Case Report

Securing Flows in the River Systems through Irrigation Water Use Efficiency - A Case Study from Karula River in the Ganga River System

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Abstract: The pressure on freshwater resources is leading to diminishing flows in some of the critical river systems across the globe and India is no exception and this is mainly because of water withdrawal for irrigation, which is often to the tune of 70% to 80% with some proportion for domestic and industrial use. While graduating from the concept of environmental flows and its assessment methodologies in India, the water-managers, the researchers and the conservationists are now moving towards answering the next question if the rivers are to be revived, then where will the water come from, especially in the case of over-allocated rivers, including the river Ganga. While the logical way is to look at the biggest user of water, i.e. irrigation, it remains to be seen whether the irrigation water savings will actually lead to enhancing flows in a river, complementing the efforts towards maintaining e-flows in rivers, or whether it will lead to more area under agriculture, bring changes in cropping patterns towards more water-intensive crops or result in something else. This is a growing debate across the globe, where India is no exception, and there has been a wide range of opinions in this regard. This paper discusses the process, findings and lessons from a joint initiative involving farmers, the Uttar Pradesh state Irrigation and Water Resources Department, Bijnor District Administration and a conservation organisation to enhance flows in a rivulet, called karula River, which is part of the Ganga river system.

Another objective of this paper is to look at the scalability and replicability of similar approaches in other irrigation command areas to benefit nearby river systems in general. Under this initiative, the team attempted to enhance flows in the river Karula by routing the saved water from irrigation supplies in a canal commanded area. This saving of water is being achieved due to 'supply-side' and 'demand-side' measures that are being adopted in the project area. With the objective of ensuring the sustainability of the initiative, efforts are made to form an institutional arrangement, through which this initiative can be sustained beyond the project support.

Keywords: Ganga; environmental flows; river conservation; Ramganga; Karula; irrigation water use efficiency; Water Users Association; minor canal

1. Introduction and context

Rivers, wetlands and aquifers are a critical source of water for nature, biodiversity and human beings. In fact, these sources have their own inter-dependent ecosystems. All of these ecosystems face multiple challenges, in the wake of:

a. feeding a growing population in a changing climate, while also conserving and restoring nature

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b. reconciling multiple competing human demands for water, further compounded by changing lifestyles, market-driven processes and unplanned developmental activities
c. ensuring sustainable water use, in line with Sustainable Development Goals 6 (SDGs) which calls for 'ensuring availability and sustainable management of water and sanitation for all'

Grill *et al.* (2015) concluded that, globally 48% of river volume is moderately to severely impacted by either flow regulation, fragmentation, or both. This situation calls for maintaining or restoring flow regimes, in the form of environmental flows, to ensure the maintenance of ecological integrity. The most referred definition of e-flows by Arthington *et. al.* (2018) is 'the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being'.

The inclusion of environmental flows in IWRM (Integrated Water Resources Management) will result in increased effectiveness of environmental outcomes along with many benefits to social well-being and economic return (Hirji and Davis 2009). Environmental flows can form the basis for an integrated approach to water allocation and river operation. Identifying environmental flows is likely to provide a strong scientific and open process within river management and for water allocation decisions at a basin scale (Overton *et. al.* 2014).

Currently 41% of global irrigation water use occurs at the expense of e-flows requirements and India contributes to about 17.7% of global annual e-flows deficit (both in terms of the total annual deficit and the number of months with transgressions) (Jagermeyer *et. al.* 2017). The river basins in South Asia (including the Ganga basin), in the Mediterranean region, and the Sahel are most sensitive to irrigation improvements resulting from the combination of local crop types, climate and soil conditions and the current irrigation system. India has 18% of world population, having 4% of world's freshwater, of which 80% is used in agriculture (Dhawan 2017).

Excessive use of surface-water and ground-water for irrigation has led to a diminishing water-table and the transformation of perennial rivers into seasonal ones. Stockle (2007) noted that withdrawing surface water implies changes to the natural hydrology of rivers and water streams, affecting the aquatic ecosystems associated with these water bodies.

In the Indian context, the concept of e-flows is in the process of being mainstreamed in river basin management. However, barring a few exceptions, efforts have been largely centred around the Ganga river, within which the focus has been on developing the technical foundations for e-flows assessment. Efforts are also being made to understand the tradeoffs, in cases where e-flows are to be maintained. However, the implementation of e-flows remains elusive and there is a particular need for practical case studies documenting how irrigation management can aid maintaining e-flows.

Recent History of E-Flows Assessment and Implementation in India

In the Indian context, a consortium of Indian Institutes of Technology, along with other partners developed Ganga River Basin Management Plan (GRBMP). This group defined E-Flows as, 'a regime of flow in a river or stream that describes the temporal and spatial variation in quantity and quality of water required for freshwater as well as estuarine systems to perform their natural ecological functions (including sediment transport) and support the spiritual, cultural and livelihood activities that depend on these ecosystems'.

WWF-India (World Wide Fund for Nature – India) has also been working towards E-Flows assessment and implementation, testing an assessment methodology with a multidisciplinary team of experts from other institutions and demonstrating field level interventions with local stakeholders. There are several initiatives from the government, civil society and academia who are working towards securing Environmental Flows in the river systems in India (updated from Gopal, 2013):

- Minimum Flows – stipulations by Central Water Commission, Govt. of India 1992
- Deliberations and recommendations around E-Flows in Indian rivers by National Institute of Technology and International Water Management institute in 2001
- E-Flows assessment (Water Quality Assessment Authority) – Govt. of India 2003-07
- Macro-level broad E-Flows assessment for Indian rivers by International Water Management Institute 2007
- Upper Ganga E-Flows assessment by a multidisciplinary team & WWF-India 2008-10
- Aquatic species-centric E-Flows assessment for Upper Ganga by Wildlife Institute of India 2010-2011
- Hydrology-based E-Flows assessment for Upper Ganga by Alternate Hydro Energy Centre 2010-2011
- E-Flows assessment by consortia of IITs for Himalayan stretch of river Ganga 2011. The initiative was part of development of GRBMP
- National Water Policy 2012, which called for maintaining E-Flows in river systems
- E-Flows for river Ganga by a multidisciplinary team, led by WWF-India for Triveni Sangam, Prayagraj location, Kumbh 2013 (Tare Vinod *et. al.* 2013)
- E-Flows initiative for Ramganga 2013 (Kaushal Nitin, Babu Suresh, Mishra Arjit, O'Keeffe Jay 2018) and continuing, led by WWF-India
- The Ministry of Environment, Forests & Climate Change (Government of India) in the standard Terms of Reference for conducting the Environmental Impact Assessment studies for any proposed River Valley and Hydro Project stipulated seasonal percentage of E-Flows that are required to be maintained
- Ganga Notification 2016 by Government of India to call for maintaining E-Flows in Ganga (National Mission Clean Ganga Gazette Notification, Government of India)
- Ganga E-Flows Order 2018 and Amendment 2019 by Govt. of India, stipulating E-Flows values for Ganga river (E- Flows Gazette Order 2018 & Amendment 2019)
- A joint initiative to assess E-Flows in all major rivers of Uttar Pradesh is underway (2019-22) by Uttar Pradesh Water Management & Regulatory Commission, Uttar Pradesh State Water Resources Agency and World Wide Fund for Nature – India. Under this initiative, the E-Flows assessment is done for Sharda, Ghaghra (Saryu), Gomti, Rapti, Yamuna, Son, Gandak rivers and plus some additional sites on Ganga River (where E-Flows assessment was not done earlier). The purpose of this exercise is to inform the exercise on River Basin Management Plans for these respective rivers.

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Tickner *et. al.* (2020) pointed out that case studies of environmental flows implementation, successful or otherwise, provide valuable insights into barriers and enabling factors, and illustrate the evolution and propagation of the practice of environmental flows globally. Kaushal *et. al.* (2019) documented approaches to understand and resolve potential trade-offs between environmental flows objectives for the Ganga river in Uttar Pradesh and agricultural water demand. They concluded that, contrary to common perceptions, the increase in water needed to restore flows is likely to be small, compared to overall water demand. Moreover, agricultural water use efficiency measures can ameliorate the potential adverse impact on farmers from changes in water allocation.

The National Commission for Integrated Water Resources Development, Government of India had estimated total withdrawal/utilisation for 2010 for all types of uses as 710 BCM in a high projection scenario. Of this, irrigation accounted for nearly 78%, followed by domestic use of 6%, industries at 5%, power development at 3%, and other activities claimed about 8% including evaporation losses, and environment and navigational requirements (CWC 2020). With this background, it becomes imperative to engage with the irrigation and agriculture sector around water use efficiency, if freshwater resources (rivers, lakes and wetlands) are to be conserved.

This paper reports on the process and lessons from an initiative to enhance flows in the Karula river, through the implementation of supply-side and demand-side measures in the Khanpur Minor canal command area in Bijnor district of Uttar Pradesh in India. The basic premise of this work is an ask – can we help secure e-flows in the river, through interventions in the irrigation sector, while maintaining sustainable and enhanced water and land productivity levels, with improved overall agricultural production?

Whilst the Karula river initiative is a case in point to discuss how flows can be enhanced through promotion of Better Management Practices (BMPs) in agriculture and irrigation it is also an example of how flows in overallocated rivers can be secured by piloting, upscaling and mainstreaming similar approaches in the command area of irrigation systems that offtake from rivers,diverting river waters for irrigation purposes. A carefully crafted approach encompassing demand-side management, while ensuring efficient irrigation system and institutional support, can actually pave the way for managing trade-offs in a scenario where water re-allocation becomes inevitable in the wake of required e-flows releases from the dams and barrages.

Project area

Under the Karula river pilot project, the aspiration has been to enhance the diminishing flows in the Karula river, a tributary of the Ramganga River, from the saved water from the irrigated command area of a minor canal, called Khanpur Minor. The catchment area of Karula river is 957 sq. km., which is little over 4% of the catchment area of Ramganga basin (25,028 sq. km.). This canal system is operated and maintained by Uttar Pradesh Irrigation & Water Resources Department (UPI&WRD) (Figure 1).

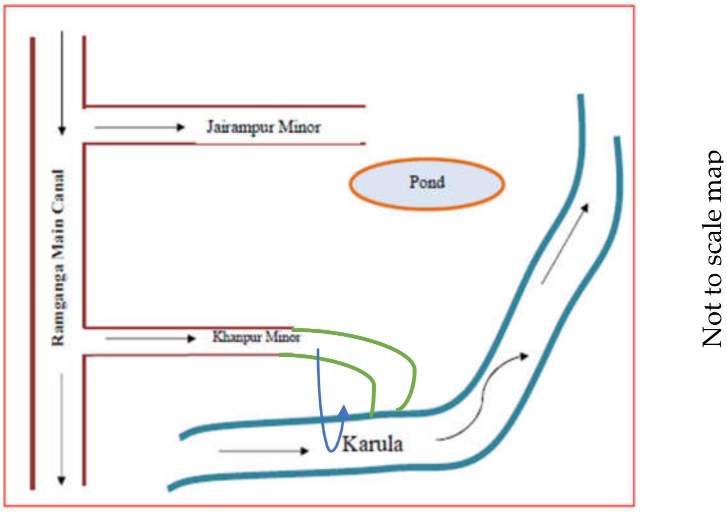

Figure 1. line diagram to explain the Karula Pilot concept.

Ramganga water resources are stored in a reservoir called Kalagarh dam, which is the second biggest dam-based reservoir (after Tehri dam) in the state of Uttarakhand, storing over 2448 Million Cubic Metres of water (National Register of Large Dams 2019, Central Water Commission). The Kalagarh Multi-purpose Project was designed for irrigation, flood protection and production of electricity with an installed capacity of 198 MW (Uttarakhand Irrigation Department). The major proportion of water in Kalagarh dam is allocated to augment the lower Ganga Canal System (85%) while the rest is allocated to small independent canal systems known as the Ramganga sub feeder (10%) and Pheeka canal system (5%) – as per the information from authorities.

As a result of the diversion of Ramganga waters for irrigation canals, the flows in the Ramganga downstream barrage (Hareoli Barrage) are miniscule for the middle stretch of the Ramganga river. The lower stretch of the Ramganga, however, just before joining the Ganga, is relatively better due to contributions from the tributaries in the middle to lower stretches of the Ramganga River.

The Ramganga sub feeder canal system takes off from Kho Barrage built on the Kho river in Bijnor district (see Figure-1). This Ramganga sub feeder main canal has a series of minor canal systems extending irrigation supplies to the farms in three districts of Uttar Pradesh; one such minor canal is called the Khanpur Minor Canal, having a designed discharge of over 3.5 cubic feet/second). The irrigation command area of this canal system largely falls in four villages (Khanpur, Meerapur, Rehtoli, Kolasagar) of Seohara Block in Bijnor district of Uttar Pradesh. Figure – 2 illustrates the location of the pilot area on the map of the country.

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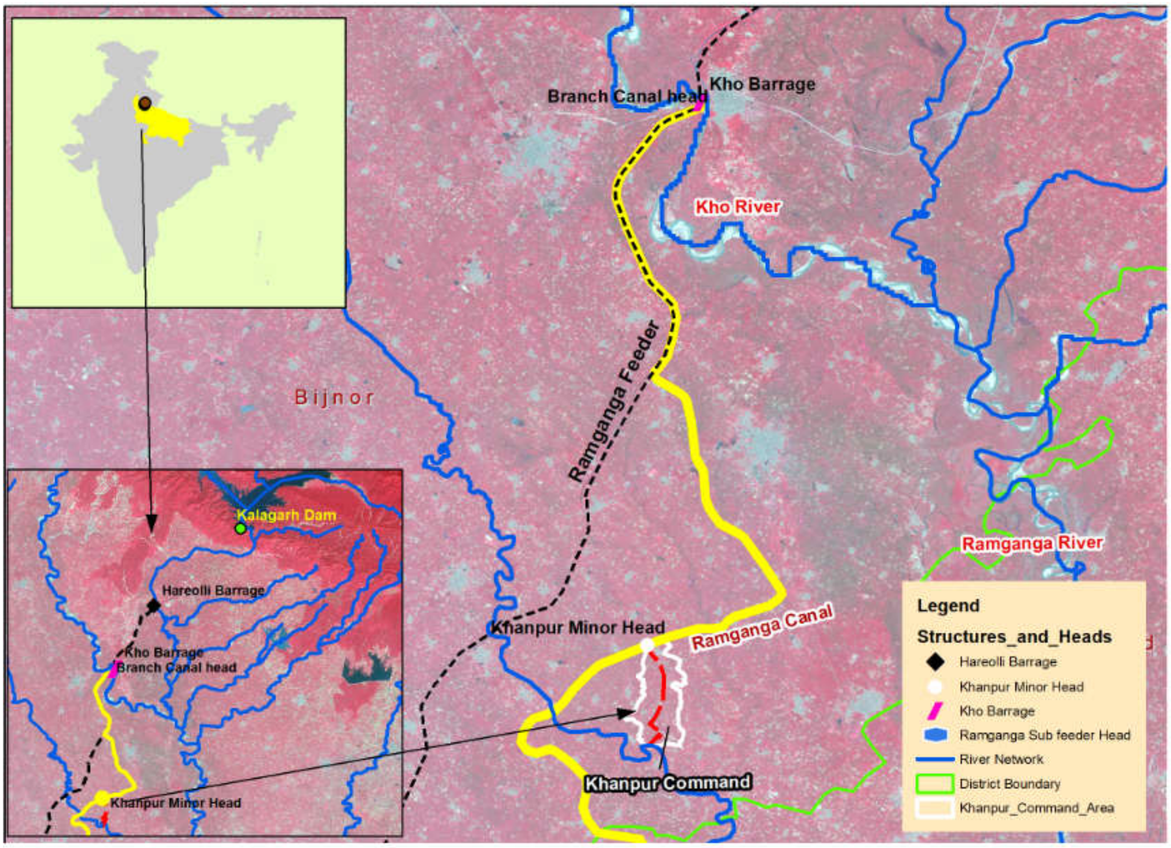

Figure 2. Location map of the Karula pilot area.

The farmers in the catchment of the Karula river predominantly grow sugarcane, not only because of rich water resources and the presence of sugar-mills in the nearby areas (Seohara and Dhampur), but also due to the high economic value of sugarcane, as a cash crop, and the prevailing Minimum Support Price, which attracts farmers for assured incomes. According to a broad estimate, about 67% of the Khanpur Minor command area, i.e., about 260 ha, grows sugarcane and on the rest of the command, the usual wheat-paddy is grown. (Landuse Map, WWF-India – available as Appendix 2)

The key statistics of the Khanpur Minor Canal are tabulated in Table – 1:

Table 1. Main Features of Khanpur Minor Canal System, including CCA (Culturable Command Area, the area which can be physically irrigated from a scheme and is fit for cultivation) and PPA (Proposed Protected Area, the area that is assured for irrigation by a scheme).

S. No.	Item	
1	Length of Khanpur Minor Canal	About 3 kilometres
2	CCA (Culturable Command Area)	389 Hectare
	PPA (Proposed Protected Area)	
	a. Rabi (Cropping season from July to October)	148 ha
	b. Kharif (cropping season from November to March / April)	124 ha
3	Number of Farmers	311
4	Passage to connect tail-end of Canal with the nearest Karula river-bank (constructed as part of this initiative)	Over 554 meters

The tail end of the Khanpur Minor canal system is about 554 metres (acceptable route) from the left bank of the river Karula. Therefore, one of the tasks under this initiative was to construct a passage to connect the tail-end of the canal with the left bank of the Karula river. This passage is a mix of open earthen and lined channel, with some portion as underground-pipeline.

This paper documents the journey of the Karula river initiative from mid-2017 to mid-2021.

2. Approach and Methods

The idea of the Karula pilot has been conceived keeping in view a stakeholder-centric participative approach, wherein the farmers, concerned state government institutions (Uttar Pradesh Irrigation and Water Resources Department) and district authorities (Bijnor district) were key stakeholders. Whilst the project team led and coordinated the entire task; the stakeholders, local knowledge and wisdom played a critical role, in terms of contextual guidance, rapport building and farmer-level coordination.

A three-pronged approach was adopted to implement the pilot activities, including:

a. Demand-Side Management (promotion, demonstration and adoption of irrigation water used in efficient ways and means, in terms of Better Management Practices, to save water)
b. Supply-Side Management (rehabilitation of the entire canal system of Khanpur Minor, including the construction of a passage from the tail-end of Minor to the riverbank of Karula)
c. Institutional Strengthening (facilitation of the constitution of the Khanpur Minor Water Users Association and capacity building of command farmers to make them well-acquainted with various key provisions of the Uttar Pradesh Participatory Irrigation Management Act, 2009 – under which the Water Users Associations are formed in the state)

Key amongst the above three aspects of the approach has been the inclusion of socio-economic aspects, technical considerations, and stakeholder engagement. During implementation of the three-pronged approach, these aspects were not only taken into account, but were of central focus.

The Karula river initiative began with the assessment of baseline information pertaining to farmers, their landholdings, literacy rate, cropping cycle and cropping pattern, modes of irrigation, agricultural yield, input cost, profit margins, the status of canals and allied infrastructure, and more. With the increased understanding about the area, the work began, wherein the role of various stakeholders (including command farmers, Uttar Pradesh Irrigation and Water Resources Department (UPI & WRD), Bijnor District Administration and WWF India) was critical.

Stakeholder engagement is seen as a means of contributing to improved water governance, where governance is defined as the policy and practices giving rise to particular forms of water management in different contexts (Wehn *et. al.* 2018). Various stakeholders under the Karula initiative had played an inclusive and iterative part in realising the larger objective. Although their responsibilities were distinct with overlapping roles, they did appreciate each other's contribution and collaborated to work for the larger water conservation goal. For instance, the supply side-interventions (rehabilitation and maintenance) on the Khanpur Minor canal is a Uttar Pradesh Irrigation and Water Resources Department task, but farmers and other stakeholders played a critical role in the overall supervision and coordination.

On the other hand, a passage was required to be constructed to connect the canal's tail-end with the riverbank, which was purely a physical activity. Here, the technical guidance of the Uttar Pradesh Irrigation and Water Resources Department was obtained, yet the farmers played the key role, as they deliberated and finalised the alignment of the passage route. In this process, the involvement of district authorities was critical to provide information about the rights (based on revenue records) on the land between the passage route. Only then could all stakeholders take the final call on the passage route and the work begin.

'Social learning' has been an added advantage of such stakeholder-centric approaches. One of the most salient aspects of social learning is the collective – rather than individual – process of learning, knowledge co-creation and accumulation of wide experiences to generate a broader knowledge and evidence base, from which decisions can be taken (Wehn *et. al.* 2018). In terms of the Karula initiative, it has been a mutual learning for all stakeholders. For instance, whilst the team promoted trench-based sugarcane farming in the Khanpur Minor canal command, farmers came up with the idea of multi-cropping by making use of moisture in the soil, and therefore growing other crops to maximise their economic gains. Some of the progressive farmers in the adjoining areas as well as the Department of Sugarcane, Government of Uttar Pradesh (*Success Stories of Sugarcane development in District-Bijnor, Uttar Pradesh, 2018)* were promoting these practices. As a result of knowledge exchange, exposure visits and personal initiatives, many farmers adopted this idea. This has also become a learning for their fellow farmers (even outside the command area)

The chronology of the stakeholders' engagement process is illustrated in Figure 3.

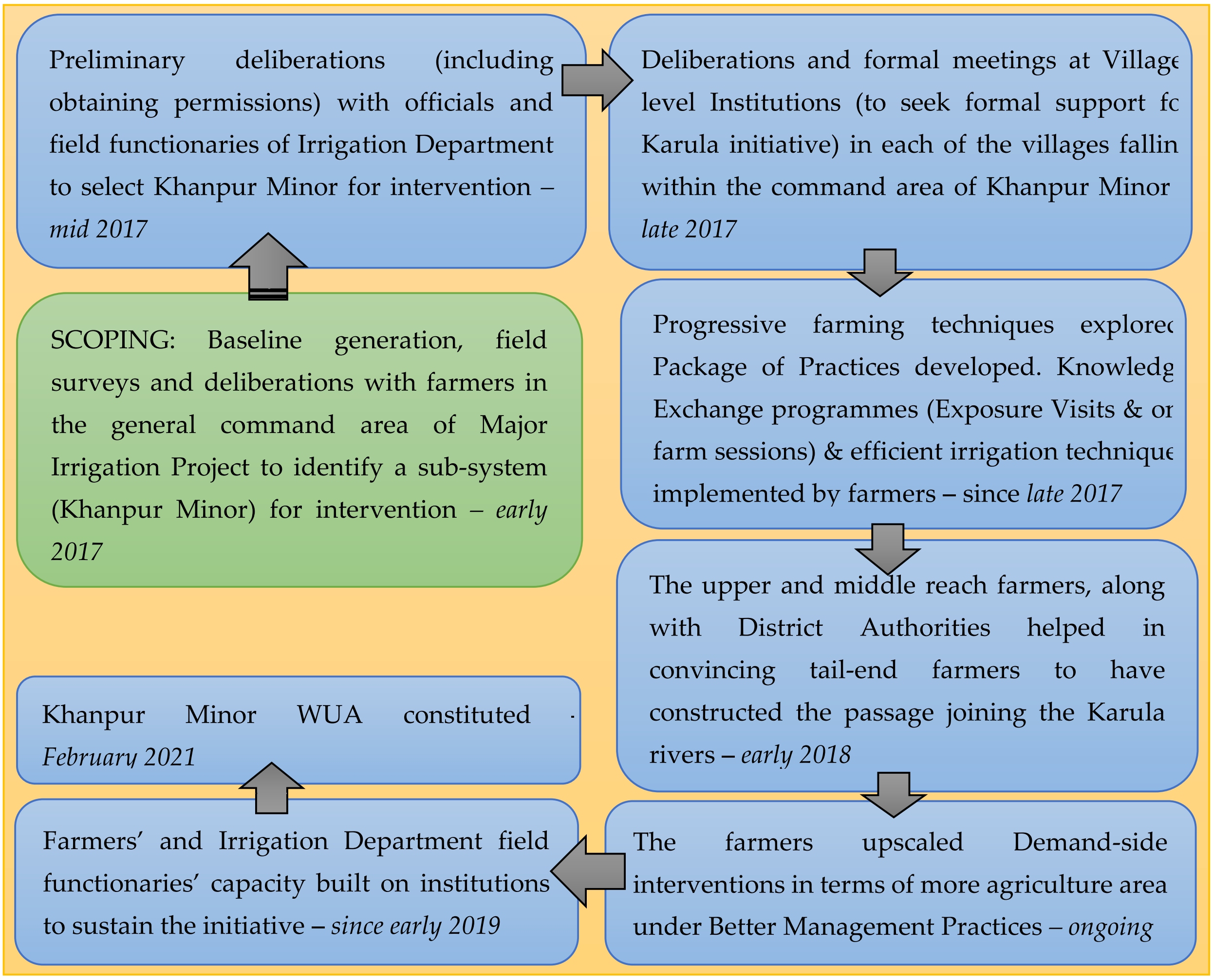

Figure 3. Stakeholder's engagement along with timelines and key steps and milestones.

The engagement of various stakeholders, in a categorised (activity-based) manner is explained in the below table along with their specific roles, the challenges that were faced and how these challenges were overcome.

Table 2. Summary of Roles, Challenges and Approach for this study.

i. Supply Side Interventions

Roles of various stakeholders				Challenges	Approach adopted to resolve
WWF – India	*UPI &WRD*	*Farmers*	*District Authorities*		
Canal works: a. Canal de-siltation b. Canal gate repair to ensure off-take of Designed Discharge throughout the canal c. Repair and Maintenance of Outlet heads d. Setting up hydrological monitoring system at Khanpur Minor and Karula River	a. Permissions to carry out proposed work b. Technical guidance in carrying out canal works, i.e. repair & maintenance c. Technical supervision & monitoring of physical works d. Regular maintenance and repair post-intervention	a. Agree to become Ramganga Mitra b. Participate in field surveys on canal for identification of works c. Supervision of physical works on canals d. Report any issue to the authorities and team	a. Support to carry out the work and provide contextual guidance, as required b. facilitate Institutional synergies, i.e. to facilitate support from other departments for the purpose of the work	Canal system was in a dilapidated state, the passing of designed discharges from the head of the canal was not possible, plus several obstructions in the canal and therefore the tail-end area of canal generally remained un-fed	Complete rehabilitation of canal system was done, including – head-works repair, canal desilting, fixing of outlet head-pipes, Gauges repair & establishing new Gauge, clearing of obstructions etc.
Canal-end to river-bank passage work: a. Along with farmers and department, identify most preferred route from tail-end of canal to Karula riverbank b. Build consensus on the route and type of passage c. Construction of passage in accordance with consensus	a. Convincing the farmers about passage formation, its route selection and support consensus building b. Technical supervision of passage construction	a. Agree on passage route b. Convince fellow farmers for the initiative c. Support while formation of passage d. Maintain passage (as WUA function), beyond project duration	a. Facilitate to identify passage route & its formation b. Convince command farmers to support this initiative	Preferred route towards river Karula has a lot of encroachments by tail end farmers (mainly extension of farm boundaries). Therefore, sparing the space for passage route was one of the most challenging and complex tasks.	Passage falls under tail-end village of command. Series of deliberations held with farmers and they were exposed to (i) the benefits of adopting improved practices and (ii) how they can contribute to a healthy Karula. Farmers got convinced to provide passage, but requested that most of the passage route should be underground and part of it should be on the edges of the farms to avoid damage to crops

ii. **Demand Side Interventions**

Roles of various stakeholders				Challenges	Approach adopted to resolve
WWF – India	*UPI &WRD*	*Farmers*	*Extension Agencies (Agriculture Science Center)*		
a. Building the capacity of the farmers towards Better Management Practices (BMPs) in irrigation & agriculture for Sugarcane b. Demonstration of BMPs (Better Management Practices) & PoPs (Package of Practices) with farmers	Cropping pattern vis-a-vis irrigation water delivery information, with respect to various reaches of the Khanpur Minor canal	a. Agree to this initiative b. Participate in trainings and exposure c. Willingness to demonstrate BMPs & Package of Practices (PoPs) on their farms d. Implementation of BMPs & PoPs on their farms	a. Progressive farming techniques b. Support in development of Package of Practices (PoPs) c. Knowledge Exchange, including exposure visits and on-farm sessions	Sugarcane crop & flood-based irrigation is predominant in the region. Equitable distribution of water was a challenge. The situation aggravated by dilapidated state of canal & excess water being used by head-reach farmers leaving little for tail-enders. Surface water irrigation is 100% subsidized for farmer's welfare, so there was no economic incentive to use less water	Being a cash crop, the recommendation for switching from sugarcane to another crop was deliberately not attempted. Therefore, the focus remained on improving the irrigation practices. The trench irrigation practice was introduced. Trench technique has not only resulted in reduction of canal water use but also reduced groundwater withdrawal, which certainly reduced input cost. In parallel, the farmers were sensitized for their role in reviving river Karula.

iii. **Institutional strengthening (including constitution of Khanpur Minor Water Users Association**

Roles of various stakeholders				Challenges	Approach adopted to resolve
WWF – India	*UPI & WRD*	*Farmers*	*District Authorities*		
a. Guide, support and facilitate the process for constitution of WUA, including –election process, voter list preparation & voter's validation b. Trainings, Knowledge Exchange and Exposure Visits of command farmer's to active WUAs in & outside the state	a. Lead and coordinate the process for constitution of Khanpur WUA with 'Government of Uttar Pradesh' b. Conduction of elections e. Notify results & WUA constituted	a. Khanpur Minor WUA constitution process b. Participate in the capacity building initiatives, including – training, exposure etc.	Facilitate and support the WUA election process	Although the State Government promulgated UP Participatory Irrigation Management Act' 2009; but the process (farmer's awareness, Voter-List preparation & its validation, election schedule etc.) for WUA formation was time-taking	Series of awareness and training programmes were conducted. National & state-level exposure visits to successful WUAs were organised. The Voter List preparation and validation was facilitated. Khanpur Minor WUA is at place now.

With an objective to assess the impact of Karula river initiative on the farmers with respect to (i) on-farm water management and water savings and (ii) agricultural productivity and economic value of produce per unit of area, a detailed questionnaire (Appendix A) was developed. Based on this questionnaire, farmer surveys were conducted jointly by some of the authors between 2018-2019 (sugarcane cropping season). The farmer surveys were conducted through a combined approach, i.e., field-level measurements and 'farmer recall' method, this echo similar approach noted by Barton and Taron 2010, while conducting representative farm surveys in the irrigation command areas in Tungabhadra River Basin, India.

There is a body of literature that talks about farmer-recall method as one of the means for conducting irrigation and agricultural surveys, especially in the absence of precise measuring and monitoring support. The analysis by Beegle *et. al.* 2011, as part of the work in three African countries, shows little evidence of recall bias impacting agriculture data quality at farm-level. They noted that, the results of their work allay some concerns about the quality of some types of agricultural data collected through recall over lengthy periods. On the other hand, Wollburg *et. al.* 2020 find that, the recall length has a significant impact on reported outcomes in all areas of interest in agriculture surveys and analysis. They therefore suggested that, to reduce the risk of recall error and to improve the quality of key variables in agricultural surveys, shorter recall periods can be one of the solutions.

The authors, therefore, collected the information from the farmers during different stages of sugarcane crop, i.e., during land preparation, sowing, input applications and harvesting. Whilst multiple visits and interactions could be resource and time intensive; but, since the Karula river initiative has been a 4-year one and the team happened to visit field numerous times, which made it possible for the team to visit the farms and have discussions with the farmers during different phases of the crop cycle. This aspect is in alignment with the suggestions made in previous studies and research (Wollburg *et. al.* 2021, Beegle *et. al.* 2011, Barton and Taron 2010). Besides the farmer surveys, for the purpose of validation of information related to water application at sample farms, the team also measured the discharge and water levels in the field channels and farms.

The farmer survey questionnaire was discussed with a small sample size, but with clear representation from all reaches of the canal system, i.e., two farmers each from the head, middle and tail end of the Khanpur Minor canal. The identification of head, middle and tail end of the canal is done by dividing the total length of the canal into three equal parts. The farms where intervention (having BMPs) was made were noted as 'Demonstration-farms' and the ones with usual agricultural practices (without BMPs) were named as 'Control-farms'. It was noted while selecting the control farm, that both the control and demonstration farms belonged to similar specifications, except for sowing methods (with trencher and without trencher). Along with the field visit to all farms, detailed interactions based on the agreed questionnaire were conducted. Among all the command area farms, six sample demo plots (two each from head, middle and tail reaches of the canal) and correspondingly six control plots were selected to assess the impact and benefits of these interventions.

Parallel to this, data on the running of the Khanpur Minor Canal and the water consumed in irrigation was collected on a fortnightly basis for the critical period. This analysis was carried out for *kharif* (July to October) and r*abi* (October to March) crop seasons.

The hydrological observations at Khanpur Minor were carried out through monitoring of gauge levels, active channel width and velocity to calculate discharges, which were used for water accounting. The observed discharge data is not available for the Karula river, as there is no monitoring station on this small river. It therefore becomes imperative to establish baselines which could later be utilised for comparison with the volume of saved water from irrigation discharged in the Karula river to improve its health.

The water used for sugarcane irrigation, both in demo and control fields, was compared with its ideal (theoretical) requirement. The actual discharge from tube wells with a 4-inch delivery pipe to the irrigation channel was measured at the site, using area velocity method and volumetric measurement. On this basis, an average discharge of 0.5 cusecs (16 litres per second) was adopted. A primary survey was conducted to gather information regarding the actual running time of tube-wells in demo and control plots for each irrigation/season. The volume of water applied in a field was calculated by multiplying the discharge with water application time. The irrigation water depth applied to a plot was calculated by dividing the total volume of water applied by the area of the plot. The

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ideal (theoretical) crop water requirement is as per FAO (Food and Agriculture Organization) norms using CROPWAT – a tool for calculating crop water requirements. The meteorological data of the nearest climatological station (Bareilly) was used. The rainfall data of the district Bijnor was taken and the value of crop coefficient "Kc" was taken from guidelines issued by CWC (Central Water Commission, Government of India) in 1984 (Technical Series 2: A Guide for Estimating Irrigation Water Requirement, Ministry of Irrigation, Water Management Division, New Delhi, May 1984). The theoretical irrigation water depth for sugarcane crop computed using FAO's CROPWAT Program is calculated as 67.6 cm, including the 25% leaching requirement. Against this norm, the current irrigation water depth in control plots (without trench method) was calculated as 87.6 cm. The irrigation water depth in demo plots (with trench method) was calculated as 72.3 cm.

The state of Uttar Pradesh promulgated the Uttar Pradesh Participatory Irrigation Management Act in the year 2009 and since then the constitution of Water Users Associations (WUAs) at canal systems has been underway in a phased manner. So far, this work was done in project areas of the Uttar Pradesh Water Sector Restructuring Project (funded by the World Bank). Hence, WUA formation in this area (Khanpur Minor, around the Karula river) had not begun. Under the Karula initiative, WUA was considered as an appropriate participatory institutional mechanism to sustain and take forward this initiative.

Work towards formation of WUA in the Khanpur Minor command area has been underway since 2018, with a series of awareness, sensitization and training programmes being conducted to build the capacity of farmers regarding WUA functioning, and its roles and responsibilities as per the Uttar Pradesh Participatory Irrigation Management Act, 2009 (UP PIM Act 2009). Exposure trips of farmers from Khanpur minor command area to successful WUAs in the state and outside the state have also been conducted. This way, a strong momentum was generated in favour of constituting the WUA and a critical mass of experts and vigilant farmers was readied to support the affairs of the WUA. Finally, in February 2021, the Khanpur Minor WUA was constituted with the unanimous election of its governing board members. The Khanpur Minor WUA was constituted following the provisions of the UP PIM Act 2009. The unanimous election results indicated the overall positivity amongst the command farmers towards the initiative as well as the institutional setup.

3. Results

This section discusses the findings of a sample survey of farms at all reaches of the Khanpur Minor canal, i.e., head, middle and tail reaches of the canal. Farmers from both typologies of farms, i.e., where interventions are being carried out, and where agriculture is still being practised in a traditional manner, were interviewed. The data from these interviews were analysed and the results are presented in this section.

This section, essentially narrates the following:

1. Water savings at farm level
2. Flows restored in the Karula river
3. Change in sugarcane productivity
4. Economic implications for the farmers and crop-water productivity

3.1. Water savings at farm level:

The sugarcane crop raised using traditional practices (primarily, flood irrigation) consumed more water, whereas the crop raised using Better Management Practices (BMPs), including trench-based technique, consumed less water. The analysis of data shows average water savings to the tune of 17.4% using the trench method of sowing, (with the range between 40% and 10%) as shown in graph – 1. The saving of water can be attributed to the larger spacing among cane rows in the trench method.

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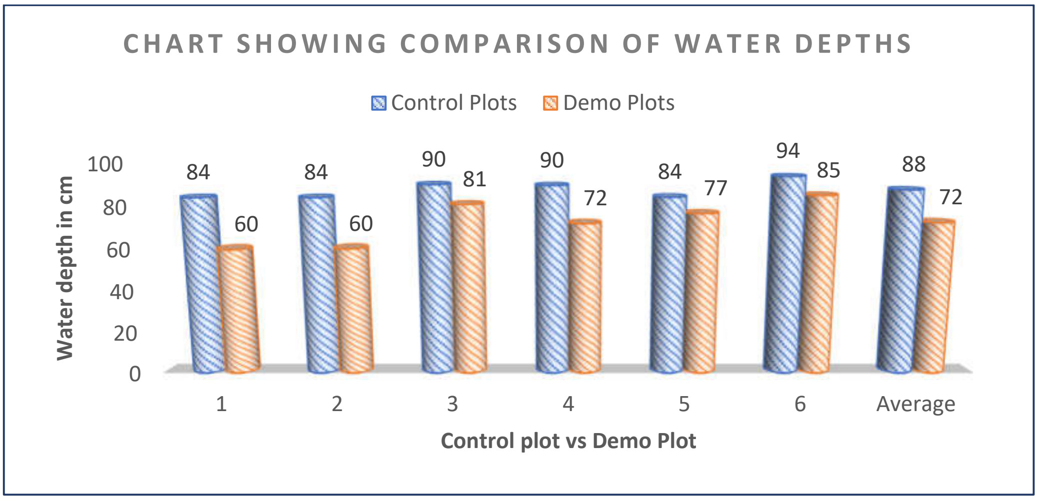
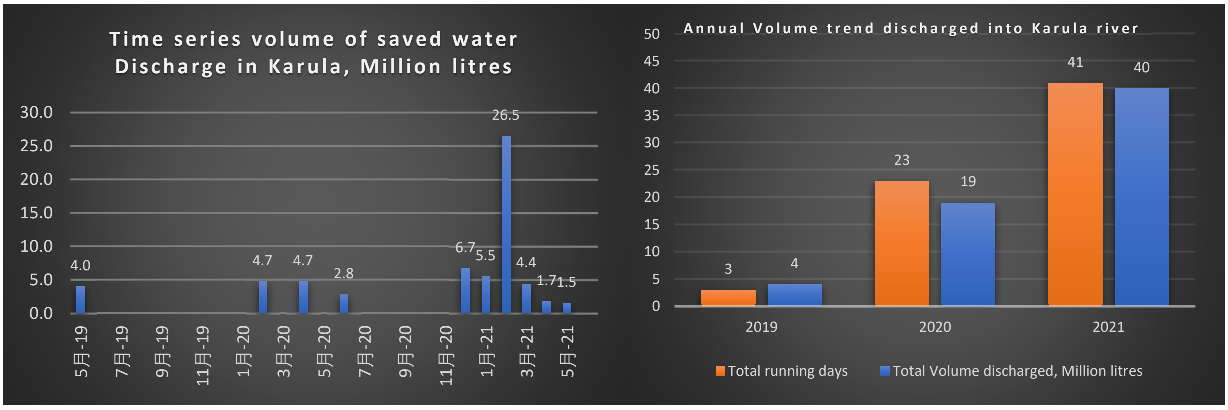


Graph 1: Comparison of irrigation water depths applied in control and demo plots.

3.2. Flows restored into the Karula river:

Now, after the rehabilitation, the irrigation system is fully functional whenever the Khanpur Minor Canal gets water as per the roster[1] issued by the UPI & WRD. The canal system is run as per the roster. The saved water from the canal is now released into the Karula river through the passage. The Khanpur Minor Canal generally runs for 6-8 months in a year (depending upon water availability in the reservoir and irrigation water demand by the command farmers). From May 2019 until June 2021, the Khanpur Minor canal, through the passage, discharged a total of 62.55 million litres of water saved from irrigation to the Karula river. This quantum of water flown into the river across 67 days from May 2019 to June 2021. The discharge from the tail end of the Khanpur canal into the Karula river within this period ranged from 0.12 -0.80 cusec, with an average flow rate of 0.42 cusec, which is 11% of the 'designed discharge' of Khanpur Minor canal. Graph-2 (A, B and C) shows the temporal variation in saved water discharged into the Karula river since May 2019.



Graph 2 A&B: Flows Dependability Curve of Observed Discharges in Karula River at critical point & Hydrological Variations in Karula river over 2017 to 2021.

[1] Roster – the mechanism of irrigation scheduling which defines the date and time of water distribution for various canals, in a turn-by-turn fashion, within the irrigation system.

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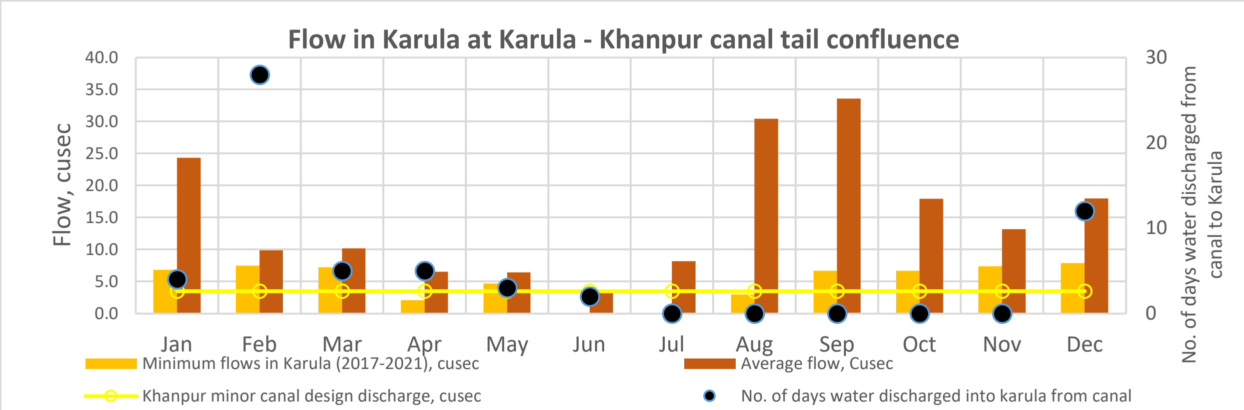
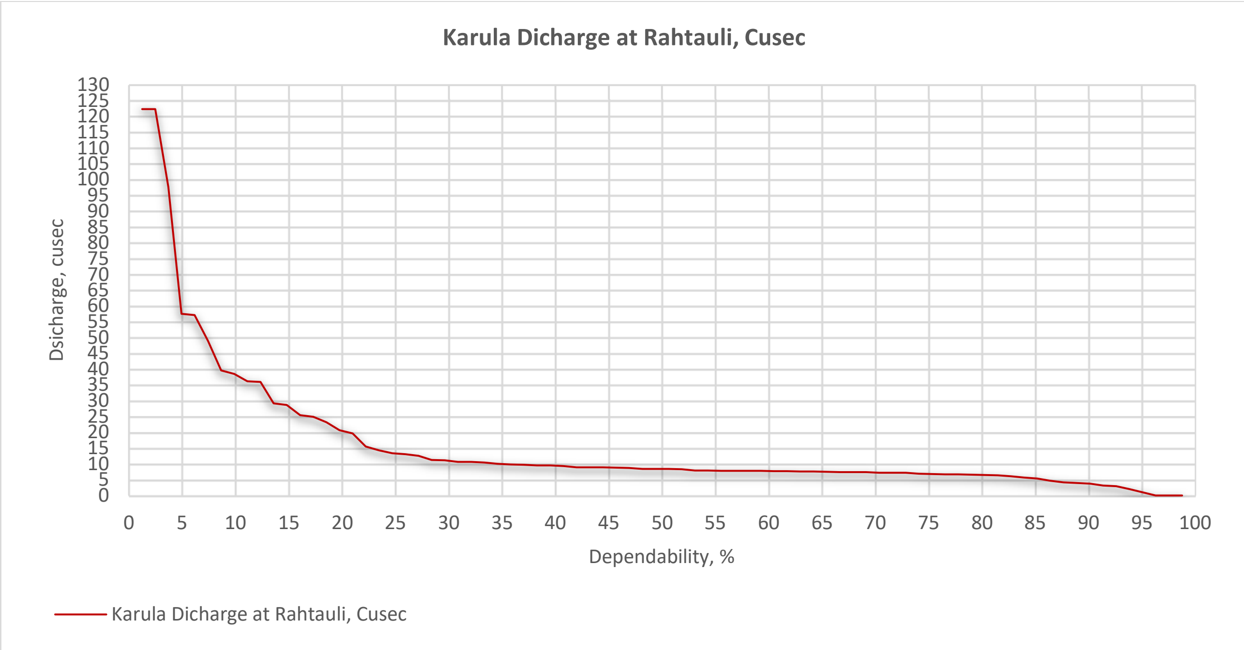


Graph 2C: A snapshot of minimum flows in Karula, Khanpur Minor discharge and number of days when saved water was released into Karula river.



Graph 2D: Flows Dependability Curve of Observed Discharges in Karula River at Rahtauli village point & hydrological variations in Karula river from 2017 to 2021.

From Graph 2 D, which shows the flow duration curve, it can be inferred that, at 90% dependability (leanest flows), about 3 cusec water is available, whereas minimum average flows of 3.6 cusec are observed in the month of June in the Karula, near the tail end of the Khanpur canal. It is also evident here that the saved water from irrigation discharged into the river Karula accounts for 7% of minimum lean season flows. It can be seen that except during the monsoon months (June to October) saved water from irrigation is discharged into river Karula during all the lean season months. With further adoption of Better Management Practices in the remaining sugarcane area in command and the scaling up of trench-based interventions, it is expected that more water will be contributed by the Khanpur command to the Karula river.

3.3. Changes in sugarcane productivity:

The data around sugarcane yield per unit area was discussed with the farmers. The figures around changes in yield (reported by the farmers) vary, depending upon the level/degree of adoption/adherence to Better Management Practices suggested, in addition to the adoption of the trench-based practice by individual farmers. Therefore, there may be some variations in the outcome or productivity levels.

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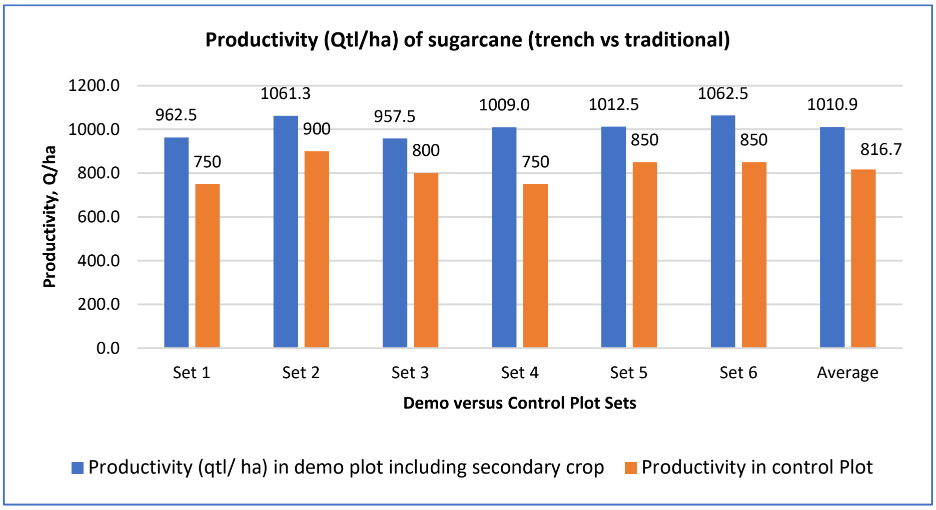
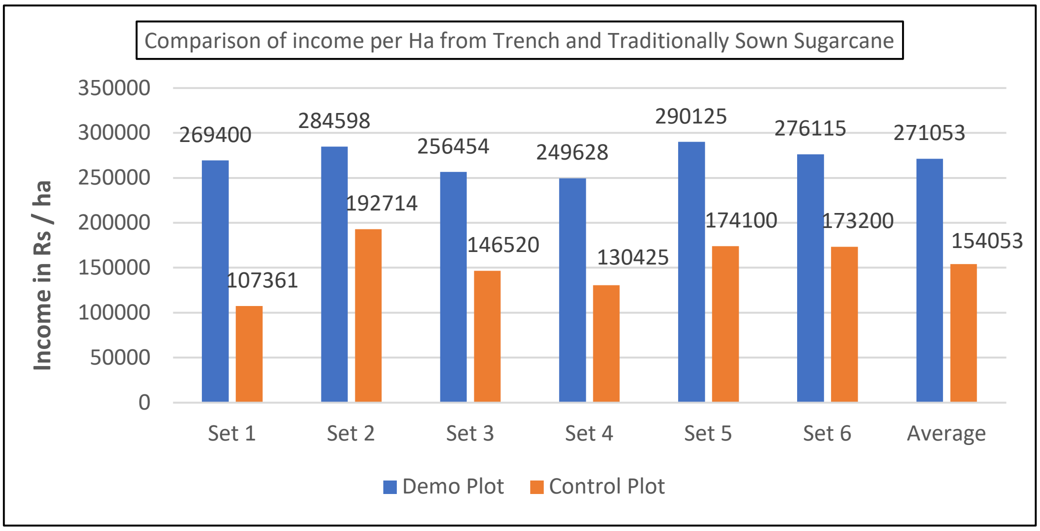


Graph 3: Comparison of productivity of sugarcane (Better Management Practices including trench vs traditional methods).

In this case, of the six farms sampled, the general average trend of agricultural productivity enhancement is about 23.8%, with the range between 34% and 19%; Graph 3 exhibits the degree of change in sugarcane productivity.

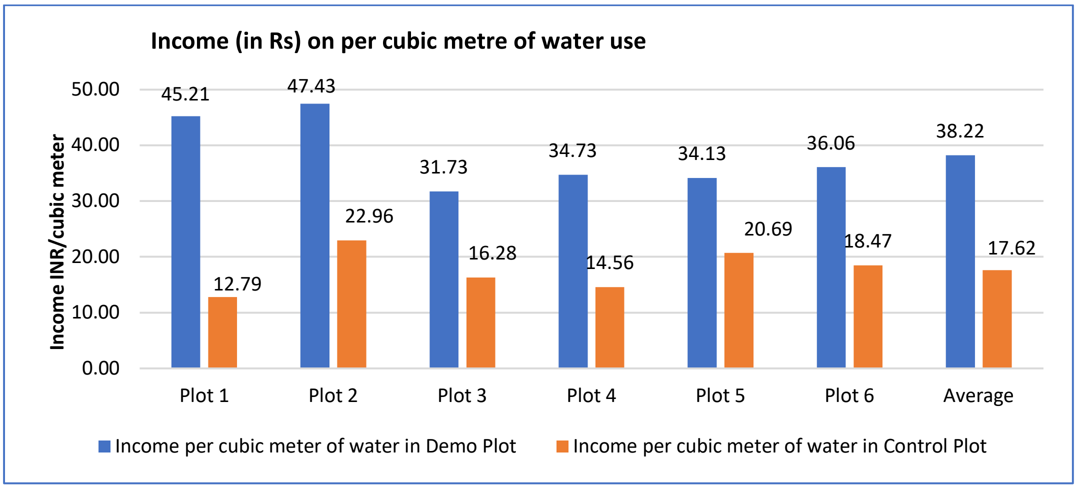
3.4. Economic implications for farmers and crop-water productivity:

Farmers have benefited in terms of earnings as well. The average income, in terms of unit area, is to the tune of Rs. 117,000/ha, whereas the range is Rs. 162,039/ha to Rs. 91,884/ha (Graph 4).



Graph 4: Comparison of income per hectare (Better Management Practices including trench vs traditional method).

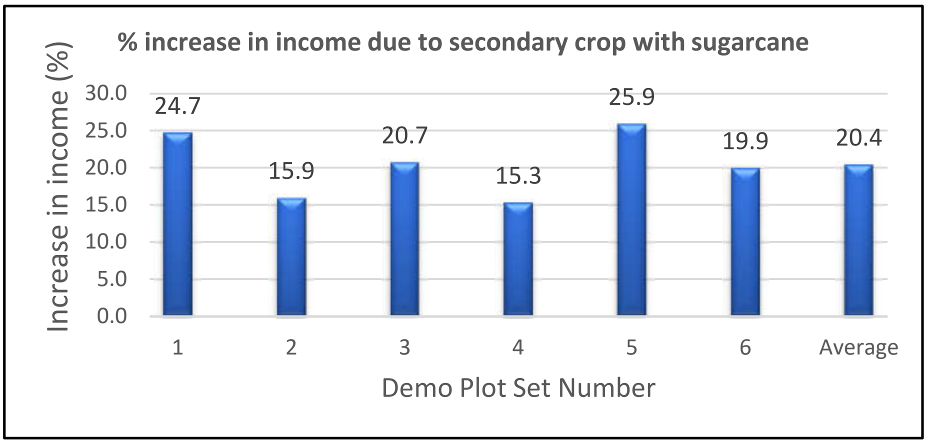
Income per unit of water consumed (irrigation applied) was enhanced by 117 % (on average) in farms using BMPs than a traditionally sown farm (Graph 5). A farmer, on average, gets additional income of Rs. 20.60 on every cubic metre of irrigation water used in the trench method. This is mainly due to a reduction in input costs (less fertiliser/pesticide, fuel etc.) and increase in yield and higher returns.



Graph 5: Comparison of income per cubic metre of water use (Better Management Practices including trench vs traditional methods).

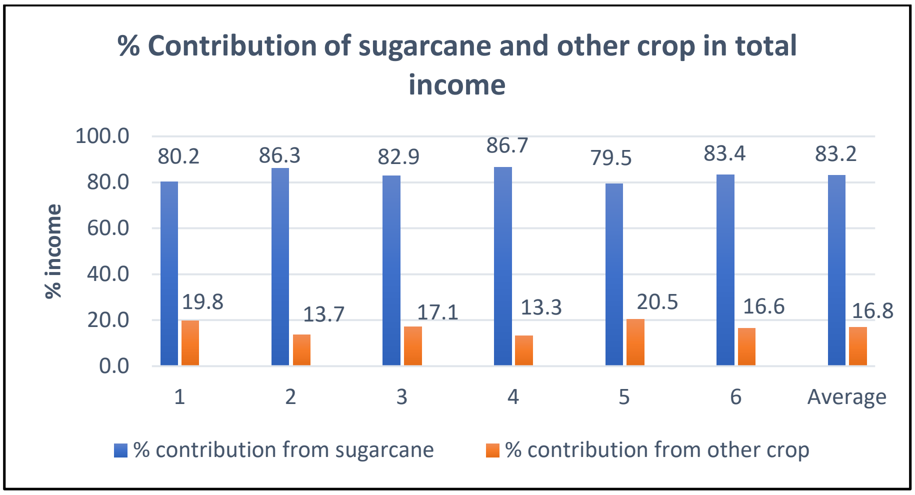
The productivity per unit area may be attributed to the spacing between rows, which allows better aeration and provides space to grow freely, which results in cane plants of larger circumference and height, and weighing more, with greater sugar content. The per unit less water consumption may also be attributed to the heavier cane, providing greater yield of more value – with less water used.

Besides changes in sugarcane productivity and saving in irrigation water, the trench method offers opportunities to the farmers to grow a second crop in the sugarcane fields, simultaneously, between the ridges. Most of the farmers grow mustard or black-gram (*urad*) as an additional crop. These crops are not provided additional irrigation as their less water requirement is easily met with the soil moisture regime of the sugarcane crop. Farmers can use the additional crop for their consumption as well as to gain extra income from it. It has been calculated from demo farm data that the average income of multi-cropped sugarcane fields is around 20% higher (with the range between 15% and about 26%) than the single sugarcane crop sown with Better Management Practices, including the trench method, as shown in Graph 6.



Graph 6: Percentage increase in income due to secondary crop with sugarcane.

The secondary crop, on an average, contributes to around 17% (with the range between 13% and about 20%) of the total income of trench method sugarcane cultivation with multi-cropping. (Graph 7).



Graph 7: Percentage Contribution of sugarcane and secondary crops in total income.

If the secondary crops had been sown alone, it would have consumed 15 cm irrigation water depth per hectare (assuming 50% area covered in sugarcane field is by the secondary crops, which consumes 30 cm water for maturity). This is totally saved by the irrigation water provided to the sugarcane. The total water requirement of both crops, if each crop is sown alone, comes to 87 cm (72cm+15cm). Thus, the saving of 15 cm water of 87 cm is 17.2%. The sugarcane crop raised using trencher tool already has a saving of 17.4% over traditional sowing, hence the multi-cropping scenario offers total water saving of 34.6% over the traditional raising of sugarcane crop.

From the river conservation and water management perspective, the major outcome and impact of this initiative is the water savings from irrigation and release of that water into the river Karula through the passage. There are two set of calculations – total water savings at farm level in view of using Better Management Practices (BMPs), including trench-based sugarcane farming, and actual water discharge data (from the gauge near the riverbank on the passage). These calculations are shown in the following table (Table No. 3):

Table 3. Current Gains due to Pilot Project Interventions.

Water savings from farm – Unit Area (in cubic meters / hectare)	Potential water saving if trench-based sugarcane adopted in all farms in Khanpur command (cu m)	Water released into Karula river from passage (in cu m) [Observed Data]
1,570	246,490 (from about 157 ha)	62,550

Water saved to the tune of 62,550 cubic metres (25% of potential water savings) has found its way into the Karula river, thereby enhancing its flows. There are substantial conveyance (seepage) losses and unaccounted withdrawals, which has significantly reduced the overall volume of actual water released into Karula river. However, this means that there is an opportunity to bridge this inefficiency gap, so that the net gains can be enhanced.

4. Discussion

The Karula pilot was envisaged as a unique initiative, but under the backdrop of a well-debated idea – whether efficient irrigation water use can actually aid flows enhancement into the rivers and ultimately support the maintenance of e-flows in the rivers. On the other hand, there were externalities, which had the potential to disrupt the aspired outcomes of this initiative. However, a carefully developed stakeholder-led initiative has begun to deliver on the stated objectives, i.e., enhancing the flows in the river Karula.

Herein, there have been favourable changes in terms of water use requirement from the demand-side and an efficient irrigation canal system, which ensured reliable water supply to the farmers. This has led to the achievement of saving water meant for irrigation and its release into the Karula river, besides benefitting the farmers economically.

The specific values of water released into the river Karula would remain a dynamic figure, as there are several associated and external factors that would influence this. Some of these key factors could be:

a. The quantum of water flows in the Khanpur Minor canal, which may vary depending upon

- ✔ Availability of water in the main/parent canal
- ✔ Irrigation demand by farmers within the Khanpur command area
- ✔ Unauthorised withdrawals from the Khanpur Minor canal

b. State of maintenance of Khanpur Minor

c. Rainfall in the local catchment

d. Maintenance of passage structure

To sustain such an effort beyond the project duration is indeed a challenging ask, as there would be an apprehension that the situation would be back to 'business-as-usual' once the external support is withdrawn. To overcome this challenge, the formation of the Water Users Association (WUA) as per the provision of the Uttar Pradesh Participatory Irrigation Management Act 2009 was facilitated. In February 2021, the Khanpur Minor WUA was constituted and the elections for Executive/Governing Body (comprising of President, Secretary, Treasurer and other office bearers) of the WUA were unanimous. This is indicative of positivity amongst command farmers about the institutional support for this initiative, besides bringing them permanent solutions to the operation and maintenance of the Khanpur Minor canal system.

Parallel to the efforts to form the WUA at the Khanpur Minor level, the capacity building of the farmers about roles, responsibilities and functions of WUA was done through training programmes, exposure visits to successful WUAs in the state and at the national level. This has helped in mobilising a 'critical-mass', who is now ready to take up the affairs of the WUA. However, the WUA is only recently established and further support will be needed for it to become fully sustainable in financial and institutional terms.

The Karula initiative was planned in such a way that the process for enhancement of flows in the Karula river fits within the current mechanism of irrigation scheduling and allocations and does not overwhelmingly change existing farm practices. This would mean that the envisaged objective is likely to achieve partial success in terms of actually maintaining the e-flows for a river. Therefore, the initiative may not achieve the full suite of e-flows requirements (locations, timing and quantity of flows) for the Karula river, but it certainly aids to enhance the flows in the river in times of need, like the lean season of November to June.

Some local factors that worked in favour of the Karula pilot were:

a. Farmers in this area largely grow sugarcane (a water intensive crop) and the produce is insured by the Central and State government through Fair and Remunerative Price (FRP) and State Advised Price (SAP). Additionally, sugar mills that buy sugarcane are mandated to purchase crops from farmers within a specified radius known as the Cane Reservation Area at the FRP, which serves as defined market linkage for this cash crop (*Niti Aayog*). The team was fully aware of this fact – due to the availability of water and assured purchase of produce by the government through sugar mills, farmers would not switch to another water-intensive crop, which is a general apprehension otherwise.

b. There has been another concern that farmers may tend to increase area under agriculture using water saved from the application of Better Management Practices (including trench use) in sugarcane farming. Nevertheless, the team still faced a situation where, since the Khanpur Minor canal did not feed all the farms in the middle to tail-end, saturation of the command area was bound to happen –once the demand-side and supply-side interventions were applied in the command area, the saved water in the head to middle reaches of the canal would be used by the tail-enders. As this was well-understood since inception and there was no hurried and strict response from the team to ensure that the saved water fed immediately into the river, the team worked with the tail-end farmers and assured them that they could use the water from the canal as well as from the passage for irrigation (by adopting trench-based technique), while letting the remaining water discharge into the river. The tail-end farmers agreed and this strategy worked well.

c. The other consideration in the Karula pilot is the promotion of local and scalable ideas to manage the demand-side aspect and not really call for hi-tech, expensive means of pressure irrigation (drip and sprinkler), at least in the early phases of the project. The idea was not to introduce something totally new to the area, but to bring some of the improvisations that are rare but known amongst the progressive farmers in and around that district. However, at a later stage, a few farmers proposed the idea of demonstrating pressure irrigation techniques and the team agreed to facilitate these.

Various scientific studies have suggested that water from seepage through unlined canals recharges groundwater (Mirudhula K. 2014) and helps build shallow aquifers that are generally used as a source for irrigation. Infiltration from the canals recharges the aquifer directly and partially compensates for water uptake from plants and evaporation (Arumi J.L. *et.al.* 2009). The idea behind this project was to support conjunctive use and reduce overall water withdrawal (canal and groundwater for irrigation), combined with improved practices in irrigation and agriculture, which is likely to reduce the losses from evapotranspiration, a matter of further investigation.

The groundwater serves the function of discharging base-flows into the river, especially during lean season. It was observed that excess infiltration from the flood irrigation technique (earlier prevalent in the command area), though, may be recharging shallow aquifers to some extent, but would also be increasing the overall evapotranspiration (ET) losses. Post field interventions, the volume of canal water applied has reduced, which may affect infiltration, but will also reduce the overall groundwater abstractions, subsequently helping in stabilising groundwater levels in the long run and will continue to feed the river through base-flows. Following the interventions in the Khanpur Minor command area to reduce abstractions, increase efficiency, and connect the canal tail to the river, the water has a more direct route to the river which augments riverine flows in its leanest flows periods. However, there are larger river-groundwater interactions in play too, which impact the riverine baseflows. Precise and conclusive information in regard to the exact benefits to the river and to the catchment can be inferred through long-term hydrological and hydro-geological monitoring.

Initiatives like the Karula river pilot can influence larger irrigation systems, as in a general scenario, the tail-ends of irrigation canals (in gravity-based systems) are close to

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rivers and wetlands. The saved water from irrigation, if conveyed to these freshwater resources, is likely to aid improvement of flows in the rivers. Arriving at such a stage is a critical milestone for maintaining e-flows in a river, because the most important question for e-flows maintenance is where the water for e-flows will come from, especially in over-allocated river basins. The irrigation water use efficiency initiative, as that of Khanpur Minor, could theoretically be upscaled at the extent of the Karula basin –about 65% (625 sq. km.) of catchment area of the Karula river grows sugarcane (as depicted in Appendix-2). The extrapolations show that there is a potential of saving about 68 million cubic metres of water from about 70% of sugarcane farms within the Karula catchment. Whilst all the sugarcane farms in the Karula catchment may not be supported by surface-irrigation facilities (that could have otherwise directly demonstrated enhancing flows in Karula); however, potentially lesser groundwater pumping in view of application of Better Management Practices would certainly benefit the aquifer and river from these savings. This is likely to contribute to river discharges through enhanced base-flows. Moreover, there are about 30 minor irrigation canals in the adjoining areas of Khanpur Minor and these are all fed by the Ramganga Canal. If this initiative could be up-scaled in these irrigation sub-systems, then more water could be augmented into the Karula river.

Whilst the apprehension may be valid that even if the water from irrigation is saved, it may lead to 'enhancing-area-under-irrigation' and/or push for 'adoption-of-more-water-intensive-crops', in certain circumstances, the Karula initiative has proved that a carefully designed participative programme can actually bear desired results in terms of enhanced flows. The Karula initiative demonstrates an alternative to promoting radical changes (suggesting newer cropping patterns or promoting pressure-irrigation in the early stages) in a short time span, without much rapport building with the stakeholders. It would be lot more prudent to look for local solutions (trench-based sugarcane farming, other package of practices including application of bio-pesticides and bio-fertilizers) and promote them in the project area. Once the benefits for the farmers are proven, they would come forward to support other forthcoming propositions as well.

5. Conclusions

As lessons learnt from the Karula initiative, the following takeaway points are made, which may not be conclusive for further replication of similar ideas, but are certainly key pointers for future considerations:

a. Integrated approach: rather than merely looking at a single aspect, a holistic and comprehensive view works better. For instance, instead of simply working on demand-side aspects, both supply-side aspects and institutional strengthening were also taken-up and this helped to achieve the objective. In addition, engagement with all key stakeholders, including the irrigation department, district authorities, local agriculture science centres and farmers, was critical for a transformational change

a. Equity and Ownership: a saturation of canal commanded area, in terms of access to irrigation water across the various ends of the canal (head-middle-tail) is a necessary and critical step in such exercises and therefore this should be acknowledged to get wholehearted support from the farmers across all reaches within the canal system. Such considerations also allow better buy-in and sense of ownership amongst the farmers in the entire canal command area

b. Monitoring: the monitoring of the transformation is a critical aspect and if this is done in a joint fashion, it adds value not only for the initiative, but also better informs the stakeholders about the change that is in the offing

c. Scalability: considering a unit for proof-of-concept that is scalable, is critical, as the demonstration at an optimum unit has far better potential of up-scaling, and therefore mainstreaming

Going forward, the team is now aspiring to upscale this initiative to about 16,000 hectare of Culturable Command Area (CCA) in the state of Uttar Pradesh, where the Ganga water resources feed the irrigation canals. This three-year programme will explore new leads, ideas, challenges, and opportunities, which would be worth narrating to the wider audience for their information, understanding and uptake.

It is fully recognized that the rejuvenation of some of the world's most populated and contested river systems continues to remain a challenging task, if the tributaries, rivulets, and wetlands in such river basins are not considered. It is in this context that the Karula pilot initiative is a pointer for policymakers and water-managers for the future. It is hoped that initiatives of this sort will help in curbing water-scarcity and will ensure wiser use of this precious resource. Moreover, the overall local ecology is set to benefit in this process as well!

Author Contributions: NK conceived the idea of the paper; he also structured, drafted and finalized the paper. SB reviewed the paper and provided valuable inputs to the paper and its structure. AM and RB reviewed the paper and provided crucial information and data for the paper. PKS and RKA reviewed and provided detailed inputs about results for farm level information and water saving data analysis. DT and CL reviewed the paper and provided critical feedback and inputs to the paper which has improved the quality of paper. NK, AM, RB, SB, PKS, RKA were part of Karula Initiative implementation team on ground.

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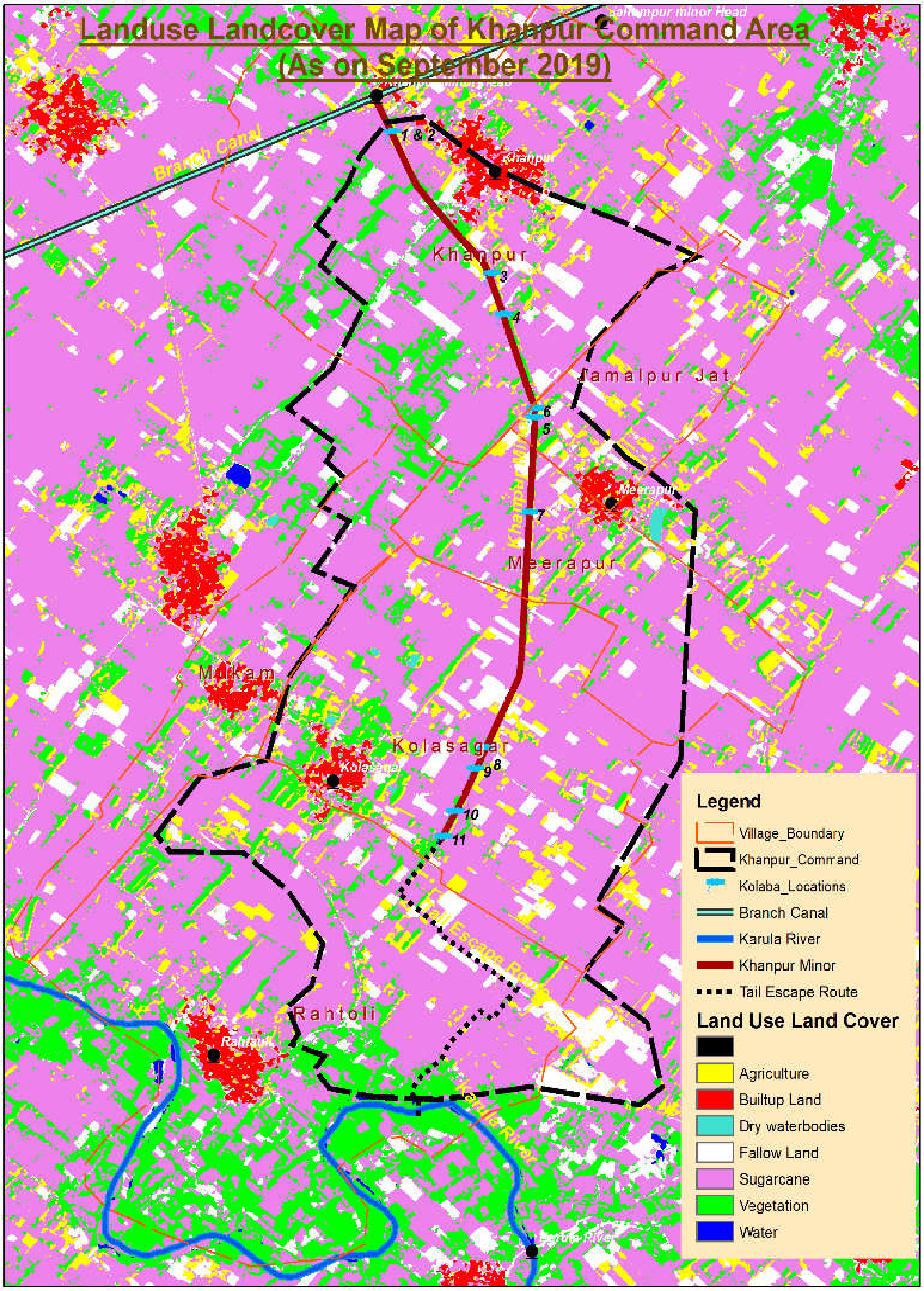
Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Appendix – 1

Landuse Map of Khanpur Command Area



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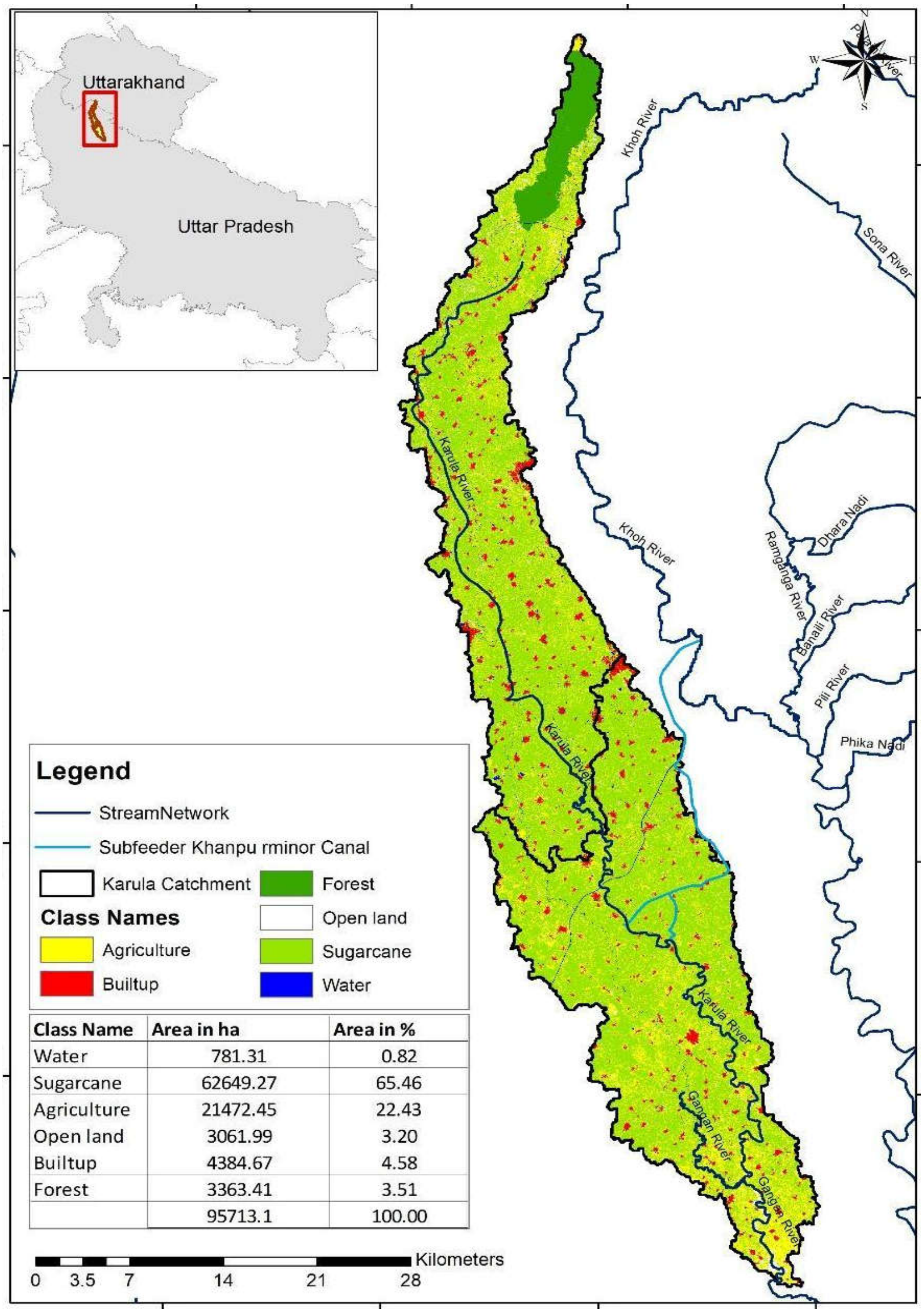
Appendix – 2

Land-use & Land-cover Map of Karula River Basin



Class Name	Area in ha	Area in %
Water	781.31	0.82
Sugarcane	62649.27	65.46
Agriculture	21472.45	22.43
Open land	3061.99	3.20
Builtup	4384.67	4.58
Forest	3363.41	3.51
	95713.1	100.00

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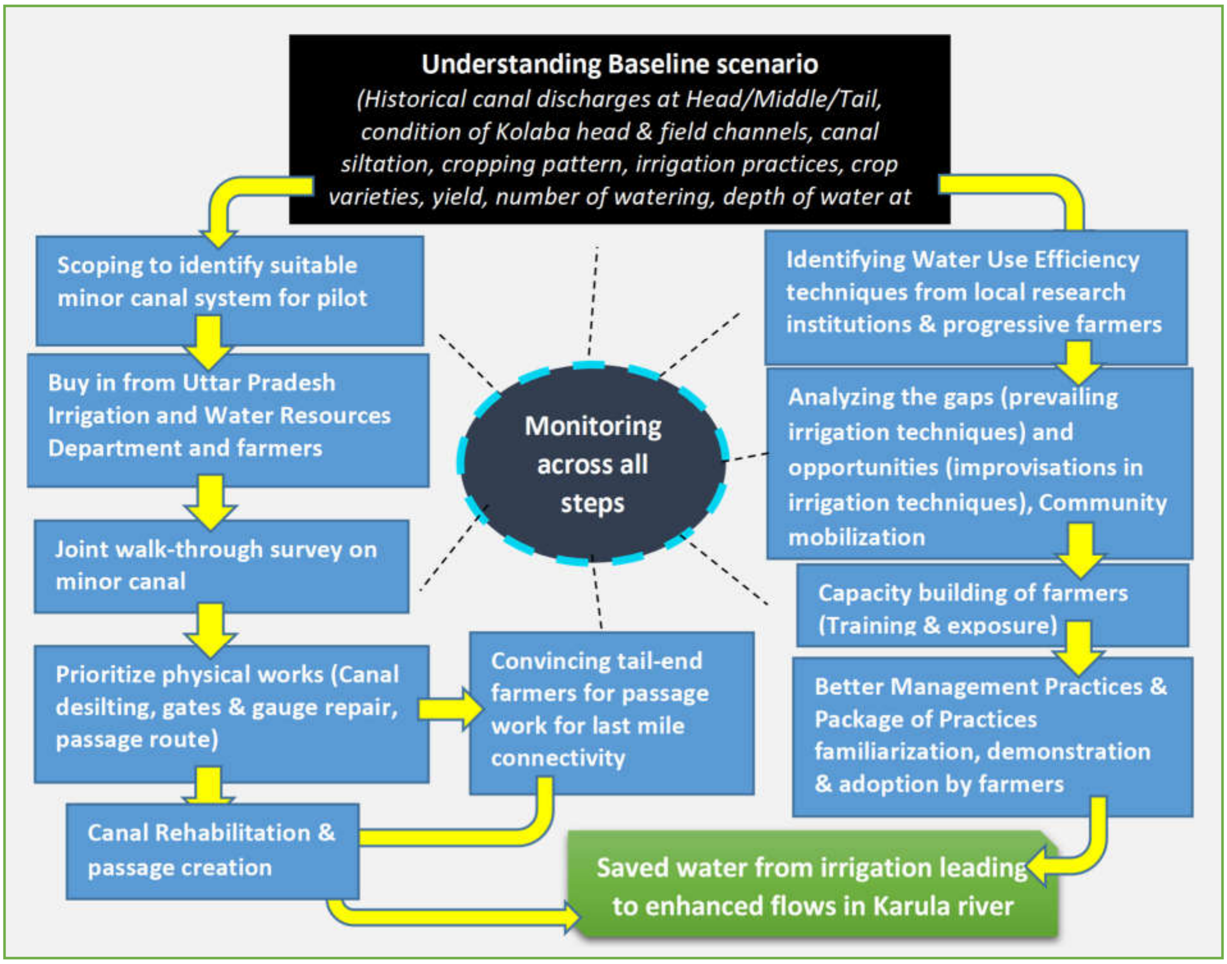
Appendix – 3

Illustration of combination of Supply-side Intervention and Demand-side Intervention leading to enhanced flows in river Karula



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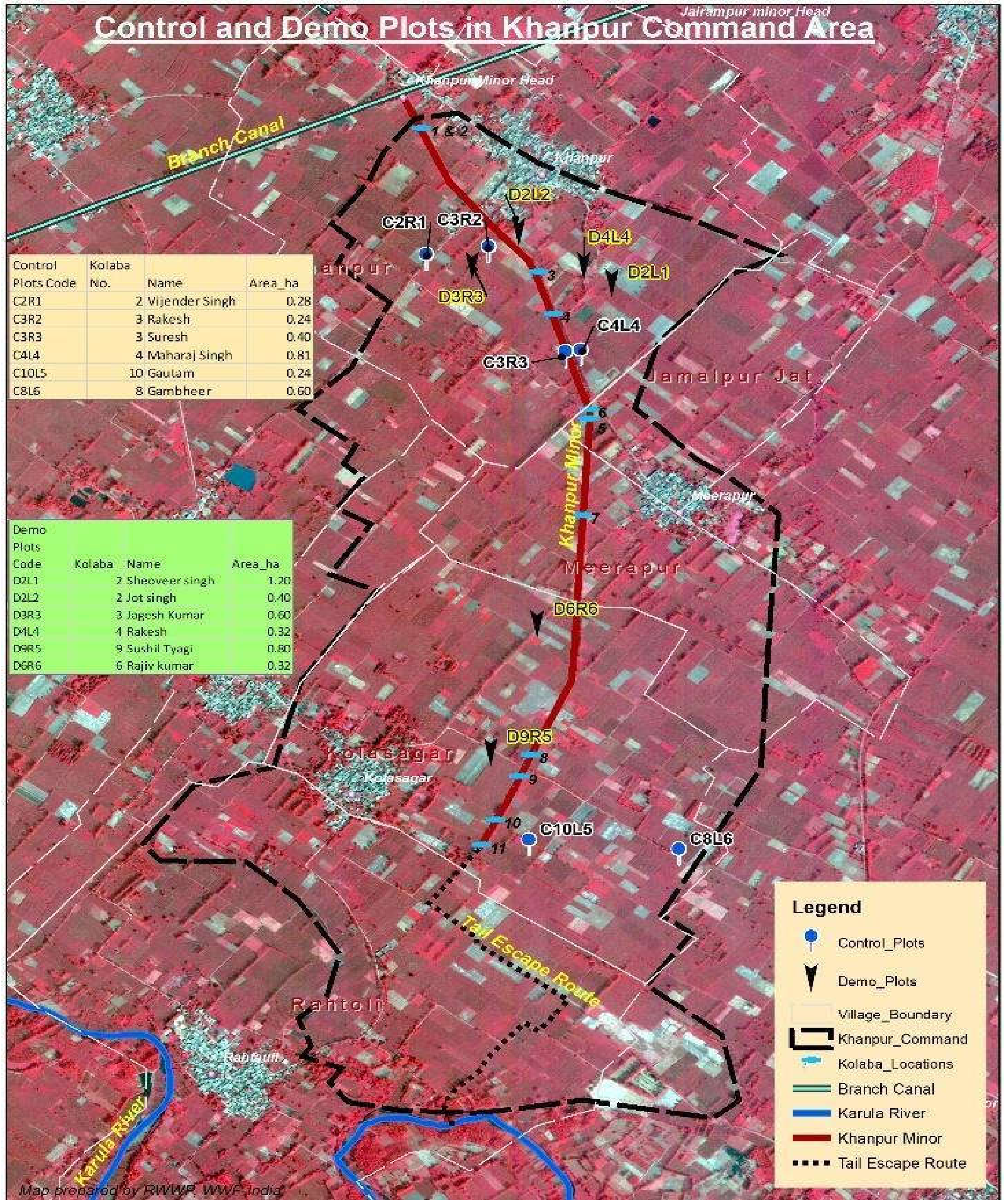
Appendix – 4

Khanpur Minor command area map with location of control and demo farms



Appendix A

Karula River Pilot

Joint Farmer Surveys

Objective

a. to understand the agriculture and irrigation practices in both demonstration farms and control farms
b. to ascertain the water-use at both categories of farms during watering and understand the variation in quantum of water that is used
c. to understand the agricultural productivity and its economic value, while calculating the entire input costing; so that net economic gains can be assessed

1. Basic details
   1.1 Date:
   1.2 Name of Farmer:
   1.3 Crop type:
   1.4 Farm size:
   1.5 Location on canal (H/M/T):
   1.6 Outlet Head Number

2. Irrigation water application

   2.1 Name of crop:
   2.2 Method of Irrigation (flooding, basin, furrow etc.):
   2.3 Source of Irrigation (canal, tube well, well etc.):
   2.4 Total time of irrigation (calculated from irrigation time per watering and number of waterings per crop):
   2.5 Total water depth applied:
3. Input details and costing
   3.1 Expense on seeds:
   3.2 Expense on labour (harrowing, ploughing, harvesting):
   3.3 Expense on compost:
   3.4 Expense on Fertilizers:
   3.5 Expense on Weedicides/pesticides:
4. Productivity and economic value
   4.1 Sugarcane productivity per unit area:
   4.2 Other crop productivity per unit area:
   4.3 Market rate per quintal of sugarcane:
   4.4 Market rate per quintal of other crop:

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