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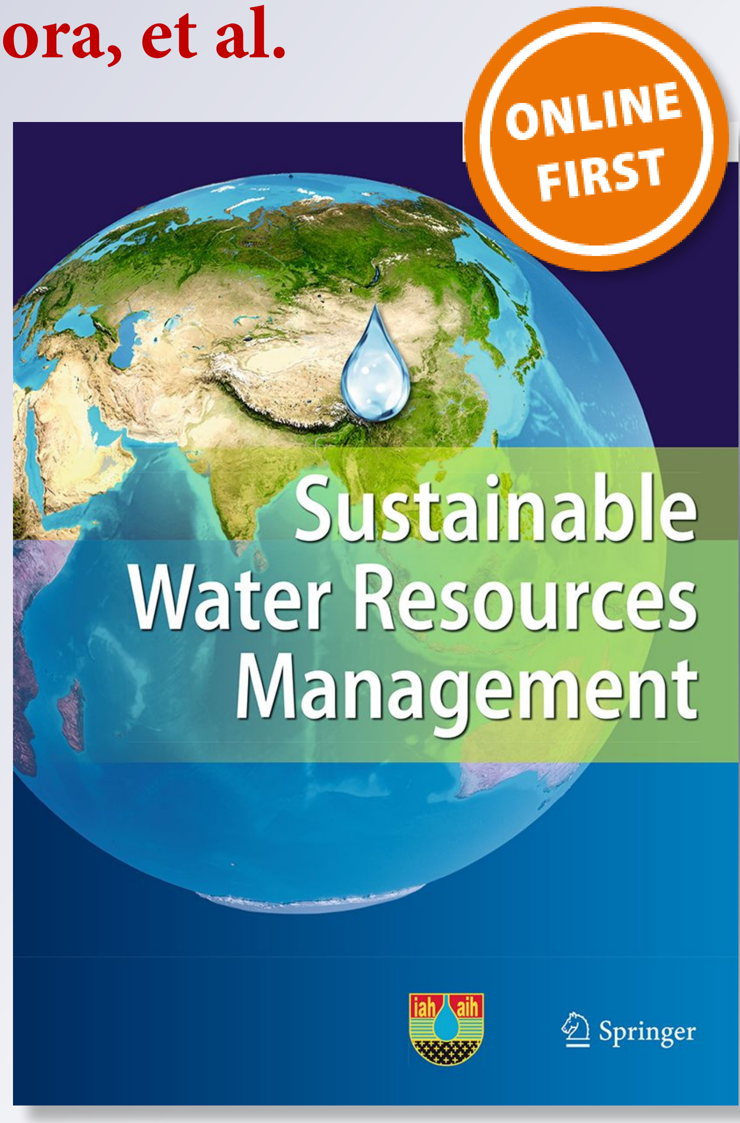

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ORIGINAL ARTICLE

Managing aquifer recharge and sustaining groundwater use: developing a capacity building program for creating local groundwater champions

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Abstract
Participatory groundwater management is increasingly being recognised for its ability to address the challenges of equity, efficiency and sustainability. It can particularly help with effective engagement at the grassroots level for monitoring, recharging and managing the groundwater as a common pool resource. The main aim of this article is to discuss the training and management process used and the lessons learnt from a participatory groundwater management project, titled Managing Aquifer Recharge and Sustainable Groundwater Use through Village-level Intervention (MARVI). In this project, researchers, rural development facilitators and local villagers worked together to initiate participatory groundwater monitoring in 11 villages from the Dharta and Meghraj watersheds in Rajasthan and Gujarat, India. The study involved educating villagers through an intensive program of capacity building, wherein the villagers who participated in the program were called *Bhujal Jaankars (BJs)*, a Hindi word meaning 'groundwater informed'. The BJs were trained in their local settings through relevant theory and practical exercises, so that they could perform a geo-hydrological evaluation of their area, monitor groundwater and share their findings and experiences with their village community. The study has highlighted that with a well-designed program of capacity building and on-going support through training and nurturing, BJs can play an important role in monitoring watertable depth and other data for estimating groundwater recharge, leading to a sharing of the groundwater information with the local village community to influence the sustainable use of groundwater. Overall they can act as local champions for groundwater futures. Further, this study has demonstrated that BJ capacity building can help to provide a scientific basis for village level groundwater dialogue and assist village communities and other stakeholders to improve their decision making regarding groundwater use, crop selection, agronomy, recharge strategies and other aspects of sustainable groundwater management. Although the BJ program has been successful and BJs can act as a valuable interface between local communities and other stakeholders managed aquifer recharge activities, there still exists some challenges to the BJ programme, such as the need for mechanisms and funding sources that will sustain the BJs over the longer term; wider acceptance of BJs among scientific communities and policy makers; and the acceptance of the role and involvements of BJs in natural resources management programs of the State and Central governments in India.

Keywords Participatory water management · Groundwater · Watertable monitoring · Capacity building

Introduction

Groundwater is an essential resource for farmers, especially in arid to semi-arid regions globally where the rainfall is a non-reliant phenomenon and its use has increased significantly over the years (Siebert et al. 2010). Net area under irrigation in India increased threefold, from 20.9 Mha in 1950 to 63.7 Mha in 2010 (Directorate of Economics and Statistics 2016). Post green revolution, irrigation in

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India encouraged irrigated agriculture initially through the use of surface water, but then groundwater use increased rapidly. Data from the Indian agricultural statistics of the Central Water Commission (CWC 2013) show a significant rise in tube well irrigated areas from 0% in 1950 to around 39% in 2003, while also showing a decreasing, though less dramatic, trend for dug well irrigated areas from 29% in 1950 to 22.5% in 2003. In comparison with canal water and surface water irrigated areas, the trend is almost the reverse, from 40.3% in 1950 to 29.3% in 2003. This clearly reflects that Indian agriculture and rural livelihood have increasingly become more dependent on groundwater use than on surface water (Shah 2008). This is supported by the decrease in the use of open wells for irrigation and the increase in the use of tubewells, indicating an on-going depletion of groundwater from aquifers, particularly in North-Western and Southern states (Shah 2009; World Bank 2010).

Groundwater is also important for drinking purposes as it supplies about 90% of drinking water in rural areas (DDWS 2006, 2009). According to NSSO (2006), approximately 56% of the drinking water supply is drawn by hand pumps, 14% from open wells and about 25% through pipe supply from tubewells. However, while the supply share of drinking water is only about 7% of the total water use, groundwater extraction for agricultural use is threatening drinking water supply in two ways. First, through an overall shortage of water, and second through water quality deterioration in terms of increased levels of fluoride and other harmful substances in groundwater from deeper depth resulting in an increasing number of villages being affected by water-related health problems (DDWS 2009).

A comparison of the assessment of annual replenishable groundwater resources for 1995–2011 by the Central Groundwater Board (CGWB) shows that the groundwater crisis covers a much larger area now and is affecting a significantly higher number of people (Central Groundwater Board 2006, 2011). Table 1 clearly shows an unfolding crisis of groundwater availability over a relatively short time of 14 years. The percentage of districts in the *safe* category of groundwater exploitation significantly decreased while those in the semi-critical, critical and *over-exploited* categories during 1995–2009 period increased, particularly those classed as *over-exploited* sharply increased.

In most cases, the deterioration of groundwater quality is closely associated with lowering of the watertable and this further increases the severity of the water crisis. Both the government and groundwater users are equally concerned about finding a solution, but considering the various characteristics and complexities of the groundwater problem, the direct user on their own is helpless in finding a solution to the problem for the following reasons: (1) groundwater is an invisible resource; (2) users are unable to identify recharge and discharge areas; (3) groundwater volume estimation requires data from multiple wells; (4) communities have difficulties visualising the geohydrology; (5) some users lack confidence that they can improve the situation by recharging activities; and (6) traditional water management practices are in many cases not adequately valued by scientific communities and government agencies.

Given this scenario, policies are needed to encourage managed aquifer recharge with good practices and holistic management of groundwater along with improved education and awareness at different levels to facilitate innovative and sustainable solutions (Dillon 2005; Kulkarni et al. 2015). It is also critical that there is a genuine collaboration between social scientists and water scientists to understand what each discipline has to offer and how it can enrich the collective thinking to resolve complex groundwater challenges of the future (Shah 2014; Barthel et al. 2017). A farmer-led groundwater recharge, monitoring and management approach at village level is a possible solution to avoid over-extraction of water through careful stewardship of the resource in combination with water-efficient farming practices (Dillon et al. 2009; Maheshwari et al. 2014). Further, transdisciplinary approach is becoming important to understand groundwater science from the community's point of view, demystifying it and transferring knowledge to relevant communities (Scholz et al. 2000; Gleitsmann et al. 2007). For this to occur there is a need for committed people from the community who are willing to take responsibility to understand sufficient groundwater science and then be able to utilise this knowledge for the betterment of their community.

Experiences of the traditional techniques of harvesting and managing water in arid to semi-arid regions have already demonstrated that communities inherently had sufficient understanding to meet local water needs for irrigation

Table 1 Ground water development in India during 1995–2009 (adapted from Central Groundwater Board 2006 and 2011)

% of annual groundwater use in an area compared to the annual groundwater available	Development risk	% of districts in			
		1995	2004	2009	2011
0–70	Safe	92	73	72	71
70–90	Semi-critical	4	9	10	10
90–100	Critical	1	4	4	4
> 100	Over-exploited	3	14	14	15

and drinking. For example, in western Rajasthan, rainwater harvesting systems, such as *bawari* (step wells), *khadin* (the use of run-off water to recharge groundwater aquifers), *kund* (small underground tanks), *nadi* (ponds), *talab* (medium-sized reservoirs), *tanka* (underground cisterns) and roof water harvesting have been used for centuries (Narain and Khan 2006). In this study, it is our contention that an understanding of traditional knowledge systems and its synthesis with adequate formal science, the community of groundwater users can better participate in groundwater management practices. Such competence-equipped community representatives are known as "*Bhujal Jankaars*" BJs (groundwater informed) in the present article (also see Fig. 1).

Knowledge gap between scientists and village community

When we talk about groundwater, geological aspects come directly into the picture from a science perspective, yet due to the complex nature of this particular science very limited knowledge has reached the grassroots level of village communities. As a consequence, efficient use and management of groundwater has not been occurring, despite government efforts to regulate the installation of tube wells and others measures to reduce groundwater use.

It is well-known that the growth and development of community competence in relation to water management is not a recent process but began in ancient times in India, as revealed by many natural resource practices that were developed and adopted by communities over time. This included earthen embankments in streams to detain water and increase recharge. Within any community there are many local experts who have a passion to evolve and develop such traditional knowledge and understanding about various subjects, including health, vegetation, crops and water. In India, in the case of groundwater, such experts are known by various traditional terms like '*Bhusunghna*', '*Harware*' and '*Jalkala*'. Along with the development of formal science and education, traditional knowledge has gradually disappeared from society (D'Souza 2006). Additionally, there is a lack of proper documentation of the scientific value of these practices.

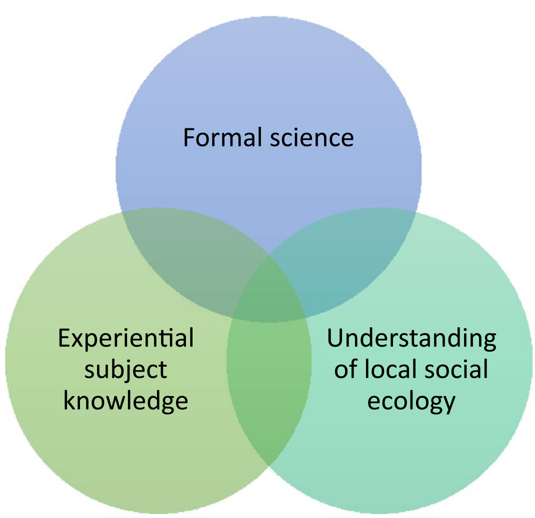

Fig. 1 Bhujal Jankaar: the fusion of three strands of knowledge

Initiating Bhujal Jaankar program

In current development programmes, especially in developing countries such as India, professionals and experts are rarely self-motivated to work for marginalised communities located in isolated areas. Given such a situation, one of the MARVI projects partner organisations selected was Arid Communities and Technologies (ACT) based in Kachchh, Gujarat, as they had already demonstrated competence in capacity building among rural youth. ACT had engaged these youths in groundwater management in arid regions by educating them through synthesising formal geo-hydrological science with traditional water management techniques. ACT along with other MARVI partners now designed a systematic approach for incremental capacity building for these selected villagers based on their previous experiences, and these trained people were termed *Bhujal Jankaars* (*BJs*), a Hindi word meaning 'groundwater informed'. The complete capacity building program, designed in a way that would easily scale up should the need arise in the future, has been demonstrated in the Kachchh and Aravali districts of Gujarat and the Udaipur district of Rajasthan.

In one block in the Kachchh district, initially 12 BJs were trained in hydrogeology to help them develop water security plans at block level. They were subsequently involved in supervising fieldwork to implement the plan. They also monitored the effectiveness of the implementation by collecting data from an established observation network. During this stage the BJs skills, such as site supervision, engineering aspects including the design and estimation of water harvesting structures and their data collection accuracy and reliability, were improved through mentoring. Finally, the data collected was also analysed by these same BJs by facilitating their computer skills which led to them developing a deeper geo-hydrological understanding of the dynamic properties of groundwater. Today these BJs are operationally totally independent and have registered themselves as a local level consulting group, thereby providing their knowledge and services on a fee paying basis to local communities and stakeholders, with the advantage that they have a clear emotional attachment to their own land and people who they are working for.

Following on from the experience of ACT in Kachchh, the BJ program was further refined in the MARVI project locations. Based on number of wells to be monitored and availability of resources, nine BJs in the Aravali district (Gujarat) and 25 BJs in the Udaipur district (Rajasthan) were recruited and trained in geo-hydrological mapping and monitoring of groundwater levels and quality throughout the project period (Fig. 2). It is important to mention here that the MARVI project paid special attention to the BJs program in regards to its potential for scaling up to district and block levels. There were two reasons for this: (1) the engagement BJs would have with the national level Integrated Watershed Management Program (IWRM); and (2) the potential range of partnerships BJs could form, ranging from those with local communities; with development facilitators; with national researchers; and with international researchers. The experiences arising from the involvement of the BJ's as community representatives for groundwater management at the local level can be viewed as the most convincing evidence of a true participatory approach for groundwater management.

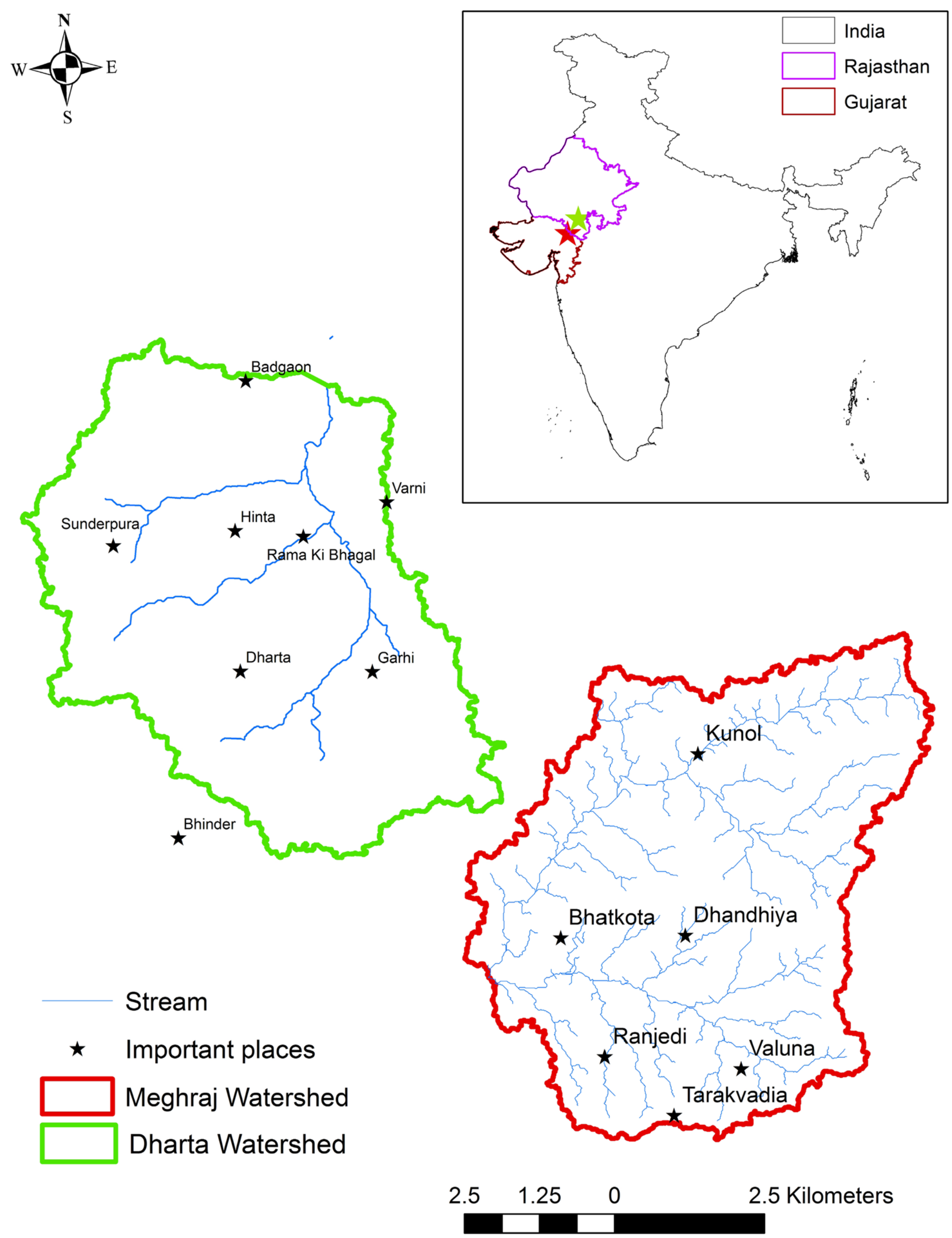

Fig. 2 Location of study areas in the MARVI project

MARVI approach vis-à-vis other approaches

The MARVI approach differed in number of ways from other approaches such as Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS), Social Regulations in Water Management (SRWM) in Andhra Pradesh, Pani Panchayat in Maharashtra and Tarun Bharat Sangh (TBS) in Rajasthan, India. In the MARVI project, the focus was to create village champions (i.e., BJs), train and support them for groundwater monitoring and prepare them to act as an interface between farmers and support agencies, and in turn BJs help facilitate change in farmer behaviour and supply them with local data for situation understanding and improvement. The ultimate aim in the MARVI project was to improve farmer livelihood and sustainable use of water through the formation of village groundwater cooperatives with their own governance mechanisms, sanctions and rules for groundwater use. Further, there was significant focus on both demand and supply side managements to improve livelihood.

On the other hand, for example, the APFAGMS project did not pursue to improve livelihoods of project participants upfront, but it was assumed that the access to scientific data and groundwater knowledge alone would help farmers to make better decisions regarding groundwater use. Further, two key Ostrom (1994) principles that APFAMGS could not follow were 'universal legitimacy of rules' and 'graduated sanctions for violators' and so the use of groundwater by farmers in the area could not be regulated (Verma et al. 2012; Reddy et al. 2014) and the impact of the project was largely limited to groundwater literacy as a means of improving livelihoods.

Similarly, the other approaches such as SRWM and TBS were successful to some extent in the areas where they were tried out but did not spread to other parts of India due to lack of all the ingredients required for sustainable groundwater management program—demand and supply side management, local champions, locally monitored data for decision making and formal establishment of village groundwater cooperative that follows Ostrom's eight principles (Ostrom 1994) that are important for common resource pool management. Table 2 provides a summary of how some approaches used in India for the management of groundwater as a common property align with Ostrom's eight principals. This summary suggest that the MARVI approach is likely to be more appealing, adaptive, effective than previous approaches for managing groundwater as common pool resource. However, there are still some challenges with the MARVI approach, particularly it requires patience of the implementing agencies to work with village communities, takes longer to implement through BJ training and empowering village communities, and requires higher level of skills and knowledge of BJs to guide village communities. Further, implementing the Ostrom's principals for the management common resource pool to succeed, flexibility and adaptive management tailored to local situation is required along with a genuine collaboration between scientists, policy makers, water suppliers, and water users (Ross and Martinez-Santos 2010).

The recognition of the community-based approaches for groundwater management by state and national governments has started to emerge, but there is still a long way to go

Table 2 Ostrom's eight principles of managing commons and their level of alignment with different approaches used in India for the management of groundwater as a common property

Principal	APFAGM	SRWM	Pani Panchayat	Tarun Bharat Sangh	MARVI
1. Define clear group boundaries	3	3	3	3	3
2. Match rules governing use of common goods to local needs and conditions	2	2	3	3	2
3. Ensure that those affected by the rules can participate in modifying the rules	3	3	3	3	3
4. Make sure the rule-making rights of community members are respected by outside authorities	2	2	1	2	3
5. Develop a system, carried out by community members, for monitoring members' behaviour	3	3	2	2	3
6. Use graduated sanctions for rule violators	1	1	1	1	2
7. Provide accessible, low-cost means for dispute resolution	1	1	1	1	2
8. Build responsibility for governing the common resource in nested tiers from the lowest level up to the entire interconnected system	2	1	1	1	2

The degree of alignment assigned all programs was subjectively ascribed by the lead authors based on available documentation of these programs

Keys: 1—alignment not yet developed, 2—alignment developing and 3—alignment well advanced for integrating such approaches as part of natural resources management programs. There is still some level of reluctance among staff in project implementing agencies due to their lack of appreciation for participatory approach and empowerment and the fear of unknown as they are more used to technical interventions and building infrastructures. Also, the need for agreement among the groundwater users on a sustainable level of extraction, an effective coordination and collaboration for equity and access and the mechanisms help in monitoring and self-regulation of the resource use cannot be overemphasised. In spite of the above challenges, the MARVI experience has amply demonstrated that direct engagement of villagers and empowering them with knowledge and local data can create cooperative environment for sustainable groundwater use.

Recruitment of BJs

As described above, this project intended that the BJs would be key people in the participatory monitoring of groundwater and also in the communication of research findings and associated consequences to the rest of the community. Thus, the selection of the right people and the training and mentoring received by them to perform such roles would be critical to the effectiveness of the MARVI work in the villages. The original aim was to have five BJs for each village; additionally, an original intention was that one BJ role from each village would be performed by the participating school of the village. In reality this did not happen for several reasons. First, monitoring the levels and sampling in dug wells, most of which had no well head protection, would put students at risk, whereas farmers were accustomed to placing and removing pumps from such wells safely. Also, the training required would need to be tailored to teams of students, rather than to individuals increasing training costs, and the honorariums expected by the BJ could not be provided to students from the actual budget available.

While women were encouraged to be BJs, only one female BJ could be recruited as it was considered unsafe for women to travel to wells which were remotely located and were at a considerable distance from their homes. In addition, the majority of these wells were open wells without any protection walls, and hence slippery and dangerous for women to work in wearing Saris. One female BJ was recruited in Rajasthan, as she was a village leader, while in Gujarat the cooperating group (DSC) had already recruited women as extension volunteers (EV) for an IWRM project which complemented activities in the MARVI project. In fact, some of the activities such as school programmes, awareness campaign, village meetings and the like were done jointly by the BJs and the women EVs in Gujarat.

Training of BJs

The training program of the BJs under the MARVI project consisted of various stages, including orientation; land and water resource management planning; aquifer mapping; and groundwater monitoring. Besides this training for the BJs, there were several other capacity building activities designed for the other stakeholders of the MARVI project, including the BJ-facilitators, the development facilitators and some community leaders. The aim of this capacity building was to sensitise these stakeholders to the importance of the BJ program for participatory groundwater management: In this article however, the focus has been restricted to the capacity building activities of the BJs only.

Capacity-building methodology to raise groundwater understanding

A prerequisite condition for geo-hydrological understanding is the practical visualisation by the BJs themselves of their own area and its groundwater characteristics; thus any training has to be designed in such a way as to ensure this happens (Figs. 3, 4). Therefore, the use and the generation of various thematic maps were used as a fundamental tool. Further to orient the BJs about the various thematic areas of geo-hydrology, the local language and terminologies were used and listed out together with equivalent scientific terms, achieved with the help of the local people. Two non-negotiable principles were followed in this process—first, that the geo-hydrologic aspect of the area were to be quantified and second, that the accuracy of data collected was to be give due attention. For this reason, it was vital that experienced trainers took care of the capacity building process and continually reviewed these aspects. In essence, three methods of training were used: lectures in both classroom and field; practical mapping and data collection exercises in the field; and the review and verification of data and maps in the classroom.

Lectures and orientations

These were designed in such a way that the BJs could visualise and understand the subject properly, keeping in mind most they had left schooling a long time ago and they were not used to traditional classroom teaching rather they had practical experiences and life skills and had developed experiential learning processes of their own. The lectures were not intended to be all traditional classroom lectures, but were organised at field sites where the BJs

Fig. 3 Classroom training workshop for BJs

Fig. 4 Training BJs in the field—measuring groundwater quality

could understand links to groundwater science by identifying specific features of the field site and what was happening there.

Practical mapping and data collections

These were considered to be the most important part of the entire training, as this not only built the capacity of the BJs, but also boosted their confidence and self-esteem. For this reason, in addition to trainers from ACT, experienced BJs from Kachchh assisted in the training process to facilitate and mentor the learning for the new BJs, acting as 'senior peers'. The BJs from Kachchh taught how to collect groundwater and other data, the methods of different thematic mapping, the estimation of and the calculations involved in water resources planning, how to analyse information and how to transfer this to maps. It is important to emphasise that a key outcome of using these experienced BJs from Kachchh was the silent building of self-confidence within the new BJs by seeing experienced BJs, who had a similar background to themselves prior to becoming BJs, and who were now able to facilitate the learning of new BJs, who could thus also aspire to train other BJs in the future.

Review and verification

This is a most important requirement of the process as it helps to build confidence within the external stakeholders and government agencies about the rigour of the BJ program. It demonstrated the authentication and validation of the data and information collected by the BJs. This process should largely be done by the experts involved in the project. Furthermore, this process can also help to improve the self-confidence of the BJs, including that their skills and competence are recognised and valued.

Keeping the above approach in mind, the capacity building training modules began with a 2-day orientation of all the BJs through observation of open wells, as this was the only way that groundwater becomes 'visible'. The observation of open wells helped the BJs to understand the importance of surface and subsurface connections of groundwater and enabled a link to be made to other scientific aspects, such as geology, geomorphology, land use and watershed development activities. This orientation was then followed by the following seven modules of learning how to develop and use the different maps required for integrating land and water resource development plans:

1. *Base map module* The purpose of this module was to enhance the BJs capacity to understand the use of various maps for planning and to develop basic mapping skills.
2. *Land use classification module* This module helped BJs to understand the types of land use and the calculation of different land use areas with the help of graph paper. This information was later used to estimate water demand during the water balance module.
3. *Geomorphology map module* This module was focussed on helping BJs to understand the relationship between various morphological features and associated land uses by village communities.
4. *Water resource mapping module* This module was about understanding the existing potential and problems of surface and groundwater resources in a particular village.
5. *Surface geology and geo-hydrology module* This module was about helping Bjs to learn about the hydrologic cycle in the context of their village, the key aquifer features and rock types and broad geology of the area.
6. *Watershed and water balance module* The purpose of this module was to help BJs develop their understanding of different aspects of a watershed and its management.
7. *Water resource development planning module* This was the final module to prepare BJs to apply the skills they had learned in other modules and to use the information collected on land use, aquifers, water sources and other aspects to develop a water resource plan for their village.

BJ data collection and validation

Groundwater management requires a comprehensive and consistent database together with an adequate understanding of the aquifers, as well as other relevant aspects, to develop effective groundwater management strategies at the village level. Until now, such a database has only been maintained and managed by qualified professionals in government offices, meaning that the data and associated information rarely reached villages for participative groundwater management. Thus, if there is to be proper village level groundwater management, the community needs information, data and skills as well as their genuine involvement and ownership of groundwater management strategies. This can occur through village-level data collection and monitoring processes, but only if there is an adequate understanding of the groundwater science involved.

As has been shown, the trained BJs can fill this gap, following their competence-building. Using their own well data gained in the first training module, the MARVI BJs have been trained to identify well characteristics and collect well data over the long term, taking observations and monitoring changes in water level and quality on a monthly basis. In this MARVI project, the BJs have monitored 360 wells in both watersheds. The project allocated a staff member called a BJ-facilitator, to assist the BJs and to ensure the reliability of the data collected by the BJs through the random inspection of data measurement and recording by the BJs. This has ensured the validity of the data collection process and the data collected. Further, the reliability of BJ collected data of checkdam water level was demonstrated in a study by Dashora et al. (2017) in which the water levels recorded by the BJs were compared with the photographs of gauge boards taken at the same time. Their study confirmed that the data collected by BJs closely matched with the levels shown on gauge board photographs (± 1 cm accuracy for 96% of BJ data).

Mentoring and competency development of BJs

Post-training mentoring of BJs is a most important aspect, particularly as the BJs are community representatives and knowledgeable resource persons. Based on the experiences of the MARVI project partners it has been concluded that three levels of mentoring are important to retain and develop the BJs for participatory groundwater management, and this will be discussed in a later section. Mentoring was needed to follow on from the initial training

Table 3 Different stages of BJ development

Stage	BJs competence
Foundation	Learning as trainee, developing understanding of new concepts and ideas, relating experiential knowledge to theory and can perform in the field with good support and nurturing of their role
Developing	Increased level of confidence, seeking recognition and can perform their role with limited supervision but still need mentoring and some on-going support
Proficient	Understand the complexity of what they are doing, ability to interpret data and present their findings and learning to village communities and motivated to work with limited or no supervision
Expert	Confident in their role, ability to work without supervision, ability to act as a service provider to government programs in groundwater and other natural resources management, ability to help in peer training and capacity building of other BJs and community stakeholders

program, as it was important to build confidence in the BJs, both in themselves and among the various stakeholders. Also, while the BJ programme provides employment opportunities, after successful implementation, there can be an increased demand for the BJs in other areas of natural resources management at the village level. The stages in BJ development are shown in Table 3.

In the case of the MARVI project, the BJs are at the developing and proficient stages and some are now moving towards the expert stage as service providers in their area.

Examples of using BJ data for understanding groundwater situation

BJs have regularly monitored 250 wells in the Dharta Watershed area and 110 wells in the Meghraj watershed areas. The watertable depth, rainfall amount and groundwater quality data collected by the Bjs were analysed by BJ-facilitators and researchers for trends in groundwater depth fluctuation, water level maps, water balance analysis and the estimation of specific yield from the aquifer. The analyses demonstrated that BJ data (groundwater levels and check dam water levels) that could be scientifically verified and thus may be used for the purpose of developing groundwater management strategies. Here are some examples of BJs data analysis:

Figure 5 is a hydrograph showing weekly monitored water levels and rainfall data of ten wells in *Badgaon* village cluster of Dharta watershed. Based on these hydrographs the following conclusions can be drawn regarding water level behaviour in terms of groundwater utilisation patterns with respect to received rainfall over the collection period. In each year, there was a rise in groundwater level from the start of monsoon in July until the beginning of October after which the level decreased rapidly during the Rabi season. It then became relatively stable after irrigation ceased until the beginning of the next monsoon season, and a few wells ran dry. In 2016, there was more rain than in previous years, refilling the aquifer so that the level of groundwater in most

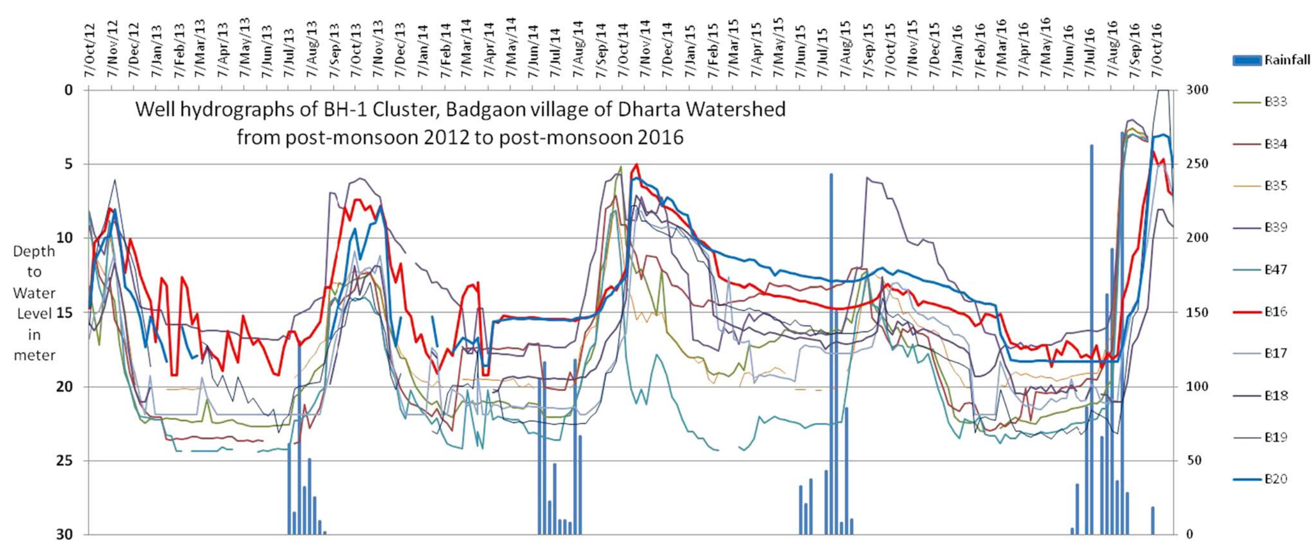

Fig. 5 Well Hydrograph in Village Badgaon, Dharta Watershed showing water level fluctuation in different seasons from year 2013 to 2016

wells was within 5 m of the land surface at the end of the monsoon.

All wells exhibited similar behaviour showing that they all tapped the same aquifer. This message was reinforced by all hydrographs without exception for each village. When farmers saw the hydrographs for their wells and their neighbours all together, no one could deny that their wells were part of a single common system that was recharged in the monsoon and drawn down by pumping. This was a very big step forward from their previous disparate views, recorded in a socio-economic survey of 500 farmers from in the Meghraj watershed (Varua et al. 2016). The survey had revealed that on average 40% of farmers claimed that if they installed a well near their neighbour's well they would have no impact on their neighbours well. The same survey also found that on average 60% of farmers said that if their neighbour installed a well near their own it would impact on their own well (Ward et al. 2016). In the absence of data, beliefs tended to follow what was the most convenient defensive position to take, even if this defied logic. The availability of multiple groundwater hydrographs awakened farmers into a new understanding of their groundwater supply and the reality that it was a common pool resource and that it would need to be managed cooperatively.

The hydrographs revealed that the water available for irrigation in each Rabi season depended on the storage in the aquifer at the end of the monsoon. Hence the post-monsoon water level measurements could become the primary management tool to inform farmers on the availability of water for Rabi crops. Potentially, this enables plantings to be scaled to groundwater availability and thus enabling all cropped area has sufficient water until harvest and equitable use among all farmers in the area. Figure 5 also shows that although pumped dug wells were used as monitoring wells, the precedence of monitoring only on Sunday morning when irrigation wells had no electricity for pumping gave time for recovery and much smoother and more reliable hydrographs than had been anticipated by groundwater experts. In general, the analysis of such hydrographs based on BJ data can help in meaningful sustainable groundwater management through dialogue within the community based on local data, creating awareness and educating water users and the community to care for their groundwater, and using this data to develop village level water security plans.

Another example is the use of BJ measurements of checkdam water levels. These data allowed researchers to estimate the water balance on check dams (Dashora et al. 2017). The decline in daily water level in dry weather allowed dry weather infiltration rate to be calculated by subtracting the evaporation rate. Dry weather infiltration rates in 2014 and 2015 averaged 27 and 42 mm/day, compared with the mean estimated evaporation rate of 5 mm/day from the surface area of dams during the time they held water (Dashora et al. 2017). However, there was a wide range of rates between check dams, and in the event that infiltration rates fall to less than 20 mm/day in any check dam that would suggest that in the dry season the dam should be scraped to remove surface clay and silt to increase recharge efficiency with the removed material, having good soil moisture retention and nutrient properties, used to top-dress fields used for cropping. In this way the BJ measurements were valuable not only for giving information on hydraulic performance of check dams but also for identifying and prioritising the need for maintenance.

Evaluation of BJ Program

Towards the end of the MARVI project, a 2-day workshop was organised for BJs from both study areas to explore the key learning outcomes from the BJ programme. The aim of this evaluation was to make recommendations on the best way to operate the BJ program for other areas of India. In addition, this workshop helped to understand how the BJs themselves have seen this entire process from their own as well as the community's point of view. The objectives of the workshop were set as follows:

- To raise the confidence level of the BJs.
- To ensure strong acceptance of BJs in society.
- To strengthen the presence of the BJs process across the nation
- To strengthen the Participatory Ground Water Management concept by involving different stakeholders.
- Sharing learning and experiences, of the BJs achieved over the 5 years of MARVI.

The following items were covered in the evaluation of the BJ program:

1. Reflection from BJs in terms of new skills learnt, working together, change in attitude, confidence level and change in their social status (personal identity).
2. Understanding of groundwater based on their data collection and insight developed during their role as BJ.
3. Was it worth it for them to be a BJ?
4. What things they did not like? What things they liked?
5. Have they themselves changed?
6. What else could MARVI have done to help them better?
7. What further training and ongoing support do they see is needed?

Changes experienced by the BJs

The BJs reported that in the beginning, village communities were seeing them as an ordinary village person, but after they had started to share their knowledge the BJs were increasingly recognised as resource persons, and they increasingly earned respect from their own village community. They collectively organised meetings with villagers, where they gave them scientific information about aspects such as basic geology, key features of aquifers, water sources, identification of water quality problems and what could be done to save groundwater through improved agronomic practices and crop selection and through improved maintenance of streambed recharge structures.

Other learning from the BJ evaluation

The evaluation of the BJ program indicated that before the commencement of the MARVI project, the communities in the two study areas had limited quantitative information about the variation of rainfall, water table depth, groundwater quality and recharge through check dams and other MAR structures in their area. With the MARVI project and on-going work of BJs, alongside the establishment of weather and groundwater monitoring networks, the village communities have begun to understand the value of water in terms of both quality and quantity, as well as the quantitative relationships between rainfall and the rise in water level in their wells. Also, the village farmers started comparing the groundwater levels from 1 year to another and relating these to the areas they could crop in the Rabi (spring) season.

Bhujal Jankaars have clearly demonstrated that villagers with no formal research experience can collect data on water table depth, check dam water levels, water quality and other data that may be supplemented by the data collected by researchers. In the States of Rajasthan and Gujarat, the government of India is implementing groundwater management and improvement programs with significant funds. Based on the experience of the MARVI project, it has become evident that BJs can be the agents of change in village communities for sustainable groundwater management thereby improving livelihoods. Small amounts of funding from these government programs could go a long way towards improving the groundwater situation, thereby reducing poverty, while also limiting the migration of rural people to urban areas in search of alternative ways to improve their livelihood. In the long-term, the involvement of BJs can help in the transformation to sustainable groundwater management, which according to Rist et al. (2007) involves social learning in which scientists, experts, politicians, farmers and other local actors work together with their scientific understanding and experiential knowledge.

In summary, the evaluation workshop indicated that the BJs seemed more energised after performing their duty of being 'groundwater informed' in rural areas. They have a strong desire to stay connected with natural resource management activities within their village areas Also, the BJs realised that being in this role over the last 5 years had increased their own value within their village, and also that they had found a new direction for their own life towards sustainable development and groundwater management. One of the important aspects that emerged was that there should be a formal network or association set up for BJs at village cluster or block level to provide their service in a more professional way to government programs and local stakeholder initiated activities.

BJs and village groundwater cooperatives

While the engagement of local people in the MARVI and similar other approaches demonstrated successful pathway for groundwater management through community participation, the process of out-scaling beyond the project area remains a significant challenge despite its long-term benefits. Community based approaches by their very nature require intensive intervention, patience with time to see results and 'hand-holding' of the locals for implementing the approach. The next necessary step in the MARVI approach, with the help of BJs, is to devise innovative mechanisms for achieving active participation and responsibility of groundwater management at the village level.

One of the important outcomes of the MARVI approach is the establishment of three village groundwater cooperatives (VGCs) in the Dharta watershed and two VGCs in the Meghraj watershed by farmers themselves. Each VGC consisted of 14–20 nearby farmers whose combined land formed a single block and each VGC represented a land area between 18 and 40 ha. The groundwater in some of these VGCs until now was shared through a barter system in which farmer who provides groundwater to their neighbours receives one-third of produce in exchange of water provided to the neighbour. Farmers who formed VGCs felt that the current barter system or the selling of water is not fair and it creates equity issues and does not support groundwater sustainability.

A key principle that has brought them together for the VGC is that groundwater will be managed, through recharge activities and improving water productivity, that no farmer will be worse off in terms of their net income after joining the cooperative. Further, once the cooperative is formed, no farmer member will deepen their well for an agreed time period and they will work together to increase recharge and reduce demand. The role of BJs will be critical in the success of these VGCs, particularly through monitoring groundwater recharge and pumping, facilitating linkage between VGCs and Gram Panchayats (Village Local Government) to access rural development programs, providing information on seasonal groundwater availability and crop planning and finally supporting VGCs through secretarial and logistic support.

The VGCs formed are at the formative stage of their development, and the critical role of BJs in the VGCs will evolve with their operationalisation in coming years.

Conclusions

This study has demonstrated that a well-designed program of capacity building together with on-going mentoring support, can empower local farmers to act as BJs and play an important role monitoring watertable depth, rainfall, groundwater quality, checkdam water levels and other data of scientific value, particularly to support in managed aquifer recharge and sustain groundwater use. Furthermore, they will also share this information with the local village communities to influence the sustainable use of groundwater. The BJs can not only help in the collection of data but can act as an interface between village communities and researchers, government agencies and external stakeholders. Further this study has shown that BJ capacity building can help to provide a scientific basis for village level groundwater dialogue and assist village communities and other stakeholders to improve their decision making regarding groundwater use, crop selection, agronomy, recharge strategies and other aspects of sustainable groundwater management.

Although the BJ program has been successful and BJs can act as a valuable interface between local communities and other stakeholders, there still exists some challenges to the BJ programme, such as the need for mechanisms and funding sources that will sustain the BJs over the longer term; wider acceptance of BJs among scientific communities and policy makers; and the acceptance of the role and involvements of BJs in natural resources management programs of the State and Central governments in India. Overall, the MARVI project has demonstrated that BJs can play the role of being local champions for village groundwater futures, as well as how such a BJ program can be implemented to improve the capacity of BJs and their communities to understand the complexity of the groundwater situation. Further, the work of BJs has for the first time in the study areas provided the ability to monitor local groundwater, rainfall and check dam water levels allowing estimates of groundwater recharge including that from check dams. In the study villages this has underpinned far more effective dialogue on the sustainable management of groundwater and ways to improve the livelihoods of village communities.

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