doi: 10.2166/9781789062786_0173

Chapter 14

What are we allocating and who decides? Democratising understanding of groundwater and decisions for judicious allocations in India

Uma Aslekar[1], Dhaval Joshi[2] and Himanshu Kulkarni[1]

[1]*Advanced Center for Water resources Development and Management (ACWADAM), Pune, India*
[2]*School of Geosciences, University of Edinburgh, United Kingdom*

ABSTRACT

India is the largest user of groundwater in the world. With current dependency on the resource, challenges pertaining to management and governance of groundwater in the country have increased tremendously. To address these challenges, various policy and programmatic interventions have been devised and implemented by state and non-state actors. In this chapter, we question the techno-managerial nature of these solutions and propose a socio-hydrogeological approach that integrates the multidisciplinary and decentralised nature of groundwater problems. To illustrate this, we draw on case studies that have emerged as part of our work on strengthening participatory processes of aquifer monitoring and mapping, decentralised groundwater allocation for agricultural decisions and management strategies that evolve through local institutions. Various programmes are underway in the country aimed at improving participation in governance of groundwater resources. If we are to achieve our goals of collectively and sustainably managing this invisible resource, there is a need to adopt approaches that move beyond the techno-managerial paradigm and embody local ways of knowing, using, and managing groundwater.

Keywords: Aquifer, groundwater, management, over-exploitation, participation

14.1 THE CRISIS OF GROUNDWATER DEPLETION AND CONTAMINATION IN INDIA

India has 17.5% of the world's population but only 2.4% of the world's land resources and roughly 4% of the world's freshwater resources (India-WRIS, 2012). The population of India has more than tripled in the last 70 years (Census data[1], various years). Meanwhile, food grain production has increased five-fold (Ministry of Agriculture, 2017). These changes have put enormous pressure on natural resources in different parts of the country, most significantly on water. For a monsoon-dependent country such as India, rainfall plays a significant role in determining the status of water availability each year. While the demand for water has grown across all sectors because of the expansion of agriculture,

[1]www.census2011.co.in

rapid urbanisation and a growing population, there has not been a significant change in the average rainfall over the years[2]

Groundwater has played a pivotal role in fulfilling the increasing demand for water to meet the country's drinking water needs, food security, and economic development. The Green Revolution ushered in an era of achieving food security by making chemicals such as fertilisers and pesticides, high-yielding variety seeds and, most importantly, water available to the farmers that helped the country achieve food self-sufficiency (Singh *et al.*, 2019). Farmers started digging and drilling wells and bore wells to secure water supplies for agriculture. About 84% of the increase in net irrigated area in the last four decades has been sourced from groundwater.

At present, nearly 70% of India's irrigation depends on groundwater (Kulkarni *et al.*, 2015; MoA, 2014) and India is the largest user of groundwater in the world (Shah 2010). As of 2017, the total annual groundwater extraction in India has been assessed as 249 billion (10^9) cubic metres (BCM) out of 393 BCM, which is the total annual extractable groundwater resource in India (CGWB, 2019). Nearly 85% of rural drinking water supplies are dependent on groundwater (NITI Aayog, 2018) and 48% of the water requirement in cities is fulfilled by groundwater (Narain & Pandey, 2012).

Such unprecedented usage of groundwater is unfolding into a crisis with various ramifications. Firstly, expansion of groundwater abstraction in the 1970s and 1980s started to be felt in the 1990s as the shallow water table was slowly depleted. As a result, farmers started exploiting the deeper confined aquifers and further faced negative impacts of resource exhaustion on their lives and livelihoods (Shah 2010; Shah & Kulkarni, 2015). Groundwater exploitation has resulted in a decrease in basic groundwater availability; in some areas, this has meant persistent, inter-annual water scarcity. The Central Groundwater Board (CGWB) is the National Apex Agency entrusted with the responsibilities of providing scientific inputs for management, exploration, monitoring, assessment, augmentation, and

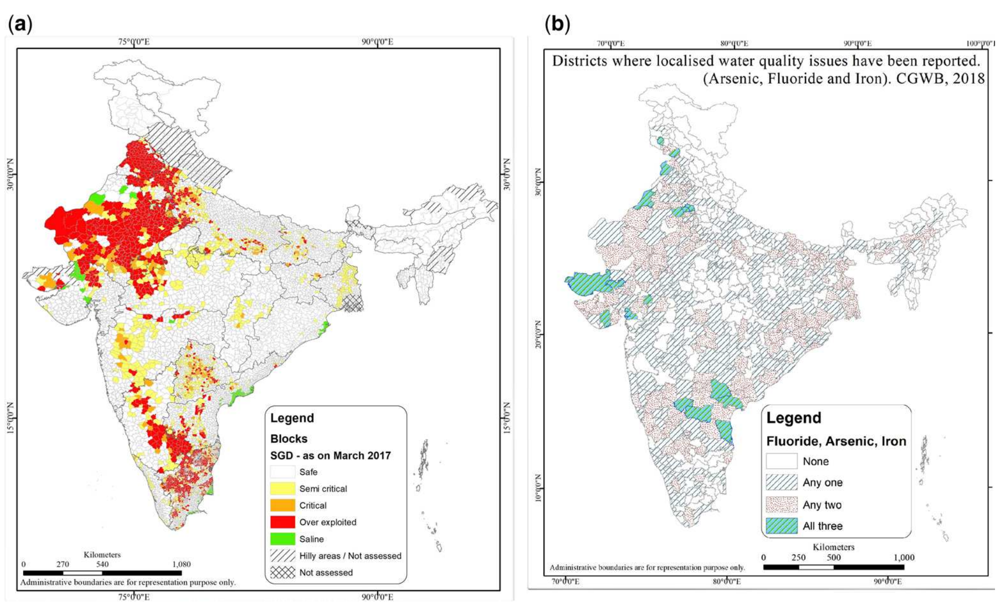

Figure 14.1 (a) Groundwater development in India by district and (b) groundwater quality in shallow aquifers by district (CGWB, 2019).

[2]https://www.tandfonline.com/doi/abs/10.1080/02626667.2010.481373

regulation of the country's groundwater resources. They conduct periodic assessment of replenishable groundwater resources of the country jointly with the State Government agencies concerned. As per the 2020 assessment, 35% of assessment units, that is the sub-district level administrative units (tehsils and blocks in different states of the country), are in various 'stages' of groundwater exploitation. As shown in Figure 14.1a below, the districts are marked in red, amber, and yellow indicating groundwater over-exploited[3], critical[4] and semi-critical[5] districts, respectively.

Secondly, problems of groundwater contamination have emerged, sometimes in association with reduced availability, leading to an acute water quality degradation. According to a 2017 report by Centre for Science and Environment (CSE), half of the country's groundwater is contaminated; 55% of districts are contaminated with high nitrate concentrations, 47% with fluoride, 22% with arsenic, and 13% with high lead. Nearly 60% of India's districts have become vulnerable to groundwater depletion, contamination, or both during the last 10–15 years (Kulkarni & Shankar, 2009), endangering the water security of many regions in the country. Figure 14.1b indicates areas experiencing groundwater quality issues.

Groundwater overextraction in India threatens drinking water supply and food security, impacts base flows, and leads to the drying-up of springs and streams. There is immense competition amongst users to tap both shallow and deeper aquifers, leading to conflicts between users. Consequently, there is an urgent need for improved water management and governance in India.

14.2 EFFORTS TO ADDRESS THE GROUNDWATER CRISIS TO DATE

Facing these challenges, the Indian government is implementing several programmes to tackle groundwater depletion. The most important of these programmes include the Integrated Watershed Management Program, one of India's flagship programmes for many years under the Ministry of Rural Development (GoI, 2008), the Drought Prone Areas Program (DPAP), and the Indo German Watershed Program. These watershed development programmes (collectively referred to as 'Programs') have resulted in a positive change in the land use pattern in most of the regions through improvement in the irrigated area and agricultural production (Palanisami & Kumar, 2009). The focus of these Programs is on supply-side interventions and resource augmentation, but these Programs fail to take into consideration the resource itself. Without an understanding of the aquifers, where groundwater resides, these interventions have severe limitations. The watershed development Programs were implemented in a 'one-size-fits-all' manner without considering the hydrogeological conditions that often govern the location, nature, and impacts of a watershed management programme on groundwater resources (Kulkarni *et al.*, 2000; Vijay Shankar *et al.*, 2011). This is evident through the periodic assessments done by the CGWB over the years. There is no significant improvement in the number of critical and over-exploited blocks in the country. Therefore, the success of watershed development programmes with respect to groundwater management seems to be limited.

In all these programmes, much emphasis was given to managed artificial recharge (MAR) that refers to the augmentation of groundwater resources involving the transfer of surface water to aquifers through human intervention (Athavale, 2003; Gale *et al.*, 2002). Initially, artificial recharge in rural India was primarily implemented through watershed development projects, and therefore designed at that scale. More specific methods such as direct recharge through farm-ponds, open wells, boreholes, and roof-top rainwater harvesting gained popularity as integral components of watershed

[3]Groundwater over-exploited area indicating groundwater extraction exceeding the annually replenishable groundwater recharge.

[4]Critical areas are the areas where the stage of groundwater extraction is between 90% and 100% of annual extractable resources available.

[5]Semi-critical areas are the areas where the stage of groundwater extraction is between 70% and 90% of annual extractable resources available.

development, as well as separate, specific, 'groundwater recharging' initiatives. Some of the village-level case studies that have emerged through this approach include Hiware Bazaar, Ralegan Siddhi and Randullabad (Aslekar *et al*., 2013; Singh, 2012).

While MAR is an important strategy, it is equally pertinent to focus on developing an understanding of groundwater resources amongst stakeholders that leads to improved decisions about cropping choices and drinking water security. Such an approach was adopted by the Food and Agriculture Organization (FAO)- supported Andhra Pradesh Farmer-Managed Groundwater System (APFMGS) programme in Telangana and Andhra Pradesh, located in central eastern India. The APFAMGS[6] project developed a participatory hydrological monitoring programme to build farmers' capacities by devising protocols for monitoring groundwater levels and developing the understanding of groundwater. During the project period (between 2004 and 2009) 638 village-level Groundwater Monitoring Committees (GMCs) were formed in 7 districts of Andhra Pradesh and Telangana. These committees regularly monitored hydrogeological parameters for developing climate-resilient crop water budgeting on an annual basis. Such has been the impact of the project that it was recognised as an inspiration for the World Bank-supported Atal Jal programme that is currently underway (World Bank, 2018).

The Sardar Patel Sahkari Jal Sanchay Yojana (SPSJSY) project, located in the Saurashtra region of Gujrat in northwestern India, is a promising example of a community-based distributed groundwater recharge system focused on developing interventions including check dams aimed at improving the recharge of groundwater. Inspired by this programme, the Government of Maharashtra implemented the Jal Yukta Shivar (literally, the water abundant farms campaign) programme between 2015 and 2019, aiming to make the state drought free by constructing cement and earthen stop dams and digging farm ponds through community participation and convergence with other programmes. About 254 000 water and soil conservation works have been completed in 16 522 villages with a total cost of 7692 crores, roughly 1100 million US dollars (Bhadbhade *et al*., 2019). The Program's limited outcomes have been attributed to the lack of groundwater management at local scales.

Although groundwater is a common pool resource, the ownership and access to it is private in nature. The Easement Act of 1882 states that anyone who owns land owns the resources under it, meaning groundwater sources such as dug-wells and bore-wells are private in nature. There is no licensing or permit system for groundwater in India or any of its states. Although recent state-led legislations have tried to identify groundwater sources and levy cess on existing sources beyond a certain depth, there is very little implementation and enforcement of the laws.

Given that nearly 65% of irrigated agriculture in the country is dependent on groundwater and with increasing evidence of improved water-use efficiency using micro-irrigation techniques (Wani *et al*., 2016), the government is now subsidising the adoption of these technologies by farmers under the Pradhan Mantri Krishi Sichai Yojana (Prime Minister Agriculture Irrigation Scheme). In India, as of 2020–21[7] about 938 193 ha[8] of land have been brought under micro-irrigation. However, it is observed that in the absence of regulation over groundwater abstraction, farmers who acquire micro-irrigation techniques prefer to intensify production rather than conserve water (Birkenholtz, 2017)

Recent water management programmes were backed by the energy reforms. Jyotigram Yojana was launched in the state of Gujarat with the intention to address the problems of growing energy subsidies and groundwater overdraft (Gupta, 2012; Shah & Verma, 2008; Shah *et al*., 2004) by providing assured 8-hour uninterrupted energy supply to the farmers. However, the programme failed

[6]https://www.fao.org/climate-smart-agriculture-sourcebook/enabling-frameworks/module-c1-capacity-development/c1-case-studies/case-study-c111-the-andhra-pradesh-farmer-managed-groundwater-systems-apfamgs-project/en/

[7]https://pmksy.gov.in/mis/rptAchievement.aspx

[8]Ha – Hectare (1 Ha = 2.5 acres)

to address the issue of groundwater overextraction. All of these programmes have focused on 'supply side interventions' to tackle the groundwater crisis.

14.3 CHALLENGES IN THE CURRENT PARADIGM

Despite some success in improving groundwater management through MAR and groundwater monitoring-based crop water budgeting, studies by different government and non-governmental organisations have highlighted the rather limited impacts of the programmes. Questions have emerged over the technical aspects of the programmes in terms of design, planning, implementation, and their efficacy in resolving the groundwater crisis (Argade & Narayanan, 2019; Bhadbhade *et al*., 2019; CAG, 2020; Richard-Ferroudji *et al*., 2018; Shah & Narain, 2019). In 2004, the CGWB started assessing the groundwater situation in the country using the Groundwater Estimation Methodology-1997[9], with subsequent assessments conducted in 2009, 2013 and 2019. During this period, the number of safe blocks, which are blocks where there is no significant long-term decline in the pre- and post-monsoon water levels and where there is groundwater development potential[10] , has gone down from 72% to 63% within a span of 15 years

Legal frameworks play a crucial role in enabling efficient groundwater governance (Mechlem, 2012). Water is governed at the state level in India and, as per the constitution of the country, the responsibility lies with the state departments to enhance, develop, and manage these hydrological systems. Every state in India frames its own rules and regulations based on the Model Legislation Bill proposed by the central government to regulate and control the development and management of groundwater that was first proposed in the 1970s (Cullet, 2019). In their analysis of the 1993 Maharashtra Groundwater Act that aimed to protect drinking water sources, Phansalkar and Kher (2006) highlighted the Act's limited understanding of groundwater resources and poor enforcement by the administration. The Act missed the premise that a single aquifer system often caters for all types of users and uses, where diverse types of uses come into conflict even within a single village that depends on groundwater for meeting agricultural and domestic needs (Kulkarni & Vijay Shankar, 2014). Some scholars argue that the close interdependencies between various aspects of management strategies such as crop choices, energy pricing, and state control often undermine the effectiveness of such regulatory mechanisms (Hoogesteger & Wester, 2017). The right to pump groundwater has been regarded as a landowner's impregnable right. This pre-existing provision has led to a strong social consensus in favour of irrigators, even if that compounds the difficulty in fetching groundwater for drinking water.

Various limitations have been outlined by scholars and practitioners such as the bureaucratic nature of the Programs and their discard of local experiential knowledge favouring 'technical guidelines' (Baviskar, 2004; Samuel *et al*., 2007). In addition to the often narrowly-focused 'supply-side' nature of such Programs mentioned above, many scholars have also outlined the (mis)conception of the village community as a homogeneous and harmonious entity as an important factor in yielding poor outcomes for the Programs (Agrawal & Gibson, 1999). Although the Program includes establishing a

[9]Groundwater Estimation methodology-1997 was the outcome of the recommendations of a 'High Power Committee' constituted by the Ministry of Water Resources, Government of India that includes detailed computational procedures to be followed while applying the groundwater estimation methodology and the assumptions behind the estimation of all components of groundwater assessment. (http://cgwb.gov.in/Documents/GEC97-Detailed_Guidelines.pdf)

[10]Safe block: The groundwater resources are assessed in units, i.e. blocks/talukas/mandals/watersheds. These assessment units are categorised for groundwater development based on two criteria – (a) stage of groundwater development, and (b) long-term pre-and post-monsoon water levels. The long-term groundwater level trends are computed generally for the period of 10 years. (http://cgwb.gov.in)

committee through a formal process of Gram Sabha[11], there are power dynamics at play which result in a capture of such spaces by the villages' social and political elites (Kale, 2011).

14.4 MOVING BEYOND TECHNO-MANAGERIAL SOLUTIONS

The various Programs discussed thus far are often very technical in scope and lack adequate mechanisms to change mindsets and secure the buy-in of communities. The participatory processes included in these Programs tend to limit the participation of communities in understanding their resources. For example, the Government of India's ambitious Jal Jeevan Mission focuses on improving the public drinking water supply by installing tap connections in all rural households by 2024. In doing so, the emphasis lies on creating infrastructure, laying pipes, installing taps and pump-sets. While this is necessary, it is much more important to focus on the institutional capacities and participation of communities to ensure inclusive and efficient local-level planning and management. Evidence suggests that groundwater-based projects that promoted local participation were far more successful than those focused solely on technical interventions (Kerr & Chung, 2002; Palanisami & Kumar, 2009). Hence, it is essential to transform how participation is envisaged in these programmes and move towards more engaging, active, and empowering participation, where communities organise and design strategies to manage and govern their water resources (including groundwater).

The Farm Pond Program promoted by the government of Maharashtra is an example of a supply-side, technical project that resulted in undesirable outcomes that could have been prevented with better, participative planning. This programme aimed to improve access to water for rainfed and drought-prone farmers by creating ponds that harvest rainwater. Despite its promises, its implementation (called '*Magel tyala Shet Tala*' which literally means 'whoever wants shall have a farm pond') has led to water equity and sustainability challenges. Many farmers have resorted to abstracting groundwater from deeper bore-wells and storing it in their farm ponds, which has led to severe evaporation losses and the capture of a common pool resource (Joshi, 2017; Kale, 2017).

Assessing the problems as simply technical or managerial in nature (e.g., lack of data) promotes techno-managerial solutions and practices (Joy *et al*., 2014; Mehta *et al*., 2019; Prakash, 2005). Instead, embedding the technical solutions into the challenge of unsustainable water use in a fully participative process would have ensured that (technical) solutions are associated with the right understanding (i.e., water is part of a complex, interconnected system) and mindset (i.e., acknowledging that an action on one part of the system will impact another part of the system). Moving away from the current techno-engineering approach requires recognising the 'governance' dimensions of water management, that is that water use is an embodiment of politics, science, culture, histories and values (Anand, 2011; Mosse, 2003; Orlove, 2002) and requires frameworks and decision-making processes that confront perspectives, understandings, and values.

14.5 TOWARDS A MULTIDISCIPLINARY AND PARTICIPATORY FRAMEWORK

Drawing from our work in this field for nearly a decade in India and other research studies, we propose a multidisciplinary framework that aims to bring together understanding from various disciplines to design groundwater management strategies for improving its allocation amongst various users and uses. We define multidisciplinarity as a practice that aims to integrate multiple voices, beyond the sciences, and values the multiple nature of groundwater beyond the biophysical characteristics, to devise a process that leads to improved governance. Through multiple nature, we intend to recognise diversity of dependencies and contexts within which groundwater–society relationships have emerged

[11] Gram Sabha means a body consisting of all persons whose names are included in the electoral rolls for the panchayat at the village level. The term is defined in the Constitution of India under Article 243(b).

over the last decades. In doing so, the multidisciplinary framework aims to emphasise the role of aquifers rather than wells and the role of communities rather than individuals (Zwarteveen *et al.*, 2021). This will also mean transforming the policy and programmatic landscape through a set of subsidies, interventions, and incentives.

Participatory processes can help enable collective decision-making. Creating engagement spaces in the form of institutional arrangements, such as aquifer federations and watershed committees, that are recognised by state and non-state actors and work closely with the communities is important. Recent changes in groundwater legislation in Maharashtra, for example, promote such decentralised decision-making spaces in the form of a Watershed Water Resources Committee, aquifer federations, and so on. Similar arrangements have been proposed in watershed Programs, such as the Jal Jeevan Mission (wherein the emphasis is on the Village Water and Sanitation Committee constituted by the Gram Panchayat[12] through Gram Sabha).

One of the impediments towards improving groundwater governance and management is the lack of data. Researchers have emphasised the role of groundwater knowledge in improving governance. Collective groundwater monitoring has been attempted in various instances such as the APFAMGS Program in Andhra Pradesh, aquifer management organisations (COTAS or technical groundwater committees in Spanish) in Mexico and groundwater user associations in Spain (Garduno *et al.*, 2009; Lopez-Gunn & Cortina, 2006; Wester *et al.*, 2011). Varady *et al.* (2016) highlight groundwater data availability as a prerequisite for governance strategies. Groundwater is an invisible resource, which is why the understanding of groundwater becomes even more challenging. In India's context, given the country's hydrogeological diversity, it is difficult to implement a common data programme that will document the nuances of different aquifer systems across the country. Another important observation is that given the sheer magnitude of groundwater use in the country and the number of sources (nearly 30 million sources), arriving at representative data in terms of their granularity and frequency is often a cumbersome task. For example, the CGWB currently monitors about 15 640 observation wells

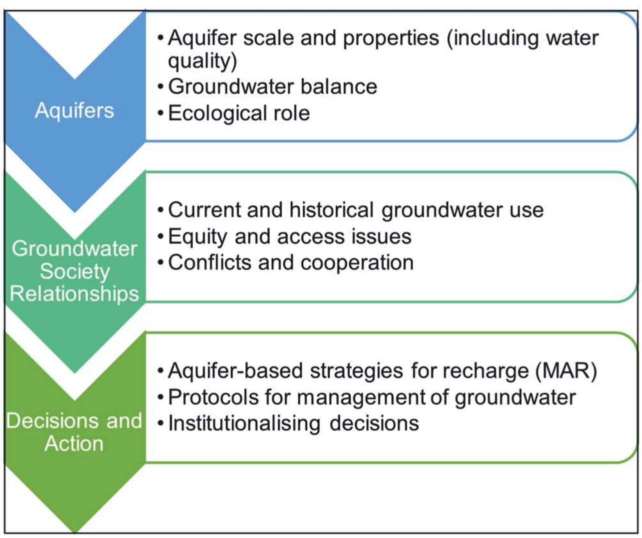

Figure 14.2 Elements of a socio-hydrogeological approach.

[12]Gram Panchayat is the local elected governing council at the village level.

across 5740 units (block, taluka, mandal) which equates to about 2.7 wells per unit. Each of these units roughly consists of about 100 villages, thus the representative figure equates to about 1 well in 35–40 villages. This gives us an idea of the scope of the challenge in terms of groundwater monitoring and associated costs.

Participatory frameworks of data collection, analysis, and interpretation will help address some of the problems discussed above. Such frameworks will also help communities and other stakeholders improve their collective understanding of local groundwater conditions. Engaging community members in data collection and preliminary interpretation shapes pathways to local management strategies.

Going beyond efforts for participatory monitoring of groundwater, our framework promotes groundwater socio-hydrogeology, which can be defined as a set of practices that interact and shape an approach that integrates the societal–groundwater relationships beyond groundwater's biophysical nature. It aims to engage with social inequities, resource distribution and questions of access to arrive at collective ways of addressing governance challenges. Experiences from ACWADAM's[13] work across India have emphasised the need for such an approach that has led to a diversity of practices to understand, manage, and govern groundwater over-abstraction (Figure 14.2).

A socio-hydrogeological approach integrates three key aspects of governance as depicted below:

These three aspects together help develop a robust groundwater management and governance plan at the local level. The next section discusses some of the innovative methods and approaches to understanding the three pillars of socio-hydrology. We shall discuss the method of Participatory Aquifer Mapping (PAQM) that has emerged from our work in rural and urban areas and engages in participatory processes of mapping and managing aquifers. To elaborate groundwater–society relationships, we draw from the experiences of groundwater balance-based crop water budgeting and allocations in rural settings where agriculture is the dominant driver of groundwater use. Lastly, we bring forth our experiences on how this improved understanding leads to decisions and actions around groundwater management and governance. We draw from diverse case studies across different hydrogeological and regional settings.

14.6 PARTICIPATORY MAPPING OF AQUIFERS

Groundwater accumulation and movement is governed by the hydrogeology of the region. The types of rocks and their properties determine the transmissivity and storativity of groundwater in the aquifers. Hydrogeologically, India is a diverse country with six predominant hydrogeological regimes (Figure 14.3), viz. alluvial (unconsolidated), volcanic, crystalline, sedimentary (hard), sedimentary (soft) and mountain systems (Kulkarni & Vijayshankar, 2014). Therefore, an understanding of local groundwater systems and aquifers as a prerequisite for groundwater management programmes becomes pertinent.

Aquifer mapping is a hydrogeological enterprise, predominantly driven by geological sciences. However, the experiences of authors suggest that communities' experiential knowledge regarding water-bearing and water-resisting rock formations forms an important basis to develop this collective understanding. Participatory Aquifer Mapping has evolved as a process where techniques of hydrogeology are coupled with local experiential knowledge to reach a common understanding of the aquifer (Figure 14.4).

The process entails conducting field surveys for observing local geology and collecting lithology samples from sources that are being drilled. A groundwater monitoring network is set up to collect water-level data for at least one hydrological year. It involves identifying sources and then setting

[13]ACWADAM stands for Advanced Center for Water Resources Development and Management. ACWADAM is a Pune based not-for-profit organisation working on the issues pertaining to groundwater and its management.

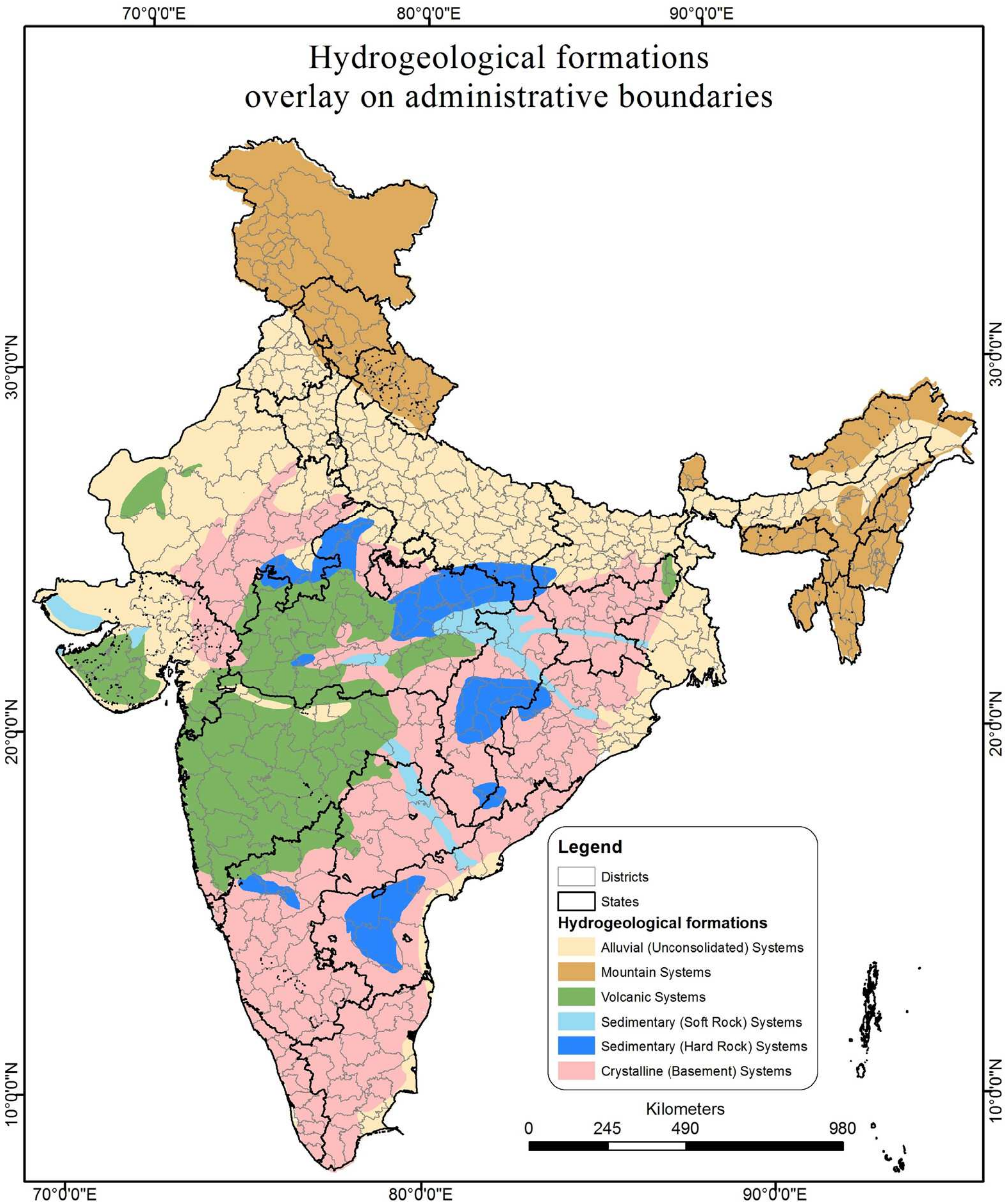

Figure 14.3 Hydrogeological formations in India (after Kulkarni & Vijayshankar, 2014).

a monitoring frequency (monthly, quarterly, seasonal). A questionnaire containing information on source type, use, year of construction, depth and water struck is then used to document responses from community members. These crowdsourced data are then validated through field observations and information from local drillers who have thorough knowledge of the groundwater systems in the area. Based on this collective effort, a conceptual map of aquifer systems present in the area is

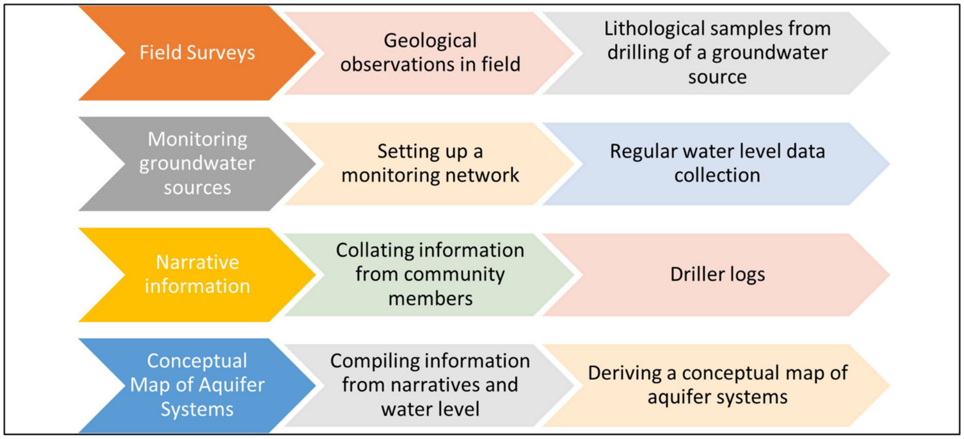

Figure 14.4 Participatory aquifer mapping process.

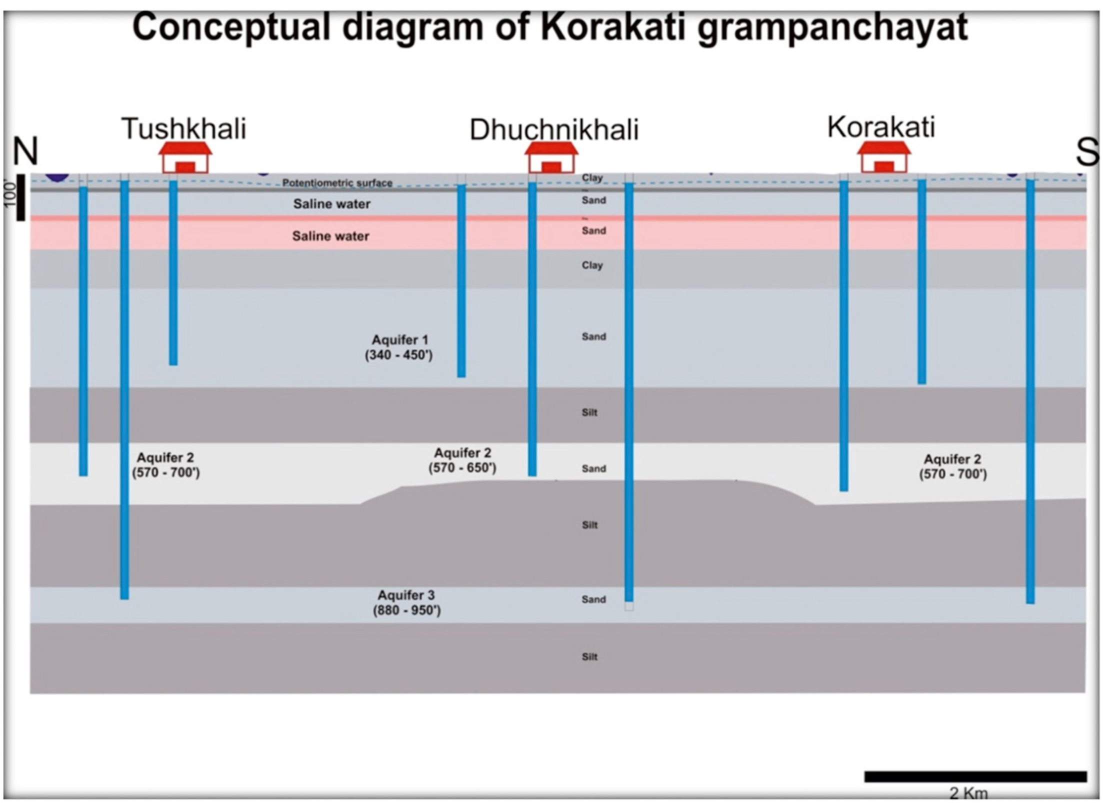

Figure 14.5 Conceptual Aquifer Map of Korakati Gram Panchayat. Source: ACWADAM (2021).

derived. In areas where further validation is required, data can be substantiated using geological techniques such as vertical electrical sounding (VES)[14] resistivity surveys, drilling observation wells, and so on.

Application of the above process was undertaken in Korakati Gram Panchayat of the Sundarbans region of West Bengal. Korakati is a part of the alluvial aquifer settings of the Ganga delta region of Sundarbans. The community depends on groundwater for their livelihoods and drinking water security; thus, mapping and monitoring groundwater becomes crucial for ensuring equity and sustainability. The PAQM process involved inputs from local drillers and community members with experience tapping handpumps and tube-wells at various depths. Figure 14.5 presents the conceptual map that emerged for the area.

The map helped create a common and shared understanding of the resource system which otherwise is understood at an individual level. A shared understanding of resource systems is critical for any positive action for resource governance. A similar exercise was carried out in multiple locations across India to prepare the aquifer maps and conceptual diagrams for different villages. Even an approximation of aquifer boundaries and aquifer characteristics can form a robust platform for launching a community-level, participatory form of groundwater management.

14.7 PARTICIPATORY WATER BUDGETING IN GROUNDWATER-BASED IRRIGATION

As stated earlier, studies have shown that the use of micro-irrigation techniques often leads to the intensification of cropping and irrigation practices (Birkenholtz, 2017). Thus, reliance on micro-irrigation alone as a panacea to tackle the agricultural water use may be misleading. Behavioural change through improved and shared understanding of resources shall enable a change in perception of farmers and their orientation towards water use in agriculture. The experiences of APFAMGS and case studies such as Randullabad have shown the importance of this approach (Aslekar *et al*., 2013; FAO, 2016; Singh 2012).

Many studies rely on standards of crop water requirements developed by various international and state agencies such as FAO[15], Water and Land Management Institute (WALMI) (2013), and so on. However, such an approach leads to approximations and may not be reflective of the practices adopted by farmers to irrigate their crops. Hence, to arrive at a more accurate understanding of crop water requirements, we implemented an approach involving identifying farmer plots that are cultivating crops grown in the village/area, complemented with documented irrigation cycle data based on farmer diaries and consolidated to arrive at crop water requirements. This allows us to undertake groundwater balance-based crop water budgeting based on local data that are more accurate and more accepted by local communities. In the Waki village in the Dhule district of Maharashtra, derived crop water requirements were compared with the groundwater balance situation to assess total annual recharge and discharge of groundwater along with changes in aquifer storage. An estimate of the groundwater balance enabled us to understand patterns of groundwater recharge, discharge and change in aquifer storage, and estimate the stage of groundwater development in an aquifer/area

14.8 PARTICIPATORY GROUNDWATER MANAGEMENT

Much of the groundwater use is allocated to agriculture in any given village. While winter cropping (known as Rabi season) is the dominant driver, farmers are increasingly resorting to irrigating crops in Kharif season, owing to irregular monsoons. Collectivising the allocation of groundwater in

[14]Vertical electrical sounding (VES) is a geophysical method for investigation of a geological medium. The method is based on the estimation of the electrical conductivity or resistivity of the medium.

[15]See e.g.: http://www.fao.org/docrep/S2022E/s2022e07.htm

rural settings is one of the biggest challenges. Although most communities understand the need for collective action for allocating groundwater appropriately, it is difficult to adopt new practices and change cropping patterns, as this is intricately linked to livelihoods, income security and the larger agricultural economy. However, community-driven, hydrogeology-based participatory groundwater management planning can help shape better local allocations.

In the Baretha village, a set of marginalised and rainfed farmers were identified, who agreed to sharing wells for irrigation. Using the information developed through local-level groundwater monitoring, potential recharge areas were demarcated to identify the location for the new wells. Once the wells were in place, a formal agreement was sought between the farmers for allocating water for each member of the group. The agreement had points referring to shared well ownership, mutual arrangement for irrigation cycles and cropping patterns, and contribution towards maintenance costs.

In the case of Sitaljhiri village, a local governance institution called Bhujal Prabandhan Samiti (Groundwater Management Committee) was constituted by the Gram Panchayat through a Gram Sabha. This institution was entrusted with decisions for managing and recharging groundwater. The Samiti decided to adopt certain norms for crop choices, which included a reduction in wheat cropping area, cultivating Bengal Gram, and adopting an improved wheat variety (locally known as 1544) that required three cycles of irrigation as compared to an existing variety called Lokwan, which needed five cycles. These choices were adopted by some farmers in the village and enabled the judicious use of groundwater. Similarly, in the Randullabad village of the Satara district of Maharashtra, the community has taken a decision to put a complete ban on drilling bore wells in the village to secure groundwater in the villages' confined aquifers. This decision is meticulously followed by the community even after 20 years, reiterating the importance of knowledge, participation, and decentralised groundwater governance (Aslekar *et al*., 2013).

14.9 CONCLUSIONS

Today, india is the largest user of groundwater in the world, a seemingly remarkable fact that hides nuances of social disparity, iniquitous competition, hidden conflicts, and the tension between traditional and modern practices. The individualised nature of groundwater sourcing, access, and distribution with groundwater usage from millions of wells (and springs in the mountains) means a centralised command and control type of regulation is difficult to implement. Decentralised mapping of aquifers and a combined understanding of groundwater characteristics and social behaviour is necessary if India's groundwater resources are to be allocated collectively. Groundwater governance through principles of managing common pool resources cannot be fully achieved unless collective decision and action is enabled through community participation and institutional decentralisation. The concept of socio-hydrogeology offers a useful instrument to conduct participatory mapping, measurement and monitoring of aquifers in India's varied geography and contexts.

Socio-hydrogeological mapping of aquifers, using people's narratives on well-logs, groundwater pumping, groundwater levels, groundwater quality and the ecosystem changes in an area can help create a three-dimensional understanding of groundwater resources. Such an approach incorporates a collaborative understanding of local groundwater dynamics, paving the way for collective decisions and actions at community levels that help prioritise allocations amongst users and uses. Formal institutions of governance, such as the Gram Panchayats (in rural India) and Municipalities (in urban India) can remain well-informed about the groundwater situation in their respective jurisdictions and about protocols of conservation, Managed Aquifer Recharge and Participatory Aquifer Management. This approach not only incorporates decentralised groundwater governance, but also embodies principles of democratising the management and governance of groundwater, particularly given India's peculiar groundwater situation.

ACKNOWLEDGEMENT

We acknowledge the support from Bharat Rural Livelihoods Foundation for the Program on 'Participatory Groundwater Management in Central Indian Tribal Belt' along with non-governmental organisation partners BAIF, PRASARI and Lupin Foundation. We would like to extend our sincere gratitude to the communities of Korakati Gram Panchayat, Sitaljhiri Gram Panchayat and Waki Gram Panchayat for collaborating on the Program.

REFERENCES

Aayog N. (2018). Composite Water Management Index: A tool for water management.

ACWADAM. (2021). Towards Decentralised Groundwater Governance in the Central Indian Tribal Belt: evidences for participatory processes and inputs for policy. ACWA/Hydro/2021/H112.

Agrawal A. and Gibson C. C. (1999). Enchantment and disenchantment: the role of community in natural resource conservation. *World Development*, **27**(4), 629–649.

Anand N. (2011). Pressure: the polytechnics of water supply in Mumbai. *Cultural Anthropology*, **26**(4), 542–564, https://doi.org/10.1111/j.1548-1360.2011.01111.x

Argade P. and Narayanan N. C. (2019). Undercurrents of participatory groundwater governance in rural jalna, western India. *Water Alternatives*, **12**(3), 869–885.

Aslekar U., Upamanyu A. and Kulkarni H. (2013). Participatory groundwater management in Randullabad. Report on ACWADAM's Action Research Initiative under the PGWM Program with Support from Arghyam Trust, Bengaluru.

Athavale R. N. (2003). Water Harvesting and Sustainable Supply in India. Rawat Publications, Jaipur.

Baviskar A. (2004). Between micro-politics and administrative imperatives: decentralisation and the watershed mission in Madhya Pradesh, India. *The European Journal of Development Research*, **16**(1), 26–40, https://doi.org/10.1080/09578810410001688716

Bhadbhade N., Bhagat S., Joy K. J., Samuel A., Lohakare K. and Adagale R. (2019). Can Jalyukt Shivar Abhiyan prevent drought in Maharashtra? *Economic & Political Weekly*, **54**(25), 13.

Birkenholtz, T. (2017). Assessing India's drip-irrigation boom: efficiency, climate change and groundwater policy. *Water International*, **42**(6), 663–677.

Central Ground Water Board. (2019). National compilation on dynamic ground water resources of India, 2017. Ministry of Water Resources River Development and Ganga Rejuvenation, Govt of India. Available at: http://www.cgwb.gov.in

Comptroller and Auditor General of India (CAG). (2020). Report no. 3 Government of Maharashtra (https://cag.gov.in/cag_old/sites/default/files/audit_report_files/Report_No_3_of_2020_General_and_Social_Sector_and_PSUs_Government_of_Maharashtra.pdf)

Cullet P. (2019). Governing groundwater: fostering participatory and aquifer-based regulation. In: Water Governance: Challenges and Prospects. Springer, Singapore, pp. 117–129.

Department of Agriculture. (2017). Annual Report 2016–17. Department of Agriculture and Framers Welfare, Govt of India, Krishi Bhawan, New Delhi. Available at: http://agricoop.nic.in/sites/default/files/Annual_rpt_201617_E.pdf (accessed 8 February 2021)

FAO. (2016). Global Framework for Action: to Achieve the Vision on Groundwater Governance. Food and Agriculture Organisation, Rome. www.fao.org/3/a-i5705e.pdf

Gale I., Neumann I., Calow R. and Moench dan M. (2002). The effectiveness of Artificial Recharge of groundwater: a review. British Geological Survey. (CR/02/108N) (Unpublished).

Garduño H., Foster S., Raj P. and van Steenbergen F. (2009). Addressing groundwater depletion through community-based management actions in the weathered granitic basement aquifer of drought-prone Andhra Pradesh-India. GW-MATE Case Profile Collection, **19**.

GOI. (2008). Common Guidelines for Watershed Development Projects. Department of Land Resources, Ministry of Rural Development, Government of India, New Delhi.

Gupta A. (2012). Red Tape: Bureaucracy, Structural Violence, and Poverty in India. Duke University Press, North Carolina.

Hoogesteger J. and Wester P. (2017). Regulating groundwater use: the challenges of policy implementation in guanajuato, central Mexico. *Environmental Science & Policy*, **77**, 107–113, https://doi.org/10.1016/j.envsci.2017.08.002

India-WRIS. (2012). River Basin Atlas of India, Ministry of Water Resources, Government of India, RRSCO West, ISRO, Jodhpur.

India - Atal Bhujal Yojana (ABHY) - National Groundwater Management Improvement Program (English). World Bank Group, Washington, D.C. http://documents.worldbank.org/curated/en/697581528428694246/India-Atal-Bhujal-Yojana-ABHY-National-Groundwater-Management-Improvement-Program.

Joshi, D. (2017). Promoting Farm Ponds. *Economic & Political Weekly*, **52**(16), 71.

Joy K. J., Kulkarni S., Roth D. and Zwarteveen M. (2014). Re-politicising water governance: exploring water re-allocations in terms of justice. *Local Environment*, **19**(9), 954–973, https://doi.org/10.1080/13549839.2013.870542

Kale, E. (2011). Social exclusion in watershed development: evidence from the Indo-German Watershed Development Project in Maharashtra. *Law Environmental and Development Journal*, **7**, 95.

Kale E. (2017). Problematic uses and practices of farm ponds in Maharashtra. *Economic & Political Weekly*, **52**(3), 20–22.

Kerr J. and Chung K. (2002). Evaluating watershed management projects. *Water Policy*, **3**(6), 537–554.

Kulkarni H. and Shankar P. V. (2009). Groundwater: towards an aquifer management framework. *Economic and Political Weekly*, 13–17.

Kulkarni H. and Shankar P. V. (2014). Groundwater resources in India: an arena for diverse competition. *Local Environment*, **19**(9), 990–1011, https://doi.org/10.1080/13549839.2014.964192

Kulkarni H., Deolankar S. B., Lalwani A., Joseph B. and Pawar S. (2000). Hydrogeological framework of the Deccan basalt groundwater systems, west-central India. *Hydrogeology Journal*, **8**(4), 368–378, https://doi.org/10.1007/s100400000079

Kulkarni H., Shah M. and Vijay Shankar P. S. (2015). Shaping the contours of groundwater governance in India. *Journal of Hydrology: Regional Studies*, **4**, 172–192. https://doi.org/10.1016/j.ejrh.2014.11.004

Lopez-Gunn E. and Cortina L. M. (2006). Is self-regulation a myth? Case study on Spanish groundwater user associations and the role of higher-level authorities. *Hydrogeology Journal*, **14**(3), 361–379, https://doi.org/10.1007/s10040-005-0014-z

Mechlem K. (2012). Groundwater governance: a global framework for country action-thematic paper 6: Legal and institutional frameworks. GEF: Groundwater Goverance: A Global Framework for Country Action, GEF ID, *3726*.

Mehta L., Srivastava S., Adam H. N., Bose S., Ghosh U. and Kumar V. V. (2019). Climate change and uncertainty from 'above'and 'below': perspectives from India. *Regional Environmental Change*, **19**(6), 1533–1547, https://doi.org/10.1007/s10113-019-01479-7

Ministry of Agriculture, Government of India (2014). Web based land use statistics information system, Various Land Use Statistics Reports, Directorate of Economics and Statistics, Department of Agriculture and Cooperation. http://lus.dacnet.nic.in/dt_lus.aspx.

Mosse D. (2003). The Rule of Water: Statecraft, Ecology and Collective Action in South India. Oxford University Press, New Delhi.

Narain S. and Pandey P. (2012). Excreta Matters: How Urban India is Soaking up Water, Polluting Rivers and Drowning in its Own Waste. Centre for Science and Environment, New Delhi.

Orlove, B. (2002). Lines in the Water: nature and Culture at Lake Titicaca. University of California Press.

Palanisami K. and Kumar D. S. (2009). Impacts of watershed development programs: experiences and evidences from Tamil Nadu. *Agricultural Economics Research Review*, **22**, 387–396.

Phansalkar S. and Kher V. (2006). A decade of Maharashtra groundwater legislation: analysis of the implementation process. *Law, Environment and Development Journal*, **2**, 67.

Prakash, A. (2005). The Dark Zone: groundwater Irrigation, Politics and Social Power in North Gujarat. Wageningen University and Research.

Richard-Ferroudji A., Raghunath T. P. and Venkatasubramanian, G. (2018). Managed aquifer recharge in India: Consensual policy but controversial implementation. *Water Alternatives*, **11**(3), 749–769.

Samuel A., Joy K. J., Paranjape S., Peddi S., Adagale R., Deshpande P. and Kulkarni S. (2007). Watershed development in Maharashtra: Present scenario and issues for restructuring the programme. SOPPECOM, Pune.

Shah T. (2010). Taming the anarchy: Groundwater governance in South Asia. Routledge.
Shah T., Scott C., Kishore A. and Sharma A. (2004). Energy-Irrigation Nexus in South Asia: improving Groundwater Conservation and Power Sector Viability. IWMI, Colombo, Sri Lanka, Vol. **70**.
Shah M. and Kulkarni H. (2015). Urban water systems in India. *Economic and Political Weekly*, **50**(30), 57–69.
Shah S. H. and Narain V. (2019). Re-framing India's 'water crisis': an institutions and entitlements perspective. *Geoforum*, **101**, 76–79, https://doi.org/10.1016/j.geoforum.2019.02.030
Shah T. and Verma S. (2008). Co-management of electricity and groundwater: an assessment of Gujarat's Jyotirgram scheme. *Economic and Political Weekly*, **43**(7), 59–66.
Singh S. (2012). Local Governance and Environment Investments in Hiware Bazar, India. Ecological Economics From the Ground Up. Routledge, London, pp. 191–202.
Singh A., (eds.). (2019). Water Governance: Challenges and Prospects, Springer Water, https://doi.org/10.1007/978-981-13-2700-1_1. Springer Nature, Singapore Pte Ltd.
Varady R. G., Zuniga-Teran A. A., Gerlak A. K. and Megdal S. B. (2016). Modes and approaches of groundwater governance: a survey of lessons learned from selected cases across the globe. *Water*, **8**(10), 417, https://doi.org/10.3390/w8100417
Vijayshankar P. S., Kulkarni H. and Krishnan S. (2011). India's groundwater challenge and the way forward. *Economic and Political Weekly*, **46**(2).
WALMI. (2013). Irrigated Crops – Part I, 4th edn. Water and Land Management Institute Publication no. 44, Aurangabad, Maharashtra.
Wani S. P., Bergvinson D., Raju K. V., Gaur P. M. and Varshney R. K. (2016). Mission India for Transforming Agriculture (MITrA), Research Report IDC-4.
Wester P., Minero R. S. and Hoogesteger J. (2011). Assessment of the development of aquifer management councils (COTAS) for sustainable groundwater management in guanajuato, Mexico. *Hydrogeology Journal*, **19**(4), 889–899, https://doi.org/10.1007/s10040-011-0733-2
Zwarteveen M., Kuper M., Olmos-Herrera C., Dajani M., Kemerink-Seyoum J., Frances C., Beckett L., Lu F., Kulkarni S., Kulkarni H., Aslekar U., Börjeson L., Verzijl A., Guzmán C. D., TeresaOré M., Leonardelli I., Bossenbroek L., Ftouhi H., Chitata T., Hartani T., Saidani A., Johnson M., Peterson A., Bhat S., Bhopal S., Kadiri Z., Deshmukh R., Joshi D., Komakech H., Joseph K., Mlimbila E. and De Bont C. (2021). Transformations to groundwater sustainability: from individuals and pumps to communities and aquifers. *Current Opinion in Environmental Sustainability*, **49**, 88–97.