30] The Government of Nepal has the national target of 'universal access to safe drinking water and sanitation for all'. As per the census data 2011, 85% of the households have access to water supply and 61% of households have sanitation (CBS, 2014).

[31] Goal 7 of the Millennium Development Goals (MDGs): "to halve by 2015 the population without sustainable access to safe drinking water and basic sanitation". Goal 6 of the 2030 Sustainable Development Goals (SDGs): "By 2030, achieve universal and equitable access to safe and affordable drinking water for all" (WHO and UNICEF, 2017: 7).

[32] The Water Supply Sector Policy of 1998 made water supply projects semi-autonomous and curtailed the government’s role to being a facilitator (Aryal, 2011; Freeman et al., 2014).

making on migration into any area. Further, we noticed land brokers often present the example of expansion of drinking water supply systems as an evidence of reliability of drinking water services, and thus attract in-migrants seeking to buy land and settle in these urbanising areas. These socioeconomic dynamics, in turn, continue urban expansion, thereby rapidly increasing water demand and management challenges for the 'community' water service providers, as seen in Dadhikot where annual population growth rate increased from 1.17% (1981-1991) to 2.5% (1991-2001) and to over 6% by 2011. In these urbanising areas, what is still referred to as 'community' actually is an increasingly diverse and dynamic society consisting of various population groups with varying backgrounds, livelihoods, identities, needs and interests, characteristic of peri-urban landscapes more generally (Narain and Prakash, 2016).

In Lamatar, STDWSSCC applied for formal registration, to qualify for the formal support on which it depended for accessing groundwater. Opposition to its registration resulted in uncertainty about groundwater access of this supply system and thus also of water access for those who depended on its services. On the other hand, the housing colony could afford the cost of extraction, and extracted deep groundwater without a licence; the petition against this was ignored. In Kathmandu Valley, poor implementation of the groundwater policy has helped powerful actors to evade the regulatory mechanisms in exploiting groundwater for their commercial interests (Shrestha et al., 2018). This exploitation often takes place without a licence from KVWSMB, as illustrated by the limited number of licensed deep borewells noted by KVWSMB and from the example of unrestrained use of groundwater in construction of the commercial housing in Lamatar. In Lamatar, water originates in the community forests. Sisneri villagers manage the forest in Ward 1 and hence claim for their rights to water originating from their forest. However, not all wards have community forests (see footnote 28), and populations of the wards without forests are not involved in such initiatives. Thus, such informal ways of governing water lack participation of the wider community, including that of the elected local government, which has the right to decide on use and reallocation of resources and is in favour of groundwater use for addressing growing water needs and demands. In addition to these institutional issues, economic and political advantages enabled the housing owner to ignore the community and its petition.

In contrast, local opposition against groundwater exploitation has added challenges in managing basic water needs for the peri-urban population that depends on community water services, as experienced by the Shashambhu-Thulaghar DWSS. Nonetheless, despite resistance and growing awareness of the dark sides of groundwater exploitation, with the diverse and growing urbanisation-driven needs and interests in water (and land) uses, peri-urban groundwater exploitation is likely to continue increasing. This trend is reaffirmed by the increasingly strong social, institutional and political priority-setting for deep borewells to improve drinking water services. Drilling of deep borewells is viewed with much antagonism by farmers concerned with their irrigation-based livelihoods. However, the number of such farmers is decreasing with the declining irrigation services and increasing urbanisation. Furthermore, there is little control over the increasing numbers of shallow wells, which are also used by farmers and widely regarded as the best alternative to the unreliable stream-fed canal irrigation systems. However, the groundwater management policy and guidelines are silent about the growing use of groundwater in irrigation. This silence shows that the focus is on drinking water, which is understandable with the responsibilities given to KVWSMB. However, this again raises questions on the effectiveness of groundwater policy in addressing the complex realities of groundwater uses, particularly in the peri-urban areas of Kathmandu Valley.

As discussed, the hydro-geologically diverse Kathmandu Valley is broadly divided into three districts. In addition to categorising the type of groundwater uses, the guideline for licensing groundwater extraction and use (see KVWSMB, 2015) aims at imposing volumetric restrictions on groundwater extraction and has identified safe, semi-critical and critical areas for groundwater exploitation from deep aquifers. However, little is known about the local hydro-geology and its relation to changing land

and water uses and management practices. For instance, the borewells for the DBDWSS system were drilled under technical support from DWSSD, following hydro-geological surveys that confirmed their feasibility. However, the borewells failed to provide the expected water services, which resulted in the need for additional borewells for DBDWSS. It also led to an increase in private household wells, to deal with the poor water quantity and quality services of DBDWSS. Such failure of borewells and subsequent increases in groundwater extraction illustrate the socio-environmental nature of groundwater management issues. In addition, these examples highlight existing knowledge gaps on hydro-geological complexities and related socio-institutional processes that justify and compel continued extraction of a resource that has already been pointed as over-exploited. Better understanding of these socio-natural and institutional processes is crucial with ongoing urbanisation and growing dependence on groundwater exploitation.

The groundwater policy has promoted groundwater recharge in the valley. Although the shallow aquifer is characterised by a high recharge rate, the high rate of urbanisation has increased impervious surface and radically reduced groundwater recharge (IDC, 2009; Shrestha et al., 2012). The potential for recharge into the deep aquifer is already low because of the widespread impervious clay layer in Kathmandu Valley (Pathak et al., 2009; Pandey and Kazama, 2012), but further decreases with urbanisation. The project piloted to artificially recharge the deep aquifer was not only costly and technically complicated, but the results of this scheme were not encouraging either (Dixit and Upadhya, 2005). Opportunities for using groundwater in Kathmandu Valley depend heavily on the ability to control land use and prevent pollution in key recharge areas (Shrestha et al., 2012; Pant, 2011; Pathak et al., 2011). Considering that the priority of the GoN in recent times has invariably been urban development (MoUD, 2016), with urban expansion in Kathmandu Valley, "the hub of Nepal's urbanisation" (MoUD, 2017), these processes are likely to continue in the future. Consequently, the potential area of open spaces for groundwater recharge can be expected to get converted into built-up areas (Thapa and Murayama, 2012).[33] In this context, despite the initiatives to improve urban water supply services and the formulation of groundwater policy guidelines, groundwater governance in Kathmandu Valley is likely to remain a major challenge.

CONCLUSION

We have shown how the use of, and dependency on, groundwater for multiple uses are increasing in Kathmandu Valley, despite the existence of the groundwater policy to regulate and control it. In a context of declining traditional water sources, an ever-increasing population, and growing water needs for multiple uses, pressures on water and competition for access are increasing throughout the valley. Although users experience a considerable decline in the quality and quantity of groundwater, it is increasingly seen as the only 'solution' to deal with growing water demands and conflicts about water access, rights, and insecurity. The peri-urban population is divided in its concerns about the impacts of groundwater exploitation on water (in)security. In this context, contestations and divisions concerning groundwater exploitation and its consequences are growing: inequalities and water insecurities create a potential for water-related conflicts to escalate (Janakarajan, 2008; Howard, 2013; Narain, 2014; 2016; Shrestha et al., 2018).

Under the current institutional conditions and groundwater use practices, groundwater is largely an 'open-access' resource (Pandey and Kazama, 2014), at least for those who can mobilise the required capital, social relations and technology to get access. Under the current conditions, groundwater

[33] The Kathmandu Valley Development Authority (KVDA), the urban planning authority for Kathmandu Valley, aims to develop infrastructure to accommodate a population of 10 million in the valley (Interview, KVDA, 21/11/2016; see also Abhiyan National Daily, 07/11/2016).

exploitation can be expected to continue increasing, with or without formal recognition, regulation and licences. In line with the government's priority for urbanisation as "the best way to sustainable development" (MoUD, 2016: 3), Kathmandu Valley has been made a rural area-free municipal zone.[34] However, as our case studies in Dadhikot and Lamatar, located in two of the newly declared municipalities, show these areas lack basic water services while water demand is increasing. With the focus of municipalities on promoting non-agricultural economic activities for 'development', water demand is likely to increase faster, adding dual pressure on groundwater: increasing exploitation under conditions of a shrinking recharge area. In the meantime peri-urban areas, despite their rapidly growing populations, remain excluded from surface water-based urban water service improvement initiatives.

These are neither 'natural' processes nor mere issues of scarcity or 'anarchy' (Shah, 2009). Within the many pressures and constraints discussed, choices are made that benefit certain actors and types of groundwater exploitation at the expense of others. A growing body of literature highlights the complex inter-linkages between water, power, politics and governance and stresses that these socio-environmental processes produce uneven outcomes for various (groups of) people over space and time (Budds and Hinojosa, 2012; Mehta et al., 2012). Considering the socio-natural properties of water, it is important to acknowledge that groundwater cannot be isolated from other socio-natural processes (FAO, 2016). Studies have stressed that top-down institutional attempts at enforcement of rules for groundwater use that were formulated outside specific water use contexts can turn ineffective (Shah et al., 2003; Shah, 2009) and even counterproductive (van Steenbergen et al., 2015b). Managing groundwater use, therefore, calls for understanding local hydro-geological complexities and their linkages to the wider socio-political and institutional environments that determine changing land and water uses.

It has been suggested that conjunctive use of groundwater and surface water could deal with the severe groundwater management and water provision problems experienced in areas like Kathmandu Valley (Howard, 2013; Dixit and Upadhya, 2005). As such, efforts to revive and conserve traditional (surface) water sources can contribute to a reduction of pressure on groundwater. Nonetheless, attention is needed that such initiatives are socially and institutionally sustained and not mobilised to justify even more intensive groundwater exploitation. Moreover, rather than merely focus on more groundwater exploitation, governing bodies will have to set, and act upon, clear and coordinated long-term priorities to regulate uncontrolled urban expansion and improve the current quantity and quality conditions of surface water bodies, as a necessary condition for improving (ground)water management.

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[34] Between mid-2014 and 2017, the number of municipalities has increased from five to 18 in Kathmandu Valley and from 58 to 293 in Nepal. The municipal declaration, as in the past, involved the clubbing of VDCs, rural administrative units, – without considering the minimum criterion for designation of an administrative unit as urban center – as proposed in the national urban policy (MoUD, 2015).

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