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Formulation of integrated water resources management (IWRM) plan at district level: a case study from Bundelkhand region of India

V. C. Goyal[a], Anuradha Garg[b], Jyoti P. Patil[a,*] and T. Thomas[a]

[a] *National Institute of Hydrology, Roorkee, Uttarakhand, India*

**Corresponding author. E-mail: jyoti.nihr@gov.in*

[b] *Department of Hydrology, Indian Institute of Technology, Roorkee, Uttarakhand, India*

Abstract

Integrated water resources management (IWRM) is being implemented all over the world, considering its wide area of applications and flexible spatial scale. Scientists have found IWRM useful in an Indian context also where a coordinated development of water and land resources is sought as part of complete economic, social and environmental welfare. The paper presents the concepts of 'Local IWRM' planning applied to water conservation and management in a case study of Ur river watershed in Tikamgarh district of Madhya Pradesh (India). The Plan considers effective utilization of land, water and other available natural resources, linked to the vulnerabilities and livelihood opportunities in the geographical area. The IWRM Plan, designed in three sections – (1) water management, (2) land management, and (3) livelihood management – provides specific suggestions on the activities under these three themes as useful inputs to the District Irrigation Plan (DIP) of the Government. The proposed IWRM Plan intends to promote the component of water demand management in district level planning and is envisioned to be an 'implementable' planning document for district level government. Acceptability of the IWRM plan is potentially enhanced as the plan was developed through a participatory process, wherein all relevant stakeholders were consulted at different stages of development.

Keywords: Bundelkhand; District planning; IWRM; Water management; Watershed

Introduction

Rio's Agenda 21 (1992) reflected water's diversity, identifying simple and systemic elements for integration, i.e. resource components (surface, ground and 'green' water); water management and management of land uses; quantity and quality of the resource; water as part of ecosystems; users and the uses they make of water – technological, socio-economic, environmental and human health considerations. Batchelor & Butterworth (2014) pointed out that the level of water security in a region can

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have a strong influence on the need for and potential benefits of adopting integrated approaches to managing water, land and other natural resources. This truly reflects the essence of integrated water resources management (IWRM) planning, which creates a framework for water management options to be introduced into broader national development planning in a structured way.

An IWRM Plan considers effective utilization of land, water and other available natural resources, linked to the vulnerabilities and livelihood opportunities in the geographical area. At national and basin level, IWRM principles are used to integrate water demand from different sectors of society and to balance this with water availability and to coordinate up-stream with down-stream uses. At the local level, IWRM is also linking water demand, water supply and water resources management in a sustainable way, involving communities in the decision-making process. The Dublin Principles placed emphasis on stakeholder-led processes meaning, in a local 'IWRM in Practice' context, identification of specific challenges and the instruments to be applied to achieve the identifiable outcomes.

A schematic depicting dynamics of the processes in preparation of IWRM Plan is shown in Figure 1. The diagram shows an inter-relationship among the various resources and the processes. It represents how agriculture and livelihood are directly affected by the availability of water, and how they altogether trigger the need for an IWRM plan for regions where agriculture is the major livelihood option.

A 'local IWRM approach' for water conservation and management in India can be effective if combined with the appropriate hydrological tools. Good use can be made of a commonly available geographic information system (GIS) software to handle the variety of spatial information collected from the study area. The use of remote sensing (RS) and GIS for integrated water management programs is an inescapable necessity for the successful implementation of water supply- and watershed-related schemes and programs in India (Sharma, 2019). Another useful tool to enhance the utility of an IWRM Plan is a decision support system (DSS), which facilitates the decision-making process for the stakeholders in selecting appropriate water management practices on a sustainable basis. The paper presents a case study demonstrating the application of 'Local IWRM' for water conservation and management planning, and brings out the potential for the IWRM plan getting implemented if internalized with the government planning at the district level.

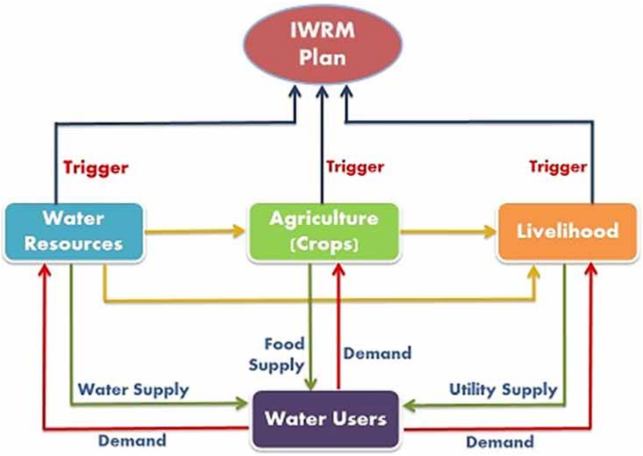

Fig. 1. Schematic diagram depicting dynamics of processes in IWRM Plan.

Earlier applications and critiques

IWRM is being implemented all over the world considering its wide area of applications and flexible spatial scale. Scientists have found IWRM to be useful in the Indian context where a coordinated development of water and land resources is sought as part of complete economic, social and environmental welfare. Hemamalini *et al*. (2015) presented a sustainable solution for tank ecosystems and livelihood management through the IWRM perspective. However, some researchers have also expressed doubts on IWRM being too advanced and unsuitable for developing countries like India where large agrarian economy prevails (Shah & Prakash, 2007). Professor Y.K. Alagh, an eminent economist, educationist and Government Policy Advisor in India, addressed the issue of IWRM implementation in India during the National Workshop on Integrated Water Resources Management (2015) and stressed on local watershed level being beneficial for efficient water management. He emphasized on the call for integrating water management systems with an agricultural system using best practices from similar agro-climatic zones. Taking an integrated perspective of water in various forms, such as precipitation, groundwater, and surface water, while scientifically planning for watershed, ensures holistic development, as suggested by the Chairman of the Central Water Commission in the same workshop.

An assimilation of various IWRM concepts makes one understand the crucial factors affecting this evolutionary process (Rana Tharu *et al*., 2016).

The IWRM principles of water management at the lowest appropriate level and the participation of community (especially women) in water management are central to the local-level IWRM. The primary aim is to address the water demands and also improve the livelihoods of poor small-scale water users. IWRM enables communities to manage their water resources in an environmentally sustainable manner and to co-design and implement water infrastructure development according to their own needs and priorities. The resulting ownership of infrastructure is the single most important condition for its financial, institutional and environmental sustainability. Increasing competition for water resources and new drivers (e.g. climate change) have led to the alignment of water resources development and management policy framework to the IWRM principles, which facilitate addressing these challenges in a more holistic and coherent way (UNEP, 2012).

The phasing out of top-down strategies and the growing popularity of participation and bottom-up processes encourages greater cooperation from local users. It is now widely accepted that bringing communities who are closest to the resource into decision-making is essential for achieving sustainable solutions for natural resource management. In order to succeed in the Indian context, IWRM has to plan in a bottom-up approach. Although activities are planned at the local level, an assessment of their impact on the watershed and basin levels is required. A sound community engagement at various stages of the IWRM Plan implementation is also essential.

The IWRM approach provides a way in which the water community addresses the complex interactions between water and humans, including the issues of equitable water allocations. Yet the limited acceptance for implementation of IWRM planning on a wider scale is attributed to the lack of participatory development and more focus on the top-down approach. Gallego-Ayala (2013) mentioned that several authors of IWRM literature have criticized the normative approaches to IWRM implementation that have been advocated and disseminated without considering the realities of local context. There were questions such as whether ‘a single paradigm of sustainable water resources management can encompass all countries of a very heterogeneous world, with very different cultures, social norms, climatic conditions, physical attributes, management and technical capacities, institutional and legal frameworks, and systems of governance' (Biswas & Tortajada, 2004; Biswas, 2008).

Butterworth *et al.* (2010) provided a list of common criticisms of IWRM and possible ways out. The critique of IWRM has been mostly on the way its implementation has progressed, and not on the underlying concepts *per se* (e.g. Garcia, 2008). Rather than ditch the IWRM concept for its obvious flaws, Butterworth *et al.* (2010) proposed to focus implementation on more practical and local entry points for applying IWRM in a light or pragmatic, adaptive way with due regard to local realities. Rather than aspiring to an ideal of 'full' IWRM that may be both unattainable and perhaps undesirable in many contexts, at least for many decades, there appear to be several possible entry points for more local initiatives to promote coordinated water management that deserve greater attention. Batchelor & Butterworth (2014) further elaborated that the 'light' IWRM aims to be problem-focused, opportunistic and adaptive/iterative when applying core IWRM principles especially at the water-user level, where it is better adapted or tailored to the political economy of the given area.

Moriarty *et al.* (2010) present a light approach to IWRM piloting in Egypt, Jordan and Palestine that focuses on building mindsets and skills (identified as a key problem) and supporting the development of appropriate light auditing tools and planning models for IWRM at the governorate (equivalent to district) level. One strength of the IWRM paradigm is that it makes conceptual space for real and significant improvements in water management at all levels – from the household to the international basin – by individuals and institutions applying its principles in the context of their own abilities and opportunities (Moriarty *et al.*, 2004). Moriarty *et al.* (2007) called this 'light' IWRM a local approach similar to what others have called 'community water resources management' or 'local water management'. 'Light' approaches aim to apply IWRM principles within sub-sectoral projects and programs at all stages of the project cycle (e.g. visioning, assessment, planning, implementation, monitoring and evaluating, etc.). The idea is that if sub-sector actors apply good IWRM practice at their own level, in their own work, it can lead to the emergence of better local-level water resources management, and be an important first step in the process of IWRM.

There have been scattered reports of IWRM ideas and applications in India. India Water Partnership (IWP) facilitated few states in India (e.g. Jharkhand, Rajasthan, Maharashtra, Odisha) on IWRM implementation, and even developed capacity building manual on IWRM for Rajasthan (IWP, 2013). Mahto & Srivastava (2012) highlighted the importance of IWRM and listed the important steps India needs to take to achieve IWRM. Tiwari & Chaube (2015) discussed the challenges of IWRM implementation in India on a river basin scale, especially in the context of water laws and water conflict resolution processes. The Central Water Commission prepared draft guidelines for Integrated Water Resources Development and Management (GoI, 2010). The National Water Policy (2012) of India, in its institutional arrangement, emphasized that 'Integrated Water Resources Management (IWRM) taking river basin/sub-basin as a unit should be the main principle for planning, development, and management of water resources'. One of the goals of the National Water Mission (NWM) of the Government of India is to promote basin level integrated water resources management.

Shah & Prakash (2010) presented a thorough discourse of IWRM in India. They proposed the idea of exploring comprehensive and multi-layered watershed development on a sub-basin scale blending the formal and informal mechanisms of governance for promoting the livelihood of the people. They argued in support of IWRM and suggested working towards a more integrated and holistic understanding on natural resources, including water, and going beyond the departmental boundaries. This paper tries to showcase the application of a 'local' IWRM approach in the district level planning with a view to propagate the concept of IWRM by internalizing with the prevailing government planning process in India.

A practical approach to IWRM: align with government functioning

Sustainable rural development requires effective utilization of land, water and other available natural resources, linked to the vulnerabilities and livelihood opportunities in the geographical area. We have to understand that water is a profoundly local and diverse resource. IWRM planning should first be able to address the issue of water availability and access at the desired spatial and temporal scales, for various designated uses. Another important issue is that of maintaining a sustainable land use system and cropping practice as we have noticed, especially in the developing countries, that once water availability improves in an area, farmers start growing water intensive crops. Thus, planned water allocation under IWRM planning is disrupted. This necessitates the use of economic planning as an integral part of water management such that the farmers are consciously informed about the consequences of unplanned water uses together with the scenarios of enhanced livelihood and income opportunities with judiciously planned water uses. IWRM thus implies a move away from traditional sub-sector foci that address domestic water supply, wastewater, irrigation, industry and the environment separately (often within different agencies or government departments) to a more holistic approach. There still remains the sense and need for such inter-sectoral coordination and a solution. A cycle of pursuance and feedback with the local stakeholders may be required before they realize and achieve the actual benefits of IWRM planning.

Harsha (2012) examined the ground realities that hinder the successful implementation of the IWRM concept at basin level as envisioned in the Indian water policies. Several districts within river basins in various parts of India are affected by various kinds of extremism and, hence, due to functional inadequacies, such areas have to be left while implementing IWRM at the basin scale. Too many policies within a single river basin complicate matters because of overlap and contradictions. As such, the other viable option of implementing IWRM is at the watershed scale (better if falling within a district). Although it is often argued that using hydrological units (e.g. a watershed) for implementation of the IWRM Plan may not be feasible as it does not necessarily coincide with the administrative unit (e.g. Tehsils/Blocks), GIS technology can take care of this requirement very well.

We have to realize that the decision makers and planners need a practical approach to transposing the IWRM concept into an operational tool for their water resources management plans (Grigg, 2008). Light IWRM supported by the inputs from a suitable DSS is likely to suit the requirements and expectations of planners and decision makers (such as the District Magistrate in the Indian context) as well as the users at the district level. At the district level, IWRM addresses almost the complete supply chain of water management (from rainfall inputs to water consumption by different users to wastewater generation and subsequent handling) and, most importantly, builds on the existing institutions. In the Indian context, the inherent cross-sectoral integration requirements of IWRM planning can be best achieved at the district level where the District Magistrate is the single controlling authority for various organizations (e.g. line departments) dealing with the different resources. Also, in the authors' view, the essence of 'equitable distribution' and 'sustenance of ecosystems' as envisaged in the IWRM can be best achieved at the watershed scale (to be operationalized at the Block level in a District).

The Government of India has introduced a scheme on 'Pradhan Mantri Krishi Sinchai Yojna (PMKSY)' in 2015 with the vision of extending the coverage of irrigation, accelerating watershed development activities, and improving water use efficiency. The PMKSY was formulated amalgamating some ongoing schemes of the government under the Ministries/Departments of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD & GR); Land Resources (DoLR) and Agriculture and Cooperation (DAC). Each district is required to prepare a 'District Irrigation Plan (DIP)' under PMKSY, which provides a comprehensive plan for water resources development in the district. The plan includes a district water profile, water availability, water requirement/demand, and provides a strategic action plan at the Block/Sub-district level for improving groundwater levels through recharge measures, enhancing irrigation coverage, soil and water conservation through structural and non-structural watershed measures, improving agriculture production and other livelihood activities.

The IWRM Plan at the local level can be successful if it is prepared in sync with the DIP and other development plans, and gives a clear picture of the required actions in a 'what, where and by whom' format. The plan should typically offer opportunities not just to build upon the existing infrastructure, but even more importantly, upon existing institutions that already have the experience, knowledge, and systems needed to manage water effectively at the local level.

Case study in Bundelkhand region of India

The present case study was conducted in a watershed of Madhya Pradesh in the central part of India. The geographical area covered under the Ur river watershed of Tikamgarh district is approximately 991 km^2. In Tikamgarh district, parts of four Blocks (local administrative unit) covering 190 villages fall in the Ur river watershed. Although district level planning is done in administrative units (i.e. Blocks), the IWRM plan offered the results and recommendations at spatial locations falling in different Blocks, which is easy to assimilate by the planners. Since the watershed majorly contains a rural population, the planning is made in a similar way of prioritizing agricultural water demands, and regulating migration to support livelihood.

Bundelkhand region lies in the central part of India covering an area of 70,000 km^2, with 13 contiguous districts, viz. Jhansi, Lalitpur, Jalaun, Hamirpur, Banda, Mahoba and Chitrakoot in Uttar Pradesh (seven districts); and Sagar, Chattarpur, Tikamgarh, Panna, Damoh and Datia in Madhya Pradesh (six districts). The region is home for more than 15 million people and 8 million livestock (Palsaniya *et al.*, 2011). The area has a semi-arid climate and receives an average annual rainfall of about 900 mm, 90% of which is received during monsoon season (June–September). The region experiences once in a five-year drought conditions; however, the ratio has been increasing for last few years (Gupta *et al.*, 2014). The other conditions making this region backward are erratic rainfall pattern, water scarcity, poor soil health, low crop productivity, low groundwater recharge potential due to hydro-geological situation and, finally, lack of sound water management planning.

Bundelkhand is a hard rock area with limited water resource availability. The surface reservoirs are mostly seasonal and groundwater availability is limited owing to the hydro-geological conditions. Agriculture and livestock farming forms the major occupation basis with a seasonal migration of workers. The watershed under study has been experiencing dry conditions for the past few years because of low rainfall and inefficient water usage systems. This altogether pressurizes the existing water resources, exceeding water demands, and thus resulting in a raised proportion of unmet demands.

The Ur river watershed, Tikamgarh district, Madhya Pradesh stretches between 78°50′E to 79°10′E longitudes, and 24°35′N to 25°5′N latitudes, having a total area of 990.37 km^2. The watershed covers parts of four blocks of Tikamgarh district, viz. Baldeogarh, Jatara, Palera and Tikamgarh (Figure 2).

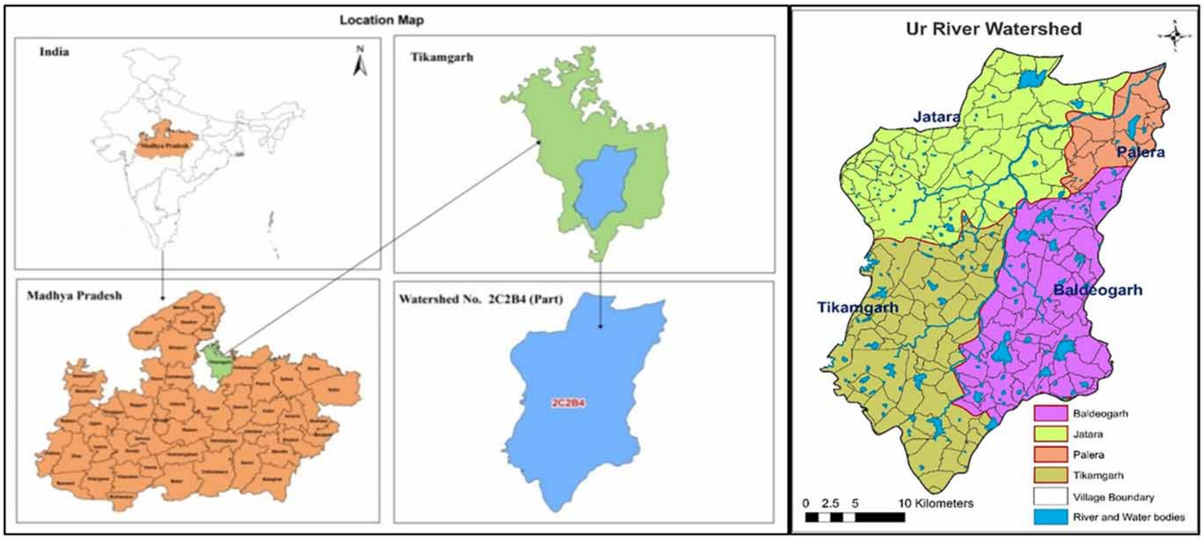

Fig. 2. Location map of study watershed.

It has been observed that most of the study area is agricultural (580.62 km^2), which is about 59% of the total watershed area. The livelihood of people is mainly dependent on agriculture. The agricultural area is spread all around the watershed, possibly because of the large number of tanks that provide irrigation and domestic demands. The tanks are also well distributed in the watershed and the Madan Sagar tank, which is a very large tank with a canal system, is located towards the north-west corner of the watershed. The major kharif crops include rice, soybean, sesame and blackgram whereas rabi crops include wheat, gram and mustard. The scrub land is the second most dominant land use in the study area covering an area of 131.18 km^2. The area covered by the settlement is 19.98 km^2, whereas dense forest occupies an area of 44.56 km^2. The river and water bodies cover an area of 34.47 km^2, fallow land covers 69.25 km^2 and barren land covers 110.54 km^2 of the watershed.

Water balance analysis of the study watershed

The comprehensive water budgeting study performed in Ur watershed gives an in-depth understanding of the dominant components of the hydrological cycle. The estimation of the various water budget components was carried out by collecting relevant data based on field investigations through established techniques. Water demands for domestic use have been computed based on the per capita demand of fresh water and the population based on the Census of 2011. Similarly, the livestock water demands have also been computed based on the per capita demand for livestock and their Census of 2007. The spatial information pertaining to the topography, land use and soil type was extracted using ArcGIS 9.3 software, which was subsequently used to quantify the important water balance components in each of these watersheds. CROPWAT 8.0, which is the standard Food and Agricultural Organisation (FAO) software for computing crop water requirements, was used for the estimation of crop water requirements of the major crops grown during the monsoon and non-monsoon season on a 10-day basis. The surface runoff was estimated using the Soil Conservation Service Curve Number (SCS-CN) method.

Water budget of Ur river watershed. The water budget of the Ur river watershed was carried out on a seasonal time scale for two seasons, namely monsoon season (June–October) and non-monsoon season (November–May). The water budget during the monsoon season yields an estimate of the major components and helps to identify those components, which may be utilized more effectively to conserve the precious water resources within the watershed. It was observed that during the period of analysis there were many below normal rainfall years. This indicates that during the 10 years (2006–2007 to 2015–2016) of analysis only three years, namely 2008–2009, 2011–2012 and 2013–2014, had rainfall above the normal value. This shows that the watershed has now become prone to receiving less rainfall compared to previous years, due to many reasons including changing climate, change in topography, and large-scale unsustainable exploitation of natural resources among others.

It was observed that sufficient runoff is generated from the basin during above normal rainfall years. The surface runoff of 313.02, 296.61 and 217.36 MCM is generated for the wet years having rainfall of 1195.75, 1173.58 and 1191.56 MCM during 2008–2009, 2011–2012 and 2013–2014 respectively. The comparison of the seasonal rainfall and seasonal runoff at the outlet of the basin is given in Figure 3. The water budget during the monsoon season yields an estimate of the major components and also helps to identify those components which can be utilized more effectively to conserve the precious water resources within the watershed. The water budget computations for the year 2011–2012 are given in Table 1. The water balance for the Ur river watershed has been established after estimation of the water balance components that play a major role in the hydrology of the watershed. The values of all these components have been substituted in the water balance equation (inflow – outflow = change in storage). The unaccounted water gives an idea of the accuracy with which the water balance components have been evaluated. It also contains the components which could not be evaluated due to lack of data. The percentage error in the water balance computations is indicated by the ratio of the unaccounted water to the seasonal rainfall during the monsoon season. The error in computation includes the errors in computations of individual inflow and outflow components of the water balance equation and also includes some of the components which have not been estimated due to lack of data, viz., change in surface water storage, base flow component in the surface runoff computations.

In this study, the hydrological assessment was made on the watershed basis. However, since the line departments of district government operate at the Block level, the results were presented at the Block level.

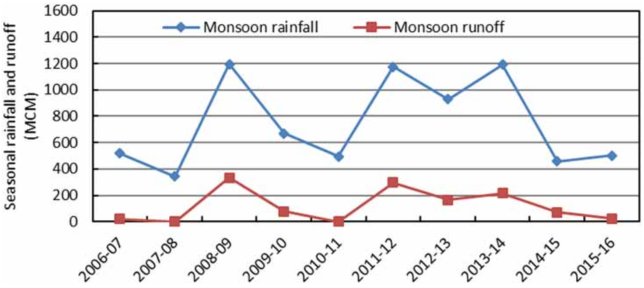

Fig. 3. Comparison of seasonal rainfall and runoff in Ur river watershed.

Table 1. Water budget of Ur river watershed (2011–2012).

Water balance components	Monsoon (MCM)	Non-monsoon (MCM)
Inflows (in MCM)		
Rainfall	1173.58	7.23
Groundwater inflow	10.57	13.75
Outflows (in MCM)		
Domestic demands	7.100	9.838
Livestock demands	1.992	2.761
Agriculture demands	16.54	200.21
Surface runoff	296.61	0.00
Forested areas	126.58	149.64
Evaporation from tanks	1.99	2.05
Groundwater outflow	10.99	15.36
Change in storage (in MCM)		
Change in storage (GW)	438.69	–414.08
Change in storage (SW)	67.79	–66.21
Unaccounted water	215.86	121.41
Percentage error	18.39	10.28

Integrated water resources management (IWRM) plan

The foremost step to water management is judicious allocation of the available water. Water demands can be managed by reducing wastage and optimizing current consumption rates to the level of water availability. Availability of water from different sources, estimated and compared with the water demand for different uses, and various options of water demand management were considered. The availability and accessibility of resources define the livelihood status of an area, water being the most important among all. Improved water availability has a direct impact on increase in crop production, which also increases other income opportunities. The IWRM plan proposes construction of water harvesting structures at suitable sites and utilizes the potential of demand management approaches such as changes in land use, cropping pattern, crop diversification, efficient cropping practices, etc.

Development of the IWRM plan began with holding an interaction workshop with local stakeholders of the study watershed. The development issues and water-related problems in the study watershed were mapped and possible solutions discussed with the local stakeholders. A vulnerability assessment exercise was conducted to identify the vulnerable areas in the watersheds. The Intergovernmental Panel for Climate Change (IPCC) approach (McCarthy *et al.*, 2001) was used to reflect the vulnerability through IPCC identified components: exposure, sensitivity and adaptive capacity. The vulnerability of people, livelihood and ecosystem was assessed, using primary and secondary data, to identify highly vulnerable Blocks within a watershed. The sustainability of the area was assessed from the Livelihood Vulnerability Index (LVI), an index used to assess risk and level of vulnerability of an area under impacts of natural disasters and other changes.

The IWRM Plan framework prepared for the watershed areas comprises of three components: (1) Water management, (2) Land management, and (3) Livelihood management. The water management component deals with the recommendations for domestic water demand, water harvesting for irrigation requirements and for groundwater recharge. The land management component deals with the recommendations for improved agricultural practices and efficient irrigation techniques. The Plan considers effective utilization of land, water and other available natural resources, linked to the vulnerabilities and livelihood opportunities in the geographical area. The Plan is designed in such a way that it provides useful inputs to the DIP of Tikamgarh district, both in terms of water supply and demand management synergized with the land management and livelihood improvement. Identification of the needs and priorities of various water users, as well as the threats in terms of land degradation, droughts, and contamination of water sources, were deliberated with the stakeholders during consultations at various stages.

Water management

Water quantity. The location of suggested water harvesting structures is shown on the map. Suitability of existing ponds for fishery purposes is also shown on the map (Figure 4). Identification of suitable sites for water harvesting structures is done on the basis of drainage, topography, and soil type. The locations of the identified sites are made available to the local user organizations in the form of geographical coordinates through a DSS developed for this purpose. With the help of GIS and DSS, the analysis is carried out on natural units (sub-watersheds) and the desired information can be made

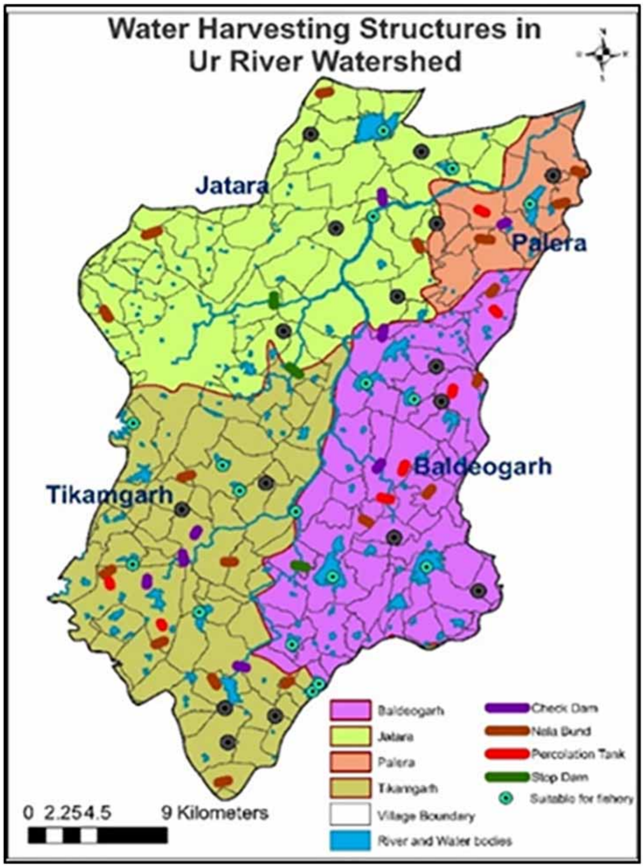

Fig. 4. Suggested water harvesting/recharging structures.

available to the users on administrative units, e.g. District, Block, Gram Panchayat (GP) or a Village (Table 2).

Water quality. The surface water quality assessment was carried out in November 2015 to monitor the in-situ water quality of various ponds in the study area. The surface water quality index (SWQI) was calculated by the 'National Sanitation Foundation (NSF)' method using drinking water quality standards recommended by Bureau of Indian Standards IS 10500 (2012). The water quality of different ponds was also assessed for fishery, irrigation and drinking and is shown in Table 3.

The groundwater quality of the Ur river watershed had been assessed to analyse the suitability of ground water for drinking purposes and other domestic applications. The samples were chemically tested for eight parameters which were further used to calculate the Ground Water Quality Index (GWQI). Results obtained from the study are compared with the drinking water quality standards by the Bureau of Indian Standards IS 10500 (2012). The results obtained from the analysis of water sampled from some of the locations within the watershed area are represented in Table 4. It should be noted that the quality of water of the given samples is poor, thus they require some amount of water treatment in order to be fit for drinking purposes. These water sources also need to be secured from further contamination to avoid adverse health effects in human beings.

Under this project, roof top rain water harvesting structures were installed in school premises in the villages of Chortanga, Bilgaibhata and Madanpur in Tikamgarh district. The arrangement was made in such a way that harvested water can directly be injected in the existing hand pumps located in school premises by passing it through suitable filter media. After successful installation, demonstrations were also given to school teachers and students regarding its working, care, precautions and maintenance (Figure 5).

Land management

The main emphasis of land management is to maintain a judicious combination of crops, water, human and financial resources, to ensure long term sustainability. The suggestions include activities to create agri-based livelihood opportunities, increase productivity, maintain soil health, etc. (Table 5). Suggestions pertaining to the major crops that are grown in the area included system of crop intensification, drip irrigation for high value vegetables and fruit crops, Wadi model for fruit and vegetable crops, crop rotations, line sowing, and crop diversification, considering the local soil conditions, nutrition value of crops, crop diversification potential, etc.

Livelihood management

As a part of livelihood linked natural resource management, the aim is to increase both availability and options of livelihood while conserving the natural resources in terms of quantity as well as quality. Through this approach, emphasis is given on utilizing the locally available resources to create livelihood opportunities that ensure food security and nutrition, curb poverty, provide sustainable agricultural practices and help in combating climate variability and related impacts, etc.

Using the IPCC approach of livelihood vulnerability analysis, the vulnerability value of each Block falling in the watershed area was calculated. Among the four Blocks, Tikamgarh was found to be the

Table 2. Suggested sites for water harvesting structures.

S. no.	Block name	Activity	Component	Total no.	Village	Location	
						Latitude	Longitude
1.	Tikamgarh	Nala Bund	PMKSY watershed/Har Khet Ko Pani	7	Banjarya	24°40′25.35″N	78°58′40.44″E
					Bakpura	24°40′28.60″N	78°55′49.69″E
					Ajnaur Khas	24°36′45.39″N	78°56′12.03″E
					Shri Nagar Khas	24°48′02.49″N	78°54′48.47″E
					Lakhora	24°44′51.67″N	78°56′27.28″E
					Madhuwan	24°44′29.84″N	78°51′46.49″E
					Madhuwan	24°41′53.50″N	78°53′44.40″E
		Check dam		4	Sundarpur	24°40′59.83″N	78°56′56.86″E
					Dhajrai	24°45′56.98″N	78°55′08.69″E
					Dhajrai	24°45′02.80″N	78°54′39.16″E
					Madhuwan	24°44′06.18″N	78°53′14.58″E
		Percolation tank		2	Madhuwan	24°44′03.29″N	78°51′49.14″E
					Madhuwan	24°42′35.58″N	78°53′48.04″E
		Storage tank		5	Jamuniya Khera	24°39′12.12″N	78°58′10.64″E
					Gudanwara	24°39′29.59″N	78°56′14.54″E
					Samarra	24°38′13.66″N	78°56′21.15″E
					Shri Nagar Khas	24°46′49.70″N	78°54′36.36″E
					Papawani	24°47′47.38″N	78°57′51.66″E
		Stop dam		1	Kamal Nagar	24°51′56.36″N	78°58′58.03″E
		Farm pond		1	Kamal Nagar	24°50′47.00″N	78°57′23.00″E
2.	Baldeogarh	Nala Bund	PMKSY watershed/ Har Khet Ko Pani	4	Jinagarh Khas	24°47′26.07″N	79°04′10.40″E
					Baisa Ugad	24°46′20.14″N	79°01′44.45″E
					Magrai	24°54′49.86″N	79°06′40.13″E
					Banpura Sapaun	24°51′33.27″N	79°06′03.62″E
		Check dam		2	Raj Nagar	24°48′26.53″N	79°02′16.37″E
					Majguwan	24°53′17.95″N	79°02′24.54″E
		Percolation tank		4	Sujanpura	24°48′17.47″N	79°03′10.76″E
					Raj Nagar	24°47′11.61″N	79°02′29.06″E
					Sijaura	24°51′09.40″N	79°05′05.18″E
					Gora	24°54′04.54″N	79°06′47.42″E
		Storage tank		4	Durga Nagar	24°45′45.94″N	79°02′48.31″E
					Lakheri	24°43′46.85″N	79°06′03.10″E
					Madori	24°52′04.24″N	79°04′27.86″E
					Sijaura	24°50′46.76″N	79°04′39.54″E
		Stop dam		1	Shyag	24°44′41.75″N	78°59′14.13″E
3.	Jatara	Nala Bund	PMKSY watershed/ Har Khet Ko Pani	4	Dhamna Khas	24°57′00.58″N	78°53′27.56″E
					Barmadang Khas	24°54′02.78″N	78°51′42.53″E
					Garrauli	25°02′10.72″N	79°00′12.05″E
					Baldeopura	24°56′33.65″N	79°03′46.60″E
		Check dam		1	Kitakhera	24°58′18.85″N	79°02′24.99″E
		Storage tank		6	Chaturkari	24°53′24.10″N	78°58′33.74″E
					Karmaura	24°54′39.74″N	79°02′58.52″E
					Muhara Khas	25°00′40.00″N	78°59′39.06″E
					Simariya	24°57′20.50″N	79°04′30.45″E
					Manchi	24°57′11.31″N	79°00′36.61″E
					Jatara (NP)	24°59′59.88″N	79° 3′55.99″E
		Stop dam		1	Chandrapura	24°54′31.54″N	78°58′12.16″E
		Farm pond		1	Dharampura	24°52′09.00″N	78°52′27.00″E

(*Continued.*)

Table 2. (*Continued.*)

S. no.	Block name	Activity	Component	Total no.	Village	Location Latitude	 Longitude
4.	Palera	Nala Bund	PMKSY watershed/ Har Khet Ko Pani	3	Mahendra Maheva	24°59′12.34″N	79°10′01.58″E
					Toury	24°58′03.18″N	79°09′22.20″E
					Magrai	24°56′43.51″N	79°06′22.71″E
		Check dam		1	Deoraha	24°57′19.61″N	79°07′06.76″E
		Percolation tank		1	Deoraha	24°57′45.62″N	79°06′16.56″E
		Storage tank		1	Deoraha	24°59′05.66″N	79°09′01.36″E

Table 3. Surface water quality assessment of ponds.

S. no.	Pond	District	Suitability of pond for: Fishing	 Irrigation	 Drinking	NSF WQI	Identified problems
1	Madan Sagar	Baldeogarh	✓	✓	x	77	Slightly high pH, high turbidity and presence of BGA observed
2	Gwal Sagar	Baldeogarh	✓	✓	x	79	
3	Detla Talab	Baldeogarh	x	✓	x	56	
4	Sarkanpur Talab	Baldeogarh	✓	✓	x	68	
5	Bhitarwar Talab	Baldeogarh	✓	✓	x	76	
6	Mamaun Talab	Tikamgarh	✓	✓	x	76	
7	Rigora Talab	Tikamgarh	✓	✓	x	78	
8	Laxmanpura Talab	Tikamgarh	✓	✓	x	76	
9	Deep Sagar	Tikamgarh	✓	✓	x	79	
10	Raiya Tal	Tikamgarh	✓	✓	x	73	
11	Prem Sagar	Tikamgarh	✓	✓	x	71	
12	Madan Sagar	Jatara	✓	✓	x	76	
13	Baharu Tal	Jatara	✓	✓	x	73	
14	Chaturkari	Jatara	✓	✓	x	80	
15	Ghura Tal	Palera	✓	✓	x	78	
Surface Water Quality Index Rating as per NSF Method							
90–100: Excellent	70–90: Good	50–70: Medium		25–50: Bad		0–25: Very bad	

most vulnerable and Baldeogarh the least vulnerable (Tikamgarh > Palera > Jatara > Baldeogarh). Suggestions for reducing the vulnerability values are given as follows:

1. Raising awareness on climate change – causes, impacts and mitigation of extreme events.
2. Building health and education infrastructures.
3. Promoting off farm and non-farm occupations (e.g. livestock and poultry rearing, pisciculture, bee-keeping, handicrafts).
4. Increasing community networks and social interaction amongst the villagers.
5. Facilitating micro-financing support.

Table 4. Groundwater quality assessment and identified problems of some of samples.

Sample no.	Latitude	Longitude	Sources	Village	Tehsil	WQI	Problems
S12	24.66037	78.99956	Hand pump	Lar	Tikamgarh	126	High Turbidity
S22	24.74444	78.92638	Hand pump	Lakhora	Tikamgarh	124	High Turbidity, Hardness, TDS
S26	24.78897	78.953	Hand pump	Kater Khera	Tikamgarh	102	High values of hardness
S27	24.93458	79.11883	Well	Pali	Palera	135	High Turbidity, Nitrate and Hardness
S28	24.94372	79.13369	Hand pump	Ghoora	Palera	130	High values of TDS and Nitrate
S29	25.00194	79.15256	Hand pump	Mahendra Maheva	Palera	131	High values of Hardness, Nitrate, Chloride and TDS
S33	24.91544	79.05394	Hand pump	Karmaura	Jatara	132	High values of Hardness, Nitrate, Chloride and TDS
S39	25.01963	79.01613	Hand pump	Bajetpur	Jatara	112	High values of Hardness, Nitrate, Chloride and TDS
S40	24.96084	78.97352	Hand pump	Bikrampura	Jatara	121	High values of Turbidity and Nitrate

Fig. 5. (a) Samara (Madanpur); (b) Chortanga rainwater harvesting system (RHS); (c) Bilgaibhata RHS; (d) and (e) educating the upcoming generation.

Table 5. Suggestions for crop management.

Component	Water efficient irrigation technologies		Crop rotation[a]	
Agriculture Technology and Management Agency (ATMA)	SRI (System of Rice Intensification)	Rice	✓ Rice → Cowpea → Blackgram → Chili/Garden pea → Rice	
	SWI (System of Wheat Intensification)	Wheat	✓ Soybean → Wheat → Blackgram →Mustard → Soybean ✓ Groundnut → Cowpea → Rice → Wheat → Groundnut	
	SCI (System of Crop Intensification)	Maize, Soyabean, Mustard, Blackgram	Component: Integrated Nutrient Management (INM)	
Per drop more crop (Micro Irrigation)	Drip Irrigation	Maize, Vegetable and Fruit crops		
AIBP	Irrigation at critical stages	Wheat (including crown root initiation and flowering stage), Soybean	Crop Diversification[b] Kharif	Rabi
National Horticulture Mission	Wadi (Agri-Horti based model)	Fruit (Guava, Pomegranate, Berry) and Root vegetable crops	Maize + Blackgram + Groundnut Maize + Okra + Pigeon Pea	Gram + Wheat + Chili/Garden Pea Mustard + Cowpea + Gram
National food Security Mission (NFSM)	Line Sowing for all types of crops like Soybean, Blackgram, Groundnut, Rice, Wheat, Mustard, Maize, etc.			

[a] Crop rotation is suggested as alternate sequences of cereals and legume crops. Leguminous crops fix nitrogen in the soil due to the symbiotic relationship between nitrogen fixing bacteria and root nodes, and thereby maintaining fertility of the soil and reducing the application of fertilizers in subsequent crops.

[b] Crop diversification is suggested, keeping in mind the crop land/water requirements, to reduce crop failures due to climatic/biological conditions.

The conventional livelihood practice in Ur watershed is agriculture, which as a result of climate variability and other consequences leading to crop failure has resulted in diminishing employment and financial gain. The focus shifts on non-agricultural employment generating opportunities which will prevent people from migrating, which is one of the largest social challenges these watersheds are currently facing. Off-farm activities such as poultry, fishing, and handicrafts are being promoted to engage people in a variety of livelihood activities (Figure 6). The livelihood activities related to handicraft, bee keeping, etc., were carried out in the Ur river watershed.

Conclusions

The paper presents the concepts of 'local' IWRM planning applied to water conservation and management in the Ur river watershed in Tikamgarh district of Madhya Pradesh (India). IWRM planning is shown to be a practical tool in district level planning for the implementation of water management activities in a Public-Private-People-Partnership (PPPP) mode. The IWRM Plan, designed in three sections of (1) water management, (2) land management, and (3) livelihood management, provides

Fig. 6. Glimpse of livelihood activities conducted in watershed. (a) Workshops on off farm activities in Tikamgarh. (b) Workshop on jute items making. (c) Workshop on mushroom cultivation. (d) Workshop on organic farming and vermicomposting.

suggestions on the activities under these three themes. The IWRM Plan, developed through a participatory approach, is better positioned to provide useful inputs to the DIP as articulated by the stakeholders during consultations. Some of the suggestions, involving technology interventions, were pilot tested in the field in collaboration with the local villagers. This not only demonstrated the concept but also helped in gaining the confidence of the villagers (leading to their acceptability).

The essence of the IWRM approach has been retained by considering the interplay among various natural resources, and an implementable solution linking water management with livelihood was arrived at for use by the district level departments and organizations. Acceptability of the IWRM plan is potentially enhanced as the plan was developed through a participatory process, wherein all relevant stakeholders were consulted at different stages of development. Identification of the needs and priorities of various water users, as well as the threats that water poses in terms of land degradation, droughts, and contamination of water sources, were deliberated with the stakeholders during these consultations.

The Plan considers effective utilization of land, water and other available natural resources, linked to the vulnerabilities and livelihood opportunities in the geographical area. The Plan is designed in such a way that it provides useful inputs to the DIP of the Government, both in terms of water supply and demand management synergized with the land management and livelihood improvement. The IWRM Plan intends to promote the component of water demand management in district level planning. A unique feature of the IWRM plan presented in this study is that mostly secondary data as available at the district level was used in developing the plan. The framework used for developing the IWRM Plan can be further downscaled to the GP level, addressing the lowest unit of governance in India (Goyal, 2016).

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