Working Paper

Digitalisation in Water Governance for Agriculture: Lessons from the field in India

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Executive Summary

Background

With water demand expected to exceed supply twofold by 2030, India faces a major water governance challenge: the fair and sustainable distribution and regulation of water resources, particularly in the agricultural sector, which accounts for about 80 percent of total water use.

Digital tools can offer benefits in water governance for agriculture, but they can also carry risks and challenges, which can mean that benefits are not equitably distributed across all stakeholders.

This report seeks to identify how local institutions can best use digital tools to make water governance more effective and inclusive, for sustainable water use and climate-resilient crop planning. It identifies three key lessons to inform the design and implementation of digital tools and associated projects.

Case Studies

We investigated the participatory use of digital tools in four water projects, with a focus on end-users such as smallholder farmers. The research sites span over five districts in four states of India, covering eleven digital tools, which were used for functions such as gathering data on groundwater levels, mapping water resources, modelling aquifers, measuring water salinity levels, water budgeting, planning water conservation measures, and more.

Data gathered from our studies were analysed in terms of the factors influencing the adoption and efficacy of digital tools, including their complexity, the benefits they were perceived to bring to users, social factors such as the gender and age of potential users, and the role of interlocutors like village-level committees in groundwater management, water stewards, or volunteers working as the interface between the digital tool and the community.

Key Lessons

Lesson 1 emphasizes that the long-term adoption of digital tools is hindered by their complexity and lack of clear benefits. To enhance adoption, projects should conduct thorough user-need assessments, invest in user-centric design, and incorporate feedback mechanisms.

Lesson 2 underscores the importance of analogue work and social innovations, alongside digital infrastructure investments, to address the 'digital divide.' Projects should align digitalisation with social needs, provide digital literacy training, and ensure continued benefits beyond project completion.

Lesson 3 highlights the role of digital tools in improving water governance but emphasizes that they should complement, not replace, participatory processes. Projects should strike a balance between digital tools and participatory approaches, integrating local knowledge for more contextually relevant water governance solutions.

Abbreviations & Acronyms

ACT	Arid Area Communities and Technologies
AMC	Aquifer Management Committee
BJ	'Bhujal Jaankars' ('barefoot hydrogeologists')
BMZ	German Federal Ministry for Economic Cooperation and Development
CDVI	Community-driven Visual Integrator
CLART	Composite Landscape Assessment and Restoration Tool
CoDriVE-PD	Community Driven Vulnerability Evaluation – Programme Designer
CRPs	Community resource persons
CWB	Crop Water Budgeting
FES	Foundation for Ecological Society
FGD	Focus Group Discussion
GIS	Geographical Information Systems
GP	*Gram Panchayat* (village council)
GWMT	Groundwater Monitoring Tool
ICT	Information and Communication Technologies
K-Marc	Kankavati Managed Aquifer Recharge through Community
NbS	Nature-based Solutions
NGO	Non-governmental Organisation
NRSC	National Remote Sensing Centre
SHG	Self Help Groups
SOPPECOM	Society for the Promotion of Participative Ecosystem Management
TDS	Total Dissolved Solids
TMG	Töpfer, Müller, Gaßner
VDC	Village Development Committee
VWMT	Village Water Management Team
WOTR	Watershed Organisation Trust

SEWOH Lab

This paper was produced as part of the SEWOH Lab. The SEWOH Lab (2020-2025) is led by Berlin-based TMG Research gGmbH. It seeks to analyse the linkages between digital and social innovations for achieving Sustainable Development Goal 2. Together with partners in Africa and India, the SEWOH Lab explores, applies, and evaluates the potential of digital innovation in three key areas: urban food systems, women's access to land, and nature-based solutions. Its primary focus lies on smallholder farmers and marginalised land users, including women. It is financed by the German Federal Ministry for Economic Cooperation and Development (BMZ).

The action research under the NbS workstream is implemented in Maharashtra, by the non-governmental organisation SOPPECOM (Society for the Promotion of Participative Ecosystem Management), with a goal of strengthening local institutions, such as Water User Associations and watchdog organizations like farmer social movements, for more equitable and sustainable water governance and management with the help of digital tools.

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1 Introduction

1.1 Climate and water contexts in India

India ranks among the countries worst affected by climate change, with severe effects on water. For 820 million people living in the twelve major river basins in the country, the mean annual per capita availability of water is lower than 1000 cubic metres (NITI Aayog, 2019), the threshold for water scarcity according to the Falkenmark Indicator (Falkenmark et al., 1989). According to the Government of India, by the year 2030, water demand is expected to be two times greater than supply, leading to significant impacts on livelihoods, health, the economy, and ecosystems in the country (NITI Aayog, 2019), and potentially triggering new water related conflicts or intensifying those which already exist.

Climate risks have been adding to this looming water scarcity problem: according to the Council on Energy, Environment and Water (CEEW), over the past two decades the frequency of floods and droughts has increased considerably (Mohanty, 2020). Thus, ensuring sustainable management of water resources, for present and future generations, is one of the major concerns in today's India.

Given India's diverse geography, climate and population, water governance[1] spans across multiple sectors and states, and involves a complex interplay of legal frameworks, institutional arrangements, technological and digital capacities, and structures and practices of community engagement.

One major challenge is equitable water distribution. For example, in Maharashtra, 1.1 million sugarcane farmers, who occupy just four percent of agricultural land, consume 70 percent of available water (Ministry of Agriculture, 2013). Furthermore, access to water is closely tied to the size of land holdings, favouring larger farms. Therefore, the water governance challenge lies in fair and sustainable distribution and regulation of water resources, with a particular focus on the largest water consumer, agriculture.

1.2 Agriculture, water governance, and digitalisation: the research context

Agriculture consumes about 80 percent of the total water resources in India (Belsare et al., 2019). Water governance in this sector involves improving irrigation efficiency, promoting water-saving techniques, encouraging crop patterns that use less water, and fairer sharing of water. Where newer challenges are emerging in the management of water, digitalisation is increasingly spurring change within the sector. Globally, a growing body of evidence indicates the positive influence of the spread of mobile technologies, remote-sensing services and distributed computing: these technologies are generally said to enhance access to information, inputs, and markets, as well as increasing production and productivity, streamlining supply chains, and reducing operational costs (FAO, 2021). Among the earliest and most established digital solutions are satellite images and Geographical Information Systems (GIS) (Colby,

1 According to the definition developed from Rogers and Hall (2003) as part of the Global Water Partnership (GWP) Technical Committee, water governance 'is the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society) (GWP). 'It is essentially about who gets what water, when and how, and who has the right to water, its related services and their benefits.' (SIWI)

2019). They have proven to be effective in planning and monitoring, by providing information on land use, water bodies, topography, and surface drainage patterns, to name a few.

In India, over the past two decades, digital tools have been increasingly adopted in water governance in agriculture. They respond to diverse challenges at project planning and implementation levels, as well as at farm level. For instance, The Bhuvan Portal[2] of the National Remote Sensing Centre (NRSC) run by the government, or the Watershed Atlas of India[3] provided by the Ministry of Jal Shakti (water), make spatial data publicly available. Such digital approaches to cartography can be combined with participatory mapping approaches (Ismail et al., 2019) that include the spatial knowledge of local land users to inform policy, planning and implementation.

Digital technology has significantly changed the way that data are collected and information transferred for decision-making. However, though digital technologies are becoming an indispensable part of human lives, they pose risks and challenges, including the creation of a "digital divide" (Mehrabi et al., 2021; Taylor, 2022), a term that refers to the gap between those who have access to digital technologies and the capacity to use them effectively, and those who do not. For example, while the Bhuvan Portal mentioned above may hold great potential in terms of making data freely available to all citizens as a "digital commons", at *Gram Panchayat*[4] level, such data are often incomplete or missing, as is knowledge on how to access and use it (Gram Panchayat, n.d., Level Documentation and Planning). Thus, the challenge of digitalisation lies not only in providing timely and robust data, but also in serving good governance generally. Digitalisation practices in agriculture water governance need to be critically appraised in order to determine how to make them more effective and their benefits more equitably distributed across all stakeholders; especially the end-users such as the smallholder farmers, including women.

1.3 Purpose of the report

This report seeks to inform policy, practice, and research around water governance, through a discussion of the opportunities offered by digitalisation in water governance, as well as the challenges which can hinder its effective and inclusive implementation. It offers lessons from existing projects in water management and agriculture about the (participatory) use of digital tools to help improve local water governance in India.

The paper begins with a brief overview of the major findings of the scoping research. This is followed by a discussion of the research findings clustered around three lessons from the field which address: the tendency of complexity to limit user adoption of digital tools and the need for end-user involvement in their co-design; the need for accompanying analogue processes to ensure last-mile connectivity and address the digital divide; and finally the continued importance of participatory processes to sustaining adoption of digitalisation. Each lesson is accompanied by recommendations for policymakers and implementers.

2 See https://bhuvan.nrsc.gov.in/home/index.php

3 See https://slusi.dacnet.nic.in/mwanew.html

4 A Gram Panchayat is an administrative unit at village level in rural India. It serves as a local self-governing body, overseeing development projects, social welfare, and infrastructure development at the grassroots level. The council is headed by an elected Sarpanch, and its members are representatives elected by the village residents.

2 Case studies: Digitalisation practices in agricultural water governance

2.1 Methodological considerations

As part of the SEWOH Lab's scoping research, we investigated the participatory use of digital tools in water projects, with a focus on end-users such as smallholder farmers. Four project cases were studied, with the underlying research question, *"How can local institutions improve effective and inclusive water governance for sustainable water use and climate-resilient crop planning, with the help of digital tools?".* Between March 2022 and January 2023, field research was conducted and enriched by expert dialogues.

For a comprehensive understanding of farmers' adoption of digital tools, we took a qualitative approach. The scoping research consisted of key informant interviews and focus group discussions with farmers (ten FGDs), women self-help groups (two SHGs), village leaders (three meetings), senior project technical staff (four meetings), and field-level technical staff (four meetings) in Maharashtra, Rajasthan, Gujarat, and Odisha. The research sites span over five districts in four states of India, covering eleven digital tools (see table 1). The field research findings were enriched by document analysis and two expert dialogues held online and face-to-face in Pune, Maharashtra, with experts from the water and agricultural sector.

Collected data were analysed in terms of factors influencing the adoption and use of tools, such as their complexity, the benefits they were perceived to bring, social factors such as gender and age, the role of interlocutors like village-level committees in groundwater management, water stewards, or volunteers working as the interface between the digital tool and community.

Overview of case studies and tools assessed.

Case study	Location	Tool
"Napo Jal Bachao Kal" initiative by Foundation for Ecological Society (FES)	Rajasthan	▪ Groundwater Monitoring Tool (GWMT) ▪ Crop Water Budgeting Tool (CWB) ▪ Composite Landscape Assessment and Restoration Tool (CLART)
'Kankavati Managed Aquifer Recharge through Community (K-Marc)' initiative by Arid Area Communities and Technologies (ACT). Non-monetary benefits/co-benefits	Gujarat	▪ Digital water level recorder ▪ Portable digital TDS meter
"Water Secure Gram Panchayat" program by Gram Vikas, in Odisha	Odisha	▪ mWATER app
"Participatory Groundwater Management" by Watershed Organisation Trust (WOTR), in Maharashtra	Maharashtra	▪ Community-driven Visual Integrator (CDVI) - 3D aquifer model ▪ Automated Weather Stations (AWS) ▪ Community-driven Vulnerability Evaluation - Programme Designer (CODrive-PD) ▪ Participatory Net Planning (PNP) ▪ FarmPrecise App – Crop Advisory

Map: Schematic map of India indicating the case study locations.

Case study 1: "Napo Jal Bachao Kal" initiative by Foundation for Ecological Society (FES) in Rajasthan

Interventions

The **'Napo Jal Bachao Kal'** ('measure water for a safer future') initiative, launched by Foundation for Ecological Society (FES) in May 2020, promotes the use of digital tools to enhance sustainable water governance, including the reduction of water-intense crops. Three digital tools were investigated:

The Groundwater Monitoring Tool (GWMT) is an open-source Android tool designed for collecting data on the water level of wells. The tool is currently in active use, and collected data are sent to an open-access web platform, the India Observatory, for analysis and water budgeting purposes. The web platform helps to visualize groundwater data by producing water table maps. The GWMT can be used off-line and is operated at the village level by community resource persons (CRPs) and other individuals.

The Crop Water Budgeting tool **(CWB)** is also an Android-based app that supports communities in managing their surface and ground water sustainably. CRPs collect crop and cultivation area data, and the app determines whether the village has a water surplus or deficit. If there is a deficit, community members discuss potential crop changes.

The Composite Landscape Assessment and Restoration Tool (CLART) is a GIS-based Android tool designed to help rural communities plan soil and water conservation measures tailored to their regions. It focuses on the recharge of groundwater or increase of surface water availability based on local geo-hydrological characteristics. FES's technical staff enter the data, and the tool produces colour-coded maps. These maps highlight the recharge and discharge zones of aquifers and visualize groundwater movement, helping villagers better understand these dynamics. CLART promotes collaboration among communities for water harvesting planning.

Outcomes

The communities are aware of the different digital tools that have been introduced and their specific applications. However, it was observed that the overall level of use of these tools by the communities, including the local institutions, is low. They are mostly dependent on the CRP to handhold the process.

Digital tools supported local communities' awareness about water availability in the project sites. With the help of the GWMT, the communities are now relatively more engaged in monitoring the groundwater levels. For example, CRPs regularly enter information into the GWMT to maintain records on the India Observatory data platform.

All villages are actively engaged in the process of creating water budgets for their respective areas using the CWB tool. Typically, a *Gram sabha*[5] should be convened to decide on necessary changes to the existing cropping pattern to avoid water shortages by the end of the *rabi* season[6]. While the village communities understand water-sensitive crop planning, there are economic, social and other constraints that affect individual crop choices. Therefore, the impact of the CWB tool in amending cropping patterns based on water availability remains to be seen.

Photo: Experimental games for sensitization on crop water use, analogue, complimentary component to the digital water budgeting tools used by the Foundation of Ecological Security.
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5 In India Gram Sabha is a village assembly of all adult residents. It serves as a platform for local decision-making, approving development plans, monitoring government programs, and discussing community issues.

6 The term "rabi season" refers to the winter cropping season in India, which typically starts in November and lasts until April. During this season, crops like wheat, barley, peas, and mustard are sown and harvested. The name "rabi" is derived from the Arabic word for spring, highlighting that these crops are harvested in spring.

Case study 2: 'Kankavati Managed Aquifer Recharge through Community (K-Marc)' initiative by Arid Area Communities and Technologies (ACT) in Gujurat

Interventions

The K-Marc initiative worked to enhance water management and community resilience in 19 villages that access the Kankavati aquifer. Local support systems for the participatory use of tools have been a critical component of the project. A cadre of local village people called the 'Bhujal Jaankars' (BJs), or 'barefoot hydrogeologists', was built as the main interface between ACT and the village communities.

Various digital tools are used for the measurement and monitoring of water, including the **digital water level recorder**, **flow meter**, **soil moisture sensor**, and **Total Dissolved Solids (TDS) meter**. These instruments were designed for direct use by farmers, though eventually they were mostly used by the BJs. In some of the villages the BJs use the digital water level recorder for measuring water levels in bore wells. The 'bore well sensor' sends data directly to the computer for further analysis, such as by ACT project staff. The TDS meter is used to monitor water quality in the bore wells. Since salinity is a major challenge in the aquifer area, monitoring water salinity helps villagers to identify when the bore wells need to be recharged.

Outcomes

The challenge of high salinity was addressed. At the time of the field visit, 100 bore wells for irrigation risked defunction due to salinity intrusion. Measurements from the TDS meter help to plan the recharging of borewells.

A case in point, according to an interview with a farmer, was in the use of the soil moisture sensor in measuring water consumption. He has been able to reduce the irrigation rotations of wheat cultivation from twelve to eight by regularly measuring the soil moisture, increasing productivity of his wheat. He is able to grow 45 quintals of wheat on his 2.5 acres of land. This is equivalent to 3.2 T/ha, which is about 15 percent higher than the average productivity of wheat in the state of Gujarat.[7] His success story can be a positive example for other farmers seeking to use instrumentation to improve their yields.

The project initially relied on analogue tools like a 3D model of the aquifer to help farmers and communities understand groundwater challenges, including groundwater retention, salinity, and subsequent soil infertility. This approach encouraged interest in digital tools. Presently, software like Google Forms and Excel sheets, managed by BJs, are used for data input and analysis. However, the project is now developing a digital app that will collect and collate data, including groundwater levels, support village water budgeting, and provide crop advisory information. Farmers could use these data to make informed decisions about managing water for their crops, marking a transition towards more advanced digital solutions.

7 See here: https://farmer.gov.in/imagedefault/pestanddiseasescrops/wheat.pdf

Case study 3: "Water Secure Gram Panchayat' Program" by Gram Vikas in Odisha

Interventions

Gram Vikas, a non-governmental and non-profit organisation in Odisha, led the initiative across 27 *Gram Panchayats* in five districts. The project site receives high rainfall, but agriculture is hindered by water scarcity due to slope-driven drainage. The initiative focuses on creating an inventory of water sources with community involvement, developing a knowledge database of local springs and groundwater, including aquifer maps, to ultimately derive water security plans for the communities.

The **mWATER app**, an open-source data collection tool, serves two primary purposes: firstly, it helps to map all water sources within the project area, and secondly, to monitor their water levels. The water source maps are utilized to create aquifer maps with GIS-based software. Community cadre members are appointed to paid positions known as 'Jal Bandhu' or 'friends of water,' by village development committees (VDCs).

They are trained to use mWATER and collect water level data on a weekly basis. mWATER also works in offline mode, so data can be synchronized once the 'Jal Bandhu' reaches a place with internet connectivity. Gram Vikas analyses and uses the collected data to produce the 'Water Passbook'. The passbook functions like a water budget, providing the amount of water available in the aquifer after the monsoon season. The VDC, through a *Gram Sabha*, then take decisions on the management of the available water resources.

Outcomes

The mWATER app has supported effective monitoring of various water sources and the keeping of efficient records of the results, even in remote areas without internet connectivity. Data provided by the Water Passbook on water availability supported the establishment of community-based water management plans leading to the adoption of soil and water conservation measures. This in turn made possible the establishment of plantations on higher slopes, including for lemons, oranges, pineapples, and bananas.

Photo: Watershed in Anusahi village, Gajapati district, Odisha © SOPPECOM

▶ Case study 4: Participatory watershed development by WOTR in Maharashtra

Interventions

The Watershed Organisation Trust (WOTR) uses digital tools to promote and improve water governance mechanisms in drought prone, groundwater-dependent areas. With the support of various digital solutions, participatory aquifer management and crop planning help manage water demand for irrigation. Findings from three digital tools are summarised below:

The **Community-driven Visual Integrator (CoDriVE-VI** or **CDVI)** tool is used to create 3D aquifer models in collaboration with local communities. CoDriVE-PD can be used to identify the vulnerabilities within a block. By characterizing villages according to the topography and surface water availability, villages are grouped in two, three or more categories. A few representative villages are identified for the detailed application of CoDriVE-PD. The consolidated findings will provide the findings and also guides development of the adaptation plan that can be upscaled to the whole block.

This tool was implemented in 25 villages under the initiative. CDVI utilizes satellite imagery, geological mapping, geophysical surveys, and local knowledge to construct these detailed aquifer maps. In parallel, capacity development activities were initiated, mobilizing villagers, and training a group of 'Water caretakers' known as 'Jal Sevak or Sevika,' responsible for sustainable aquifer management. These caretakers facilitated the formation of Village Water Management Teams (VWMTs) in 14 villages, which were later consolidated under an overarching Aquifer Management Committee (AMC). Each *Gram Panchayat* nominated two members from its VWMT to join the AMC. Once the AMC was established, CDVI models were created for both surface and sub-surface aspects with inputs from key villagers. Subsequently, AMC members presented these models in village *Gram Sabhas* and meetings, encouraging community engagement and involvement in water management decisions.

The **Community Driven Vulnerability Evaluation - Programme Designer (CoDriVE-PD**) serves as a tool for assessing vulnerability in communities, particularly focusing on natural resources like soil and water, as well as socio-economic factors. Trained facilitators collect data on various parameters, including irrigated land, agricultural land use, net area sown, rainfed land, total cropped area, and historical and socio-economic factors. Using this data, the tool generates a systems map that shows how soil health, water, biodiversity, crop yield, and fertilizer application are interconnected, suggesting appropriate actions to improve water and soil management. These actions are determined based on the vulnerability rating and assessment report for both the village and households. Community involvement primarily occurs during the data collection and resource mapping phase. While community members are not directly involved in collecting or logging data, they do contribute in community consultations, by mapping their surroundings, identifying important water sources, and highlighting factors that impact water availability, such as land use practices and deforestation.

The **FarmPrecise** app was developed by WOTR to address challenges of weather variability, pests and diseases, and high input costs. Developed as an android-based mobile application, it provides farmers with a weather-based, decision support system which they can customise to their specific crops and farm resources across key agricultural operations. FarmPrecise was rolled out in December 2019 in five languages (English, Marathi, Hindi, Telugu and Odiya) and in four states in India (Maharashtra, Telangana, Madhya Pradesh and Odisha). By November 2023, 92,640 farmers had downloaded the app, which provides advisories for 26 crops, besides advice on weather and various other features.

Outcomes

WOTR's digital tools have shown promise in enhancing water literacy, promoting sustainable water usage, and supporting informed agricultural practices within communities, despite facing various challenges and differing adoption rates. Reports from projects, feedback from farmer discussion groups (FDGs), engagement with women's self-help groups (SHGs), and interviews with project staff and community representatives, including trained village personnel, reveal that the use of digital and analogue tools is enabling community-based self-regulation and the implementation of effective management measures.

The CDVI tool also assists stakeholders in understanding complex groundwater systems, promoting water literacy, and fostering consensus on groundwater governance at the village, block, and aquifer levels. For example, according to the FDGs with farmers and project staff, explaining the 3-D models in *Gram Sabhas* helped improve understanding of water as a shared resource and the interactions between upstream and downstream areas. This understanding has led to improved water management in certain villages, such as Kotha Jahangir village, through the AMC.

The Vulnerability Assessment Tool (CoDriVE-PD) has proven valuable in generating village and watershed baseline reports and vulnerability assessments, leading to improved planning and increased participation among the broader farmer community.

Usage varies between users based on their perception of its benefits, whether they possess all the skills required to operate the app, and other factors. Women's SHGs stated that the app contributes to better pest control and reduced pesticide use, leading to increased tomato production and lower production costs.

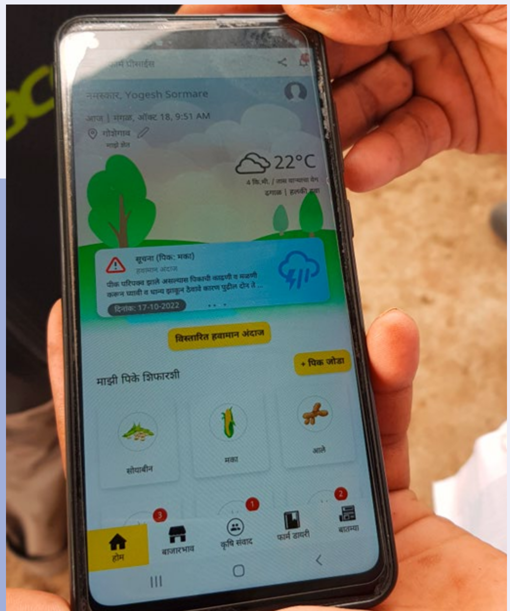

Photo: FarmPrecise app for customized farm advisory, developed by WOTR © Larissa Stiem-Bhatia, TMG Research gGmbH

3. Lessons from the field

This section presents the key insights of our scoping research highlighting the challenges and opportunities of digitalisation processes in participatory water governance and agriculture.

▶ Lesson 1: Users’ long-term adoption of digital tools is undermined by their complexity and lack of clear benefits

Digital tools offer significant advantages in project planning, implementation, and monitoring, providing water managers and policymakers with valuable insights with which to address water-related challenges. However, alongside these benefits, there exists a potential downside – the complexity of digital tools can inadvertently undermine community participation in water governance. Further, digital tools are often brought in as a ‘finished product’ by the implementing organisations. Thus, they may not adequately meet context-specific needs.

The complexity of digital tools makes farmers dependent on ongoing assistance

From four case studies focusing on tools for monitoring and managing common water resources, it was evident that the use of the tools by the communities themselves was minimal. Data collection and analysis encompass highly technical elements like hydrogeological and topographical measurements. For example, all the water budget apps investigated are currently too complicated for farmers to use on an individual basis. Thus, farmers and communities are generally highly dependent on trained – partly paid or incentivized – community resource people to operate the digital tools including maintaining well water and rain records. Even in simpler formats like filling up a google form and sending it to the project implementing organisation, the information is collected by project staff. Hence, even though each of these tools has its benefits and can provide good decision support, they require tremendous on-field support to be effectively used by the farmers.

Farmers’ use of tools varies depending on their perception of the benefits

Complexity was less of an issue when it came to the use of the FarmPrecise app. We observed that its use by farmers varied depending on their perception of its benefits. In one village farmers were generally sceptical about the use of apps for farm advice. In another village, farmers mostly saw the benefits of using weather data but ignored other functions like the farm diary. These observations imply that an app useful in one area may not be equally useful in another, raising the question about the trade-off between the ‘flexibility’ and ‘specificity’ of an app.

We also found that the impetus for digital tool development does not primarily originate from grassroots or community needs but is driven by NGOs seeking to meet their own needs around i) understanding of water and other natural resources, ii) ease of data collection, and iii) better visualization and quicker interface with other digital formats like excel and GIS based software. This is consistent with the findings of Steinke et al. (2022) and Santoyoa and Rojas-Mendizabalb (2017), which highlight the persistent challenge of a “mismatch” between farmer needs and tool offerings.

The FarmPrecise App for targeted pest and other farm advisory

A women's Self-Help Group (SHG) in Ambelohal village, Jalna district in Maharashtra provided a detailed account of their usage and benefits from the FarmPrecise app. Approximately 50 to 60 out of 183 members have been using the app for around two years. They primarily use it for pest management by photographing affected plants and following the provided advice. The app thus reduced their reliance on local vendors who often give biased pesticide recommendations.

As a result, the SHG was able to decrease pesticide usage, leading to more effective pest control. With weather advisories tailored to their locality, they now spray pesticides less frequently and at more optimal times. The women SHG was able to double their tomato production due to better pest control. Additionally, group members use the app's features for market price updates and notifications on government schemes. Besides sharing information through WhatsApp groups, the SHG employs biweekly and monthly member meetings to disseminate FarmPrecise information.

Recommendations

1. **Conduct a comprehensive need assessment before app development.** Prior to the development of any app, a comprehensive need assessment survey should be conducted to understand the needs of the communities. Any app features that are added without taking into account the actual needs of the people will lead to redundancies.

2. **Invest in the user-centric design of tools for greater simplicity and intuitiveness.** Use a simple interface that is intuitive and easy to navigate by avoiding unnecessary features and complex terminology and using clear and concise language for instructions. A step-by-step audio/visual guide may enhance the process. Incorporate audio and visual elements such as graphs, charts, and maps to present information in a comprehensible manner. Visualizations can enhance understanding and facilitate decision-making. For people who cannot see or those who cannot read, audio instructions will be effective.

3. **Incorporate a feedback mechanism that allows users to provide input on the tool's functionality and usability.** Regularly gather feedback and make improvements based on user suggestions. This mechanism may need to be built into the implementation activity to enhance the user experience during the project period.

Lesson 2: Alongside investments in infrastructure, social innovations are key to ensuring last-mile connectivity and mitigating the 'digital divide'

Digital solutions are not a silver bullet. Although digital solutions may lead to efficiency improvements in project planning (Kuma et al., 2012), they also have the potential to risk exacerbating existing inequalities. This may be the case when particular social groups do not have access to digital technologies or the information generated from them. This challenge is commonly referred to as the "digital divide" (Mehrabi et al., 2021) and typically relates to factors such as gender, age, wealth, or place of residence.

Access to information and communication technologies (ICT) in rural areas is rising at much slower rates than in urban areas. Nearly 30 percent of the rural population are connected to the internet, compared to over 93 percent internet connectivity in urban areas (Shruthi et al., 2021).

Beyond unequal access to infrastructure (McCaskill, 2019), social factors like gender affect farmers' access to digital information. Other constraints relate to the structural divide in knowledge and experience in using ICT (also known as e-literacy). Especially among the older generations, many people, and especially older women, have had less access to education on the basis of caste affiliation and religious norms. This applied in most of the cases identified in our scoping studies.

The social dimensions of the digital divide often remain unaddressed in debates around digitalisation and at the periphery of discourses on digitalisation in agriculture (Mehrabi et al., 2021; Willitts-Kind et al., 2019). For example, 'last mile connectivity' (Lambrechts and Sinha, 2019) is mostly understood in terms of physical and infrastructural challenges, to which solutions such as "last-mile cellular network deployments" or Wi-Fi as a "cost effective last-mile access technology" are proposed.[8]

The digital divide can exacerbate existing social barriers

Our scoping research also revealed that factors such as gender, age, and education level create social barriers limiting digital adoption. Digital solutions can, unintentionally, exacerbate the digital divide by creating disparities in technology access, digital literacy, and e-literacy. Android-based apps like Farm Precise, mWATER, or the CWB require users to possess a functional smartphone, whereas our scoping studies have revealed that farmers, particularly the elderly and women, tend to have limited access to smartphones and therefore will be unable to benefit from these digital tools. Generally, such digital disparities are especially pronounced among marginalized groups, such as women Dalits, and Adivasis (indigenous communities), as evidenced by the 2023 Mobile Gender Gap Report (WRI, 2023), which indicates a 40 percent gender gap in smartphone ownership and internet adoption.

Therefore, technology-driven interventions cannot be considered a one-size-fits-all solution; they must be accompanied by investments in digital literacy and education on a larger scale. This aligns with the findings of the World Development Report (World Bank, 2016), which emphasizes that the rapid evolution of digital technologies can sometimes divert attention from addressing the actual needs and preferences of the intended beneficiaries, as well as making the necessary compromises in resource-limited settings.

8 See here: The Last-mile Internet Connectivity Solutions Guide).

The role of social innovation in last mile connectivity

One decisive method common in all four case study sites for mitigating the digital divide and making the digital tool and generated information more accessible to less tech savvy and smartphone-less people was the approach shown in the figure below.

In the implementation of water monitoring tools, our scoping research indicates that digital tools in water governance can bridge the digital divide through inclusive and participatory project design. Here, the emphasis is on the role of the Jal Bandhu, BJ, CRP, or Jal Sevak. These locally-recruited and trained intermediaries provided last mile connectivity, and have been the most important interface between the village communities and project implementers. However, their capacity is somewhat limited, and they often require project staff support for basic functions like monitoring and app usage.

Ensuring post-project sustainability for community resource people

How does one ensure post-project sustainability? Either the communities have to take ownership of a project and maintain the records themselves, or the employment of the staff appointed under the project under the *Gram Panchayat* funds must be continued. This was seen in the case of Gram Vikas, where the village-level cadre is appointed by the VDC and is directly paid by the village through individual contributions. This, to a certain extent, can ensure post-project sustainability, at least until a point at which prominent members of the village *Gram Panchayat* or other institutions like the VDC, VWMT, and even SHGs understand and adopt the digital tools. But village-level technical staff that can provide support to the farmers are a necessity. These must be paid positions.

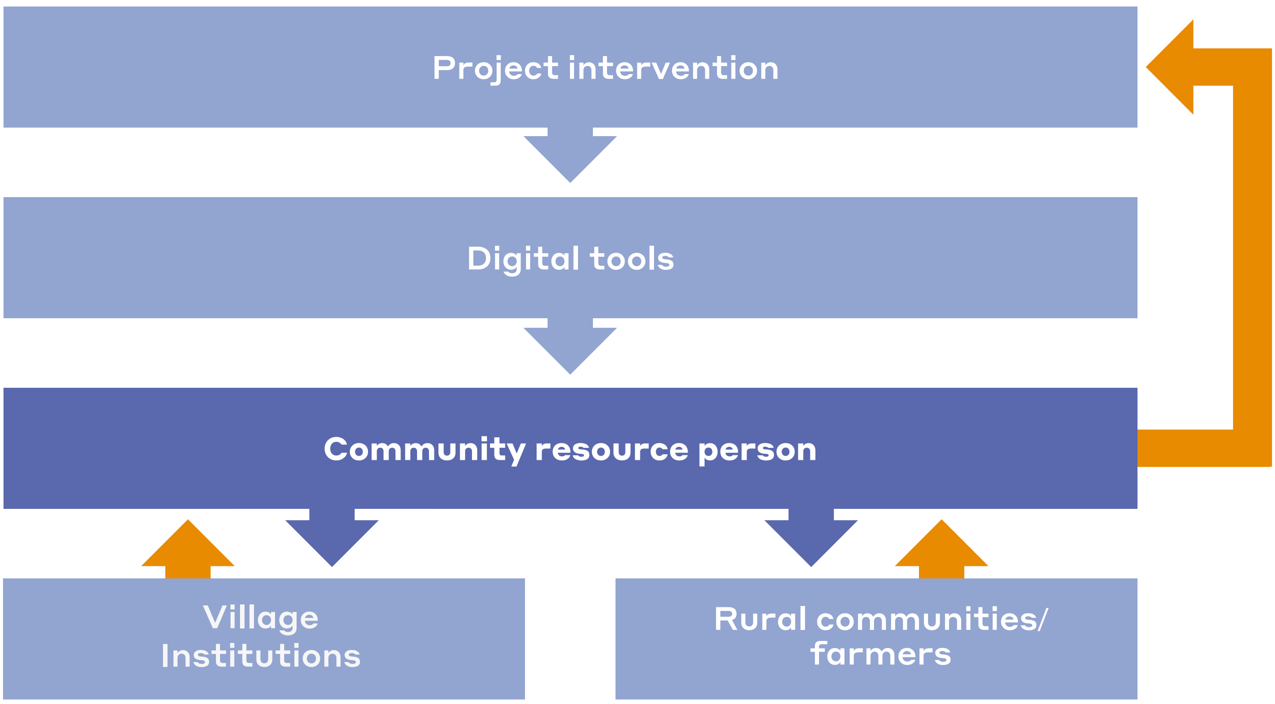

Figure: Schematic illustration emphasizing the role of community resource persons for grounding digital tools at grassroots level, including feedback loops (in orange) for adjustment of digital tools (authors' illustration).

The roles of "Jal Bandhu" and village development committees in the Gram Vikas site

The water in Anusahi village in Gajapati district in Odisha was managed by the ***Gram Panchayat*** **(GP).** The members of the GP itself were the members of the village water management committee. The main role of the members of the Gram Panchayat were to coordinate with the 'Jal Bandhus' to understand the different water sources in the village. Since springs are an important part of the landscape here, sensitizing the village communities to spring conservation is a critical role of the GP. The planning and management of water resources after the monsoon is the other main role of the GP.

Jal Bandhu, or "friend of water", is a paid position under the GP that helps in the mapping and monitoring of water sources. The Jal Bandhus also coordinate with the project implementers to develop the water balance for the villages which is then given to the GP for the planning of water resource use. This also ensures that the 'Jal Bandhus' continue to work beyond the project period ensuring post project sustainability.

Recommendations

1. **Align digitalisation to social needs to address the digital divide.** Given that specific social groups face structural exclusion due to factors like class, caste, ethnicity, gender, and age, ensure that decision-making bodies in water governance include representatives from marginalized communities. This can enable them to participate in discussions and have their voices heard. Involving more farmers in the process of developing and applying monitoring tools will increase their awareness and ownership of these tools, promoting sustainable water use in future.

2. **Provide training in digital and e-literacy for communities.** Implement programs to improve digital literacy among communities that lack access to digital resources and e-literacy. This can include training sessions on basic computer skills, smartphone usage, and internet navigation. Additionally, context specific training must be adopted so that the end-users can relate to the benefits of using a certain digital tool.

Photo: Community resource person "Jal Bandhu" at the Gram Vikas project site monitoring the water level in a well. © Neha Bhadbhade, SOPPECOM

▶ Lesson 3: Digital tools can improve water governance, but they should not replace participatory processes

It is essential to recognize that while digital tools bring valuable advantages, they cannot replicate or replace the benefits of participatory processes involving stakeholders and local communities. Participatory approaches seek to ensure due consideration of the perspectives and needs of local stakeholders, including farmers, by engaging them in co-design and use of digital tools and information and related decision-making. As noted by Pretty et al. (1995), participatory approaches can empower farmers to become active participants in shaping policies and practices related to the management of natural resources, including water.

The importance of traditional knowledge in digital innovation

One important aspect of developing participatory approaches alongside digital solutions is that combining digital technologies with local knowledge can lead to more contextually relevant and innovative solutions for water governance (Imoro et al., 2021). This was also seen in the case of the CDVI's 3D aquifer model, where the villagers could make better informed plans for groundwater management after understanding the geophysical constraints on their aquifers. Similarly, the CLART tool involves the participation of key individuals at village level from the data collection phase onwards, collaborating with technical staff to map local resources. The digital tool and community engagement together generate easy-to-understand maps, which aid in planning water harvesting structures.

Digital solutions can only work in combination with participatory, analogue processes

Tschakert and Dietrich (2010), emphasise the importance of integrating social-ecological frameworks into water governance, acknowledging the need to include both technical expertise and participatory approaches to effectively address water management challenges. Our field studies demonstrated that digital applications like the water budgeting (CWB) app achieved their best results when combined with participatory processes that enabled farmers to make use of the digital data.

Overall, our firsthand observations underscore the idea that digitalisation should function as a tool to fulfil predefined social goals, such as consensus-building and specific decision-making, which should take precedence over technological solutions. It seems that an even greater effort will be needed when (new) digital solutions are brought in, involving a diverse spectrum of stakeholders in water-related decision-making, and ensuring that end-users are at the centre of governance processes (Akhmouch and Clavreul, 2016).

Recommendations

1. **Strike a balance between the use of digital tools and participatory processes.** Digital tools undoubtedly offer invaluable contributions to water governance by enhancing data-driven decision-making, monitoring, and information dissemination. However, participatory processes remain indispensable in achieving effective and inclusive water management. Balancing these two observations is key to ensuring that decisions are not based solely on data but also consider the preferences and needs of the end-users, including their social realities.

2. **Merge local knowledge and digitalisation.** Local communities possess valuable traditional knowledge and insights about their water resources and agricultural practices. Engaging them in the digitalisation process allows for the incorporation of this local wisdom into decision-making and the co-design of technology development.

Photo: Focus group discussions with a women self-help group in Maharashtra

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