Freshwater resources analysis from Water Harvesting Structures in the Sambhar Salt Lake region, Rajasthan

Report of Researcher Exchange March 2019

May 2020

INDIA-UK
Water Centre
भारत-यूके
जल केन्द्र

Freshwater resources analysis from Water Harvesting Structures in the Sambhar Salt Lake region, Rajasthan

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www.iukwc.org

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The India-UK Water Centre promotes cooperation and collaboration between the complementary priorities of NERC-MoES water security research.

भारत-ब्रिटेन जल कें द्र एमओईएस-एनईसीआरसी (यूके) जल सुरक्षा अनुसंधान के पूरक प्राथमिकताओ के बीच सहयोग और सहयोग को बढ़ावा देने के लिए करना है

Front cover image: Aerial image of the Sambhar Salt lake (Google Earth)

Contents

Executive Summary ii

1. Activity Leads 1

2. Activity Participants 2

3. Activity Background 3

4. Activity Aim and Objectives 5

5. Activity Structure 6

6. Activity Conclusions and Outputs 9

   6.1. Key themes/points/outcomes arising 9

   6.2. Specific knowledge and data gaps/specific recommendations 11

   6.3. Conclusions and next steps/recommendations from the activity 12

7. Future 12

8. Annexes 13

Executive Summary

This activity report was produced as an output of a Junior Research Exchange on 'Freshwater resources analysis from Water Harvesting Structures in the Sambhar Salt Lake region, Rajasthan' funded by the India-UK Water Centre (IUKWC). This report documents and discusses the activities carried out by the researcher Paula A. Vicente during the duration of the Research Exchange, which received collaboration from Water Harvest, Water Wisdom Foundation, Indian Institute of Science Education and Research (IISER) Bhopal and Indian Institute of Technology (IIT) Gandhinagar from 3 March – 22 March 2019. It presents an overview of the background, aims and objectives of the project as well as the structure and outcomes arising from the activities undertaken.

Acknowledgement

The lead researcher wishes to thank all the support received on field during the Junior Research Scheme by Shri. Somendra Sharma and Shri. Om Prakash Sharma (Water Harvest), Dr Deepti Sharma (Water Wisdom Foundation), Shri. Banshi Bairwa, Shri. Seetaram Jhajhoriya and Shri. Vinod Bairwa (PKS) who assisted in the organisation and delivery of sampling collection and workshop with local stakeholders.

At academic level, Dr Pankaj Kumar at IISER Bhopal and Dr Vimal Mishra at IIT Gandhinagar, as well as the members of their research teams, contributed to the setup of the climatic and hydrological context of the region of study and I thank them for their time and cooperation. I also thank Sunita Sarkar and Priya Joshi at IUKWC for their constant assistance throughout the past months and helpful comments on this report.

Furthermore, the working time spent to undertake this project was funded by Water Informatics Science and Engineering Centre for Doctoral Training (WISE CDT) under a grant from the Engineering and Physical Sciences Research Council (EPSRC) EP/L016214/1.

1. Activity Leads

The Junior Research Exchange was convened by the India-UK Water Centre (IUKWC) and led by the principal researcher:

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The project was held at the Dudu Block, Rajasthan with the collaboration of Water Harvest and Water Wisdom Foundation NGOs, and at the Indian Institute of Science Education and Research (IISER) Bhopal and the Indian Institute of Technology (IIT) Gandhinagar between 3rd and 22nd March 2019.

2. Activity Participants

Deepti Sharma is CEO, of Water Wisdom Foundation. Water Wisdom Foundation (www.waterwisdomfoundation.org) is a Not-for-Profit Company incorporated in November 2017 and is implementing and providing techno managerial support to innovative, replicable and demonstrative water projects/ works/ assignments in dryland parts of India. Deepti has Ph.D. in Water Laws from University college of Law, MLSU, Udaipur. Being an environmental Engineer and masters in law her keen interest is how to develop a cadre of young water literate / wise water communities through enhancing their knowledge. She is carrying 10 years' experience of teaching and environmental issues consultancies. She has attended many national level seminars around water and legal issues. Her latest book is on Water Laws in Rajasthan.

Om Prakash Sharma is Country Director at Water Harvest – India Liaison Office (www.water-harvest.org). He has 30 years of experience working in drylands of India with various civil societies. He is a Civil and Water resources Engineer. Over the years he has developed his expertise in socio technical solution to water issues specially blending traditional water harvesting wisdom with modern technologies. He has participated and shared views on water issues and their solutions in many national and international conferences. His recent publication is about Wise Water Solutions in Rajasthan. Water Harvest, UK has been working with rural communities to harvest the monsoon rains, enabling the poorest people to reap the benefits of safer and sustainable water for over 31 years and has data and knowledge of the changes in traditional and more recent water harvesting techniques in the selected area for this research. They installed 120 family roof Top Rain Water Harvesting in Charasada and a high number of them in other locations across Rajasthan.

Dr Pankaj Kumar is working at Indian Institute of Science Education and Research (IISER) Bhopal, as Asst. Professor. Presently his group is engaged in two broader topics, (i) coupling a regional atmosphere model with an ocean model to understand the dynamics of air-sea interaction for monsoon studies, and (ii) coupling of the regional model with a dynamical glacier scheme (DGS). He also does climate services and is actively involved in capacity development. His regional interest is in climate change related impacts in South-Asia, where he has contributed to several past and ongoing research projects. Presently he has several running projects. Dr Kumar has published 17 international publications. His research interest is focused on the monsoon dynamics, changing climate regimes, regional extremes, area and mass balance of Himalayan glaciers and its impact on the monsoon and the spatial-temporal distribution of freshwater resources. Also, uncertainties associated with climate models and climate change projections.

Vimal Mishra is working as Associate Professor at Indian Institute of Technology Gandhinagar. He is interested in water resources management, climate change and global food and water security. He is project investigator for a series of projects funded by the Ministry of Water Resources in impacts of climate variability and climate change on water resources in the Sabarmati River basin. Presently, his group is involved in research areas of hydrologic monitoring and prediction of droughts, irrigation mapping and understanding hydrologic sensitivity of groundwater to human and natural changes. He has international research experience and has published in international papers and books.

This research scheme also had the close collaboration of Somendra Sharma, Programme Coordinator of WaterHarvest - India Liaison Office, and the three members of Prayas Kendra Sanstha Harsoli (PKS) Banshi Bairwa, Seetaram Jhajhoriya and Vinod Bairwa.

3. Activity Background

In India 85% of rural drinking water is derived from groundwater; recently, these resources have been further overexploited, especially in arid and semi-arid regions where they are largely used for irrigation purposes (Kulkarni, Shah and Shankar, 2015). In rural areas, flood irrigation is widely extended in agricultural practices; the imbalance between extraction and recharge has led to a drastic drop in the water table of the surrounding aquifers. This is exacerbated by the increase in temperature and decrease in rainfall patterns in India caused by climate change, and by the rapid rate of population growth which is consequently increasing the need for more agricultural crops and thus irrigation systems. The water availability in the state of Rajasthan is restricted further as a consequence of the high concentration of fluoride and heavy metals present in most groundwater sources (Reddy, 2010). Consumption of this water has negative impacts on human health, especially on children's teeth, spinal cord and joints (WHO, 2011).

Study Area

The Sambhar Salt Lake situated in central Rajasthan is the largest inland lake in India. The lake is a designated wetland site under the Ramsar Convention and has a catchment area of 5600km^2 (Singh, 2013). Monsoon usually reaches this part of Rajasthan by mid to end of July and ends by September.

The ground water in and around the lake has been reported to be saline, and is found to be coupled with high fluoride levels (Vikas et al., 2013). The lake region has also been found to be affected by recurrent droughts, making the search for new and improved approaches in water resources management an imminent need. If the climate projections for dry regions in Asia are accepted, less rainfall and more severe droughts are likely to happen in the future (Rathore, 2015), representing a major threat for the water resources management and the economic activities of the region dependant on water, such as for instance the agricultural sector.

Charasada Village is located near the Sambhar Salt Lake (Figure 1); given the year round water scarcity the practice of rainwater harvesting during monsoons was observed to be highly popular in the village. The first type includes the main being ponds, small dams, farm ponds, and percolation ponds which contribute to groundwater recharge. These structures are found to suppress salinity in the ground water and fresh water is available to be drawn through open wells. The second type of structures in use includes roof top rain water harvesting mechanism, which involves the collection and storage of rain water in underground tanks.

This Research Exchange focused on analysing the quality and quantity of freshwater resources in the Sambhar Salt Lake region of Rajasthan; and assesses how rain water harvesting can contribute to mitigating impacts of droughts. Some of these findings were shared with local people and NGOs during a one-day workshop held on 15th March at Dudu, Rajasthan.

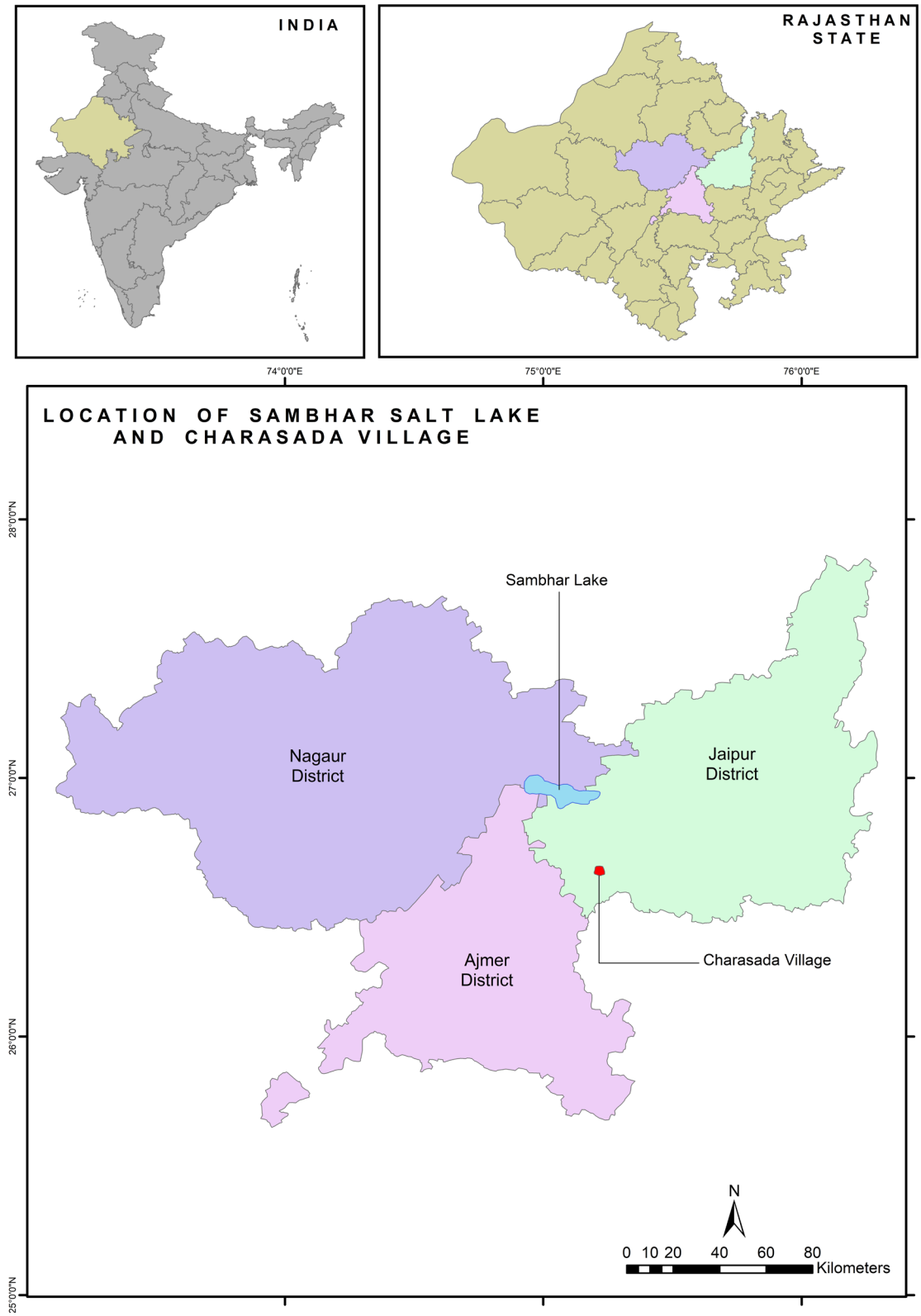

Figure 1: Location of study area: Charasada Village (Source: Water Harvest)

4. Activity Aim and Objectives

The India-UK Water Centre is based around five key cross-sectoral themes and aims to deliver a portfolio of activities across these themes. This research activity focused on the theme: Using new scientific knowledge to help stakeholders set objectives for freshwater management.

The aim of this Research Exchange was to assess quality and quantity of freshwater resources in one of the decentralised (Figure 2) and most arid regions of India and determine how water harvesting can contribute to mitigate drought impacts. This work made use of qualitative and quantitative research and was based on a case study conducted in the Sambhar Salt Lake region of Rajasthan. Charasada, Bhojpur and Chhappya villages were selected as representative case study villages where more than 140 rooftop water harvesting structures have been built with the collaboration of Water Harvest, Water Wisdom Foundation and Prayas Kendra Sansthan Harsoli (PKS).

This exchange had three objectives:

1. (a) To assess the quality of water stored through rain water harvesting interventions like ponds, rooftop rainwater harvesting and other infrastructure created by rural communities;

   (b) To assess quality of groundwater which is also being partially recharged through rain water infrastructures;

2. Evaluate the impact of rain water harvesting structures, especially rooftop water harvesting structures in mitigating drought impacts; and

3. Create a more collaborative and successful approach towards drought adaptation in the study area.

The findings and recommendations from this work are based on a case study of villages located in a buffer zone of Sambhar Salk Lake, Rajasthan, India. The methodology can be applied to other water scarce rural areas located in arid or semi-arid areas, in India or elsewhere. It would be key to always consider the specific local needs and context to contribute to development of successful local scale drought adaptation measures.

Figure 2: The three villages are connected to the central water system but water does not reach there during the majority of the year. The tap in this picture is located in the centre of the village but people need to get water from other sources.

5. Activity Structure

This Research Exchange was conducted between 3rd March – 22nd March 2019. The activities proposed within the project included both field work in collaboration with NGOs, and academic work at two universities in India (See Annex A for the Exchange agenda). A brain storming and planning meet was held on 4th March with Mr. Somendra Sharma (Water Harvest, NGO) to plan the work for the first two weeks. The activities undertaken during the three weeks were planned to be implemented in four phases.

The first phase involved visiting the facilities of a local laboratory with the Water Harvest team to arrange all the necessary equipment for the sampling work and agree on the water parameters to be analysed. The team conducted a preliminary site visit of the three villages to get an idea of the landscape and to identify suitable and representative sampling points to collect the water samples from. During the first day of field work the team collected a total of 31 water samples from various sources like open wells, bore wells and hand pumps (groundwater), and roof top harvested water (Figure 3) that had been stored in underground tanks and retention ponds (Figure 4). The water samples were transported to a local laboratory under cold conditions for chemical and microbial contamination analysis; the data from the laboratory reports would be later analysed to assess the quality of water from different water sources of the villages. On the second day, interviews were carried out with the support of Somendra Sharma (Water Harvest) and Seetaram Jajoria (PKS) who acted as translators. Families and farmers were asked a list of questions which had been previously prepared and submitted for approval to the Ethics department at University of Exeter, UK . The stakeholders were questioned around use of water, problems faced and current solutions implemented to overcome water shortages.

Figure 3: Monsoon rain is collected on the roof and led by pipes to an underground storage tank. A valve allows the discharge of the first rains containing contaminants deposited on the roof outside the tank. This is a measure to only store clean water in the tanks.

The second phase of the work involved organising a workshop for local NGOs, representatives of the local communities and Government authorities after the water quality results from the laboratory had been received and analysed. Water Harvest has been working with rural communities in Rajasthan for over 31 years; their aim being to promote and enable water harvesting of the monsoon rains and facilitate the access of safe water to the poorest strata of society. Water Harvest has a database of knowledge associated with changes in traditional and more recent water harvesting techniques from the study area which has been generated over years through in depth engagement with different stakeholders of the region. This phase of the work therefore consisted of coordinating and delivering a one-day workshop with the participation of interested stakeholders (rural community, NGOs, Government, etc.) in order to identify the biggest challenges faced by the rural communities around the Sambhar Salt Lake and determine the best water management solutions at different scales. The aim of this workshop was to create a more collaborative and successful approach towards adapting to droughts in this rural arid region of India. This workshop took place at Rotary Mahaveer Bhavan, Dudu, Jaipur district and a total of 30 people attended the event. There were a series of presentations delivered during that day, including one from the principal investigator Paula A. Vicente. In her talk, Paula presented the assessment of the water quality analysis of the different water sources sampled in the villages. Other presenters of the workshop were Water Harvest, Water Wisdom Foundation, PKS, and some of the local NGOs. The talks were followed by a group discussion session on current challenges and possible solutions in water management in the region around the Sambhar Salt Lake (See Annex B and C for the workshop poster, agenda and list of participants). All participants had an opportunity to speak and this exercise led to a collection of information on important issues faced by people working and living on the ground level, and potential interventions that could be implemented to address these challenges.

The third phase of the project involved collaborating with academics to understand the climatic conditions and physical environment of the study area. Paula spent two days visiting Dr Pankaj Kumar and his research team at the Climate and Glacier Modelling Lab, Indian Institute of Science Education and Research (IISER) Bhopal and three days with Dr Vimal Mishra's team at Department of Civil Engineering, Institute of Technology (IIT) Gandhinagar. During her time at IISER Paula discovered the Panoply software and how climate data can be visually represented at global scale using this tool. She learnt how climate datasets are used to study past and future droughts and assist in characterising a region's climate. This knowledge and technique was applied to the area around the Sambhar Salt Lake. From the water resources point of view, working at IIT gave her an opportunity to use for the first time the Soil and Water Assessment Tool (SWAT) to model hydrological processes at watershed level linked to ArcGIS. This was done using digital elevation models (DEM), soil maps, land use and land cover (LULC) changes map and forcing data (temperature and precipitation). She was also able to attend two seminars, one on groundwater resources and the second one on irrigation effects in water availability, which were very related to the presented research project.

The final phase of the project involved a second round of water sampling with the aim of having a larger and more representative data set. At the end of April, Water Harvest and PKS undertook another set of sampling work in the three villages. These samples were submitted to the laboratory facilities and the results obtained were further analysed along with the ones received from the first round. Having two sets of data assisted in the development of a more robust discussion around the quality issues of the different water sources used by local people in Charadasa, Bhojpur and Chappya villages.

Figure 4. Run off from Monsoon rain is collected and stored in farmer ponds which are then used for irrigation.

6. Activity Conclusions and Outputs

This section summarises the key outputs obtained from field work, workshop and academic work undertaken during the three week research project. These outputs cover a wide range of disciplines and thus, it is representative of multidisciplinary nature of water resources planning and management.

6.1. Key themes/points/outcomes arising

The information required to assess the extent of the water resource management problems and the solutions to those in decentralised rural locations in Rajasthan is characterised by the following:

Local scale climate data

Different General Circulation Models (GCM) and dynamical regional models have been extensively developed by making use of mathematical models to forecast changes in weather and in climate patterns. However, due to their large scale and low resolution they cannot take into account local variability and therefore they are unsuitable for the planning of water resources at small scale for communities in arid and semi-arid areas which depend directly on rainfall and water harvesting.

In the absence of climate models, observed data could be used for the development of statistical models to forecast future scenarios. However, in these areas there also exists a lack of observed measurements.

Hydrological processes

Understanding the hydrological processes at small scale also requires the use of models. These models need to be calibrated with observed data; availability of such data is very limited in these regions.

Another factor hindering the assessment of water resources management is the lack of control in groundwater abstractions in this region as well as in the country. This fact linked to the complexity of groundwater modelling makes tracing contamination and pollution flows affecting groundwater quality a difficult task.

Water quantity and quality

According to climate models and meteorological records, Rajasthan has experienced an increase in the average annual rainfall in the last years. However, ponds and reservoirs in the area which were filled in previous years are nowadays dried up. This is creating water scarcity problems which affect both drinking and agricultural purposes.

Most of the current water sources in rural villages around the Sambhar Salt Lake provide water contaminated with *E.coli* and coliforms, fluoride and high level of hardness, or both.

Like in most rural areas in India, agriculture is the main source of income in the three villages of this study. Large areas of water intensive crops like wheat and soybean are being cultivated. This plays an important role in lowering the water table of aquifers and at the same time may lead to an increment in the groundwater contamination by infiltration of pesticides and fertilisers. Increase in the groundwater contamination and salinity levels further affects its suitability for agricultural uses.

The water quality analysis conducted in this study brought to light the significance of roof top water harvesting structures in maintaining water quality. It was found that the roof-top harvested water presents a higher water quality both chemically and biologically than the rest of the sources in the village. However, it is important to keep in mind that this water may not be free

from biological contamination, which many times comes from bird droppings and airborne dust deposited on the roofs and thus, treatment before consumption is highly recommended.

Social challenges

The social hierarchy is very remarkable in rural locations dictating the division of water sources according to the social groups. For instance, in the case study assessed here, there exist different open wells, but not all of these are accessible by everyone in the villages. Depending on the cast, women collect water from either one or another open well, and in some cases, open wells for higher casts provide water of higher quality than the rest. From the water resources planning point of view, this complicates what it is already a very complex situation of water scarcity.

Water related government schemes aim to improve drinking water sources and water availability for agriculture. However, this information does not reach the neediest segments of the population which are largely located in rural areas, and who due to lack of information and resources find very difficult to access any kind of government scheme. There is also a common belief among people belonging to lower casts that they do not qualify to access these schemes.

Priority must be given to the most vulnerable people thus contributing to poverty alleviation. The NGOs Water Wisdom Foundation, Water Harvest and Prayas Kendra Sansthan Harsoli (PKS) prioritise the installation of roof top water harvesting structures in households which are most vulnerable. Women and girls are usually responsible for collecting water from common sources twice a day, in the morning and in the evening, having to walk long distances of up to 2km each way and carrying heavy pots on their heads. Being able to fetch water directly from their property was found to improve women's health and quality of life drastically, as it is the case of some women in the villages who now have time to create their own small businesses.

Imperative need for collaboration with Indian partners

Working closely with Indian partners is a must especially when working on field. There exists a language barrier to communicate with all communities and this barrier can only be narrowed by collaborating with local Indian experts. English is not broadly spoken in the region and sometimes even the Hindi language makes local rural people feel uncomfortable so it is advisable to speak in the local dialect. It is very challenging for foreign researchers first to understand the real needs of the end users and second, to achieve any results in the planning and further implementation of water resources interventions without the close collaboration with local Indian partners, who have the potential to act as a bridge between locals and foreign researchers.

In this specific work, Water Harvest provides financial support for the installation of roof top water harvesting structures while Water Wisdom Foundation contributes with technical aid. Nevertheless, it is the local NGO (PKS) whose partnership with the above two results in the implementation and follow up of the intervention. This structure facilitates the adaptation of the interventions as per the real needs of the local communities and provide successful outcomes.

Educational programs

Water Wisdom Foundation and PKS have developed a series of board games which are used in schools to teach and educate children on the importance of hygiene and water quality.

PKS also work very closely with the communities to instruct them in the use and management of roof top water harvesting structures and prevent tank water to be mixed with other water sources which would lead to the contamination of the safest drinking water source available to the households.

6.2. Specific Knowledge and data gaps/specific recommendations

Local scale meteorological and climatic modelling

High resolution climatic models which could represent changes at local scale should be developed. This will require a faster and new modelling capability, and the acknowledgement of the relevance of studies in decentralised water system areas.

Investment in data collection and monitoring would also be necessary in order to quantify the accuracy of the models and to measure and overcome uncertainty issues.

Water quality studies at local level

Even though the Sambhar lake region is characterised by high levels of fluoride and hardness in groundwater, this situation differs geographically and it is a risky and challenging task to generalise and apply the same interventions somewhere else without having previously studied the local context.

Monitoring is needed to obtain records of observed data which can then be statistically studied and included in groundwater simulation models. This needs large amounts of data, field work and modelling expertise.

Although some low cost water treatments currently exist, further research for affordable and easy to use water treatments at household level in rural areas is needed.

Understanding the bigger picture of short and long term water resources interventions at all scales

In order to plan localised interventions, it is first required to study sustainable water management practices in rural areas which would benefit the society and the conservation of natural resources. Secondly, it is necessary to understand the overall picture of feedbacks among surface water, groundwater, ecosystems and human abstraction; and the feedbacks and interactions among adaptation strategies at different scales.

Issues of social vulnerability and equity in the planning for water resources

Social differences may be exacerbated under extreme climatic conditions such as droughts. Therefore, there is a need to further analyse these aspects, and for their consideration and inclusion in the planning of water resources, especially in decentralised water systems, through a holistic approach.

Cooperation among all stakeholders

The Indian Government is currently funding a series of works for the construction of rooftop water harvesting structures and is also providing financial support to farmers to construct farmers' ponds. A link between government and local NGOs would facilitate the transmission of this information to locals and the success of such interventions by being supported with social and educational programs. These educational and social programs would ensure the suitability and correct operation of the water harvesting structures as spreading the sense of ownership among the families and farmers has been proved very beneficial for the maintenance of the water harvesting systems. This bottom-up approach would therefore bring more benefits than the current top-down strategies followed by many institutions.

Multidisciplinary water management

The social Indian hierarchy is very remarkable in rural locations dictating the division of water sources according to casts, which may be a defining factor of the water quality consumed by each social stratum in rural societies. Furthermore, these areas do not always have access to centralised water systems, making them more vulnerable to changes in weather and climate patterns.

These social and policy aspects should be included in the water resources management and planning. Climate and hydrology experts could provide a valuable input in the development of water resources management guidelines under future climate projections. NGOs working on ground can easily identify gaps in knowledge and/or lack of structures at different scales from local to regional level which are relevant for the successful planning and implementation of climate adaptive interventions.

Education

Water education interventions should target school programs and public engagement. Engaging with children at an early stage is very important for the evolvement of health and water management related practices in the near future. Projects focused on community engagement and public participation are necessary in order to disseminate the importance not only of water quantity but also water quality, and to promote water conservation and health risk reduction practices among the population.

6.3. Conclusions and next steps/recommendations from the activity

This activity provided valuable scientific knowledge to be used by stakeholders to implement water resource management interventions amongst rural communities in order to improve their resilience to droughts and reduce human health risk to water contamination. An accompanying Water Brief identifying specific knowledge and data gaps, and specific recommendations arising from the Researcher Exchange can be found at www.iukwc.org.

As main outputs from the workshop delivered on 15th March with stakeholders, it can be highlighted that this activity proved to be a platform for sharing ideas and discussing opportunities. Attendees found the event very helpful and thanked for the opportunity to participate and being heard.

The lead felt very pleased to hear this and considering the productive outcomes it can be highlighted that providing the space and time for stakeholders' discussions to happen is the best start to building the water management policies for the future.

7. Future

This IUKWC activity report has outlined the activities undertaken during the three week Research Exchange to India. Key outcomes from this project are presented in the Water Brief which highlights key challenges in the implementation of water resources strategies in rural locations of the Sambhar Salt Lake region of India. The main effort was to focus on the analysis of water quality from different freshwater sources in three villages in the Sambhar Lake region to understand the severity of water crisis in the area.

The work undertaken by Water Harvest, Water Wisdom Foundation and PKS shows that the application of roof top water harvesting structures in decentralised water systems contributes to improve drinking water security and wellbeing of the households. Nevertheless, it is essential to build close collaborations with local and regional governments to work together in these initiatives and overcome financial and technical challenges.

There is also a future need to study a broader range of alternatives that could provide larger quantity of water of an adequate quality to be used in agriculture in rural areas and which would contribute to a reduction in the current overexploitation of aquifers.

8. Annexes

Annex A: Research Exchange Agenda

Date	Agenda item
3rd March	Arrival in Jaipur
4th-8th March	Meeting with Indian partners to plan the work for the following two weeks. Visit to the laboratory facilities to discuss and arrange final price and which parameters analysis sought after. Everything would have to follow the Indian standards Field work in the Charasada, Bhojpur and Chhappya villages in Dudu block. This included first contact with local NGOs, sites visit, identification of suitable sampling points, sampling work and interviews to local families, which have top-roof water harvesting structures installed, and local farmers. Visit laboratory facilities to arrange the type of water quality analysis we want, which parameters would be measured and the Indian standards these analysis would follow
11th-14th March	Interviews transcript, literature review of water quality in the region, visit to the workshop venue and arrangement of necessary equipment, food and refreshments for attendees
15th March	Workshop day held at Rotary Mahaveer Bhavan, Dudu, Jaipur district
16th March	Fly to Bhopal
17th March	Meeting with Dr Pankaj Kumar at Indian Institute of Science Education and Research (IISER) Bhopal to plan the work for the following couple of days and get the data needed
18th-19th March	Data analysis of climatic characteristics of the Sambhar Lake region. Fly to Ahmedabad
20th-21st March	Meeting with Dr Vimal Mishra at IIT Gandhinagar. Attending two seminars in groundwater management and irrigation Introduction to ArcSWAT with the assistance of his students
22nd March	Fly back to UK
24th April	Second round of sampling by Water Harvest and PKS

Annex B: References

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

Rathore, M. S. (2015) CLIMATE RESILIENT DEVELOPMENT. A case study of Mashi Sub basin in Rajasthan. Jaipur. Available at: https://www.gwp.org/globalassets/global/gwp-sas_files/wacrep/2015/report-on-case-study-of-mashi-sub-basin---rajasthan.pdf.

Reddy, V. R. (2010) 'Water sector performance under scarcity conditions: A case study of Rajasthan, India', Water Policy, 12(5), pp. 761–778. doi: 10.2166/wp.2010.135.

Singh, B.P., Neha, S. and Singh, S.P., 2013. Modern salt (halite) deposits of the Sambhar Lake, Rajasthan and their formative conditions. Current Science, 104(11), pp.1482-1484.

Vikas, C. *et al.* (2013) 'Genesis and geochemistry of high fluoride bearing groundwater from a semi-arid terrain of NW India', Environmental Earth Sciences, 68, pp. 289–305. doi: 10.1007/s12665-012-1739-3.

WHO (2011) Guidelines for Drinking-water Quality - 4th ed. Available at: https://www.who.int/water_sanitation_health/publications/dwq-guidelines-4/en/

Annex C: Workshop poster and agenda

सांभर झील क्षेत्र में जल संसाधन प्रबंधन पर कार्यशाला
Workshop on Water Resources Management in the Sambhar Lake Region

रोटरी महावीर भवन, दुदू, जिला जयपुर
Rotary Mahaveer Bhavan, Dudu, Dist. - Jaipur

दिनांक - 15 मार्च 2019
Date - 15th March, 2019

Aim: To understand the water availability in the region, current and future challenges and potential solutions.

Agenda

10.30 -11am Registration and tea

11.00-11.45am Introduction of organisers and workshop participants

11.45-12.15 Presentation: Quality of freshwater resources in the Charasada, Bhojpur and Chhappya villages

12.15-13.30 Water Harvest UK / PKS presentation

13.30-14.00 Lunch and tea

13.30-14.30 Group discussion

14.30-15.00 Group representatives will speak out

15.00-15.30 Water Wisdom Foundation

15.30-16.00 Question

16.00-16.15 Session wrap up

Water resources management in the Sambhar Lake Region Workshop

Date: 15th March 2019

Aim: To understand the water availability in the region, current and future challenges and potential solutions.

Agenda

10.30 -11am Registration and tea

11.00-11.45am Introduction of organisers and workshop participants

11.45-12.15 Presentation: Quality of freshwater resources in the Charasada, Bhojpur and Chhappya villages

12.15-13.30 Water Harvest UK / PKS presentation

13.30-14.00 Lunch and tea

13.30-14.30 Group discussion

14.30-15.00 Group representatives will speak out

15.00-15.30 Water Wisdom Foundation

15.30-16.00 Question

16.00-16.15 Session wrap up

Annex D: List of NGOs and Government organisations participating in the workshop

NGOs and govt. organisations participating in the workshop
Water Havest
Water Wisdom Foundation
Gramin Manav Kalyan Shikshan Sansthan
Swera Sansthan
Grameen Vikas Shodh Avam Takaniki Kendra, Pachewar
Gramothan Sansthan, Malpura
Komal Bal Avam Mahila Kalyan Sanstha, Ajmer
Sparsh
Gram Vikas Navyuvak Mandal Laporiya (GVNML)
Marwad Sewa Sansthan (Nagaur)
Sampark Sansthan, Kuchaman
Prayas Kendra Sansthan, Harsoli
Representatives of Pani Panchayat (village committee), Charasada
Representatives of Pani Panchayat (village committee), Bhojpur
Farmers from the three villages
Government: Block Development Officer (Dudu Block)

Back cover image: Aerial image of the Sambhar Salt lake (Google Earth)

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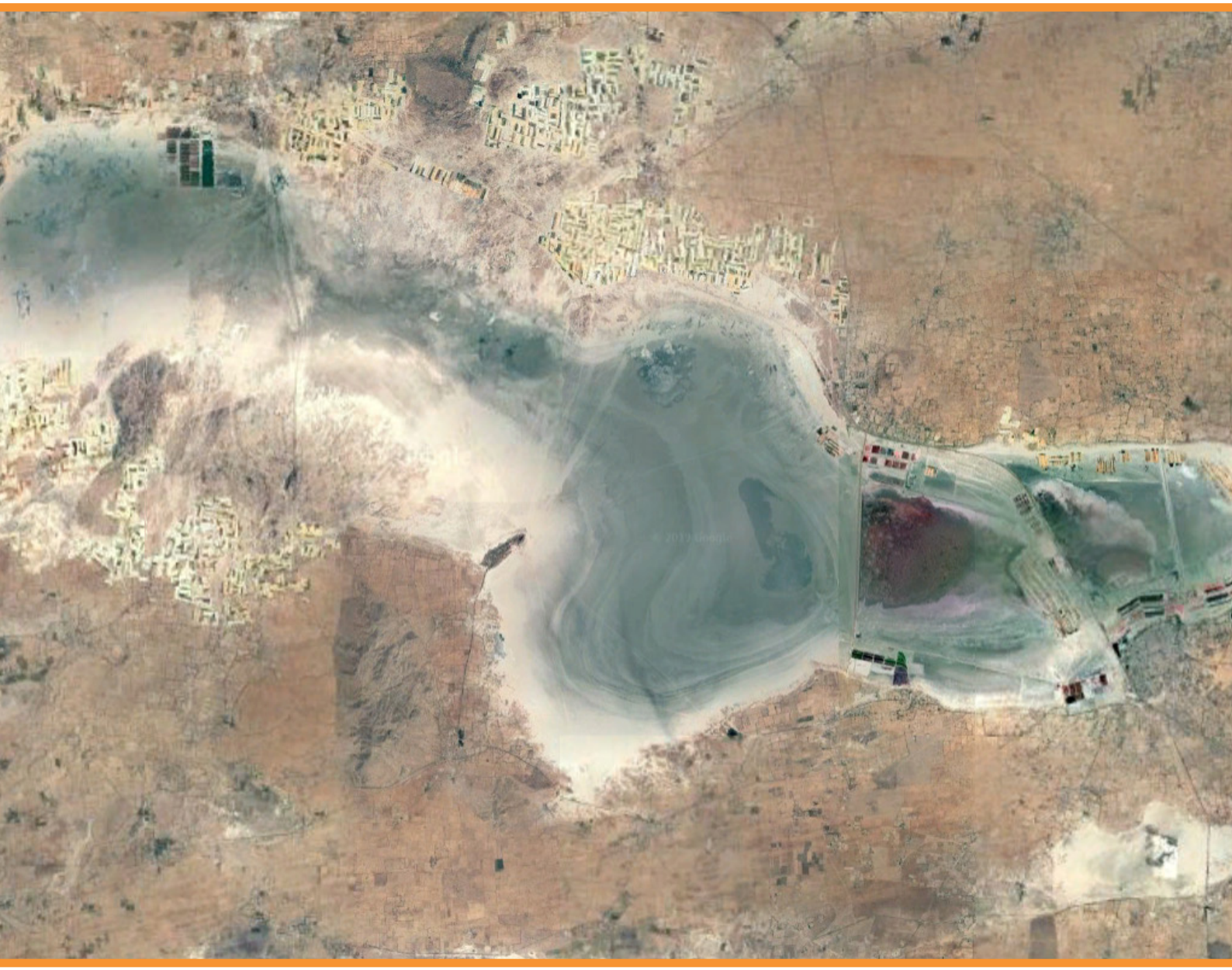

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