BENEFIT-COST ANALYSIS

WATER RESOURCE MANAGEMENT

Western Rajasthan: Expansion of Irrigation through Improvements in Water Use Efficiency in RAJASTHAN

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RAJASTHAN PRIORITIES
AN INDIA CONSENSUS PRIORITIZATION PROJECT

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Western Rajasthan: Expansion of Irrigation through Improvements in Water Use Efficiency and Rejuvenation of Traditional Water Harvesting Systems

Rajasthan Priorities
An India Consensus Prioritization Project

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Academic Abstract

This research paper is part of the India Consensus project undertaken by the Copenhagen Consensus and Tata Trusts which aims to promote greater focus on effective solutions for the country, informed by evidence of the benefits and costs of various interventions and policies. This paper evaluates the benefits and costs of two developmental interventions in the water sector that were identified for the state of Rajasthan namely 'Expansion of Irrigation through improvements in Water Use Efficiency' and 'Renovation of Traditional Water Harvesting Systems'.

Expansion of irrigation in the desert region of western Rajasthan through lifting canal water into diggies and using it for irrigation through sprinkler system and selection of crops that are less water-intensive enables farmers to take up crop production even in undulating land, having saline groundwater, thereby reducing irrigation water application requirements. An evaluation of the benefits and costs of such an intervention, arrived at by comparing the amount of water required to attain the income from a sprinkler irrigated plot under the traditional irrigation method using the same amount of water as consumed in the sprinkler irrigated plot, put the private, economic and social benefit-cost ratios at 2.25, 2.02 and 2.92 respectively, considering a discount rate of 5%.

The other intervention, Khadins, are runoff-harvesting systems which store water from the rocky catchments in the soil profile of the reservoir bed, for later use in crop production. A benefit- cost analysis of the direct income benefits of enhanced crop production in the khadin bed due to rejuvenation of the Khadin as well as the indirect benefits arising from improved recharge of groundwater in the shallow aquifer due to large water storage in the khadin, indicates a private benefit-cost ratio of 2.55 and a social benefit-cost ratio of 2.68 at a discount rate of 5%.

Sensitivity analysis shows that both the suggested interventions are valuable even at a higher discount rate (8%). It is expected that these interventions will find their place in the list of top interventions that would be promoted by the India Consensus at the end of the project as the most effective solutions to the country's challenges, so that the arable but arid land in

western Rajasthan can be used productively for increased agricultural output thereby leading to greater economic prosperity in the state.

Policy Abstract

Background

The India Consensus project conducted by the Copenhagen Consensus and Tata Trusts aims to promote greater focus on effective solutions for the country, informed by evidence of the costs and benefits of various interventions and policies. At the conclusion of this research project, the interventions will be ranked by an eminent panel of Nobel laureates and leading personalities in India and the top-ranking interventions will be promoted by the India Consensus as the most effective solutions to the country's challenges.

This research paper evaluates the benefits and costs of developmental interventions in the water sector for the state of Rajasthan. The study involved identification of two potential interventions in the state related to water management and also the region where the interventions were to be made, after which the benefit-cost analysis of each intervention was carried out. 'Expansion of Irrigation through Improvements in Water Use Efficiency' and 'Renovation of Traditional Water Harvesting Systems', are the interventions that have been identified for the water sector in Rajasthan after extensive review and study of literature, data and the ground realities in the state.

The following sections elaborate on the problems in Rajasthan with regard to the irrigation water sector, the interventions suggested, implementation considerations and the cost-benefit analysis for each intervention.

The Problem

The arid region of Western Rajasthan has vast amounts of arable land, probably the highest in India in per capita terms. The very low rainfall with high inter-annual variability and extreme aridity increase the demand for water for crop production. Crops cannot grow well in this region without external water inputs.

This study seeks to identify solutions in water resources development and water management in Rajasthan, initiated by the national or provincial governments or by national or international developmental agencies or private institutions, which have the potential to generate significant developmental outcomes with and without alterations, through benefit-cost analysis, in a manner that identifies and considers both the direct and indirect costs and benefits.

A substantial increase in area under irrigation and economic outputs from irrigated production would be possible only with the help of efficient irrigation technologies supported by storage, resulting in rational use of the imported surface water. Net income from a sprinkler-irrigated area was compared with the income from area irrigated by traditional method using the same volume of water as used under the sprinkler method. In addition to the direct benefits, the positive externality associated with water saving was estimated. In order to estimate water saving, the amount of water required to attain the same income from the irrigated plot under traditional irrigation method was compared against the actual water consumption in the sprinkler-irrigated plot.

Traditional runoff harvesting systems like Khadin store water from rocky catchments in the soil profile of the reservoir bed, for later use in crop production. The benefits and costs of renovating Khadins for runoff harvesting for crop production in the non-rainy season was analysed to identify the degree of impact of the intervention on the income benefits from enhanced crop production.

Intervention 1: Expansion of Irrigation

Overview

Expansion of irrigation in the desert region of western Rajasthan through lifting canal water into diggies and using it for irrigation through sprinkler system and selection of crops that are less water-intensive enables farmers to take up crop production even in undulating land, having saline groundwater, thereby reducing irrigation water application requirements. The incremental return per ha of (gross) irrigated area, against the incremental cost was compared. The incremental return from surface irrigation per ha of irrigated area was analysed for both direct gravity irrigation and pressurized irrigation using diggie and sprinkler.

Incremental return from surface water irrigation was evaluated by estimating the difference in current net return from irrigation over the net return that pre- surface water import (under rainfed condition or well irrigation) produced. In order to estimate water saving, the amount of water required to attain the same income from the irrigated plot under the traditional irrigation method was compared against the actual water consumption in the sprinkler-irrigated plot.

Implementation Considerations

The suggested intervention is irrigation expansion through water use efficiency improvement in the command area and the potential area of intervention is western Rajasthan. The traditional method of irrigation is small border irrigation. It is proposed to increase water use efficiency (WUE) through the use of micro sprinklers supported by storage using diggies.

It is assumed that farmers would adopt micro sprinklers with more water allocation to efficient crops and optimal dosage of farm inputs, to bring about high water use efficiency. The level of confidence in this intervention is high as is established by the study of primary data. The risk that may be considered in this intervention is the non-adoption of efficient irrigation technologies by some farmers.

The indicators for success would be increased rate of adoption of sprinkler irrigation technology, aggregate reduction in water use by farmers, reduced quantum of farm inputs including labour, crop area expansion and increase in water productivity.

Costs and Benefits

Costs

The annualized private capital cost discounted at a rate of 5% and assuming the life of the system to be 10 years, is Rs 15,069. Annualized Capital Cost (economic) with the initial capital investment (without the subsidy component) amortized using discounting techniques is Rs 16,747.

Benefits

Incremental income with sprinklers per ha of irrigated crop is Rs 33,900. Positive externality brought about by water saving of 1736 m3 per ha is Rs 14,986. Considering a discount rate of 5%, the private benefit-cost ratio is 2.25 and the economic benefit-cost ratio is 2.02. Social benefit which is the sum of private benefit and positive externality is Rs 48,886 and the social benefit-cost ratio is 2.92.

Intervention 2: Renovation of Traditional Water Harvesting Systems

Overview

Khadins are runoff-harvesting systems that store water from rocky catchments in the soil profile of the reservoir bed, for later use in crop production. Western Rajasthan, especially Pali and Nagaur districts, have thousands of traditional water-harvesting systems including Khadins.

This paper analyses the benefits and cost of renovating Khadins for runoff harvesting for crop production in the non-rainy season. The direct income benefits of enhanced crop production in the khadin bed are compared against irrigated production in the neighbouring areas to estimate the incremental economic benefits due to khadins. In addition, the indirect benefits of improved recharge of groundwater in the shallow aquifer due to large water storage in the khadin, is also considered in the benefit-cost calculations.

Implementation Considerations

The area suggested for renovation of the Khadins is western Rajasthan. The intervention is expected to directly impact the income, due to enhanced crop production in the khadin bed. In addition, the indirect benefits of improved recharge of groundwater in the shallow aquifer due to large water storage in the khadin, is also expected.

The confidence level for this proposed intervention is high, based on fieldwork carried out in Pali and Nagaur districts. One potential risk relates to maintanence of Khadins as they are productive only for three years after which maintenance works need to be carried out for their continued functioning. If the farmers fail to undertake maintenance work, the performance of the Khadins will be affected.

Indicators of success include increase in net income per ha brought under khadin bed, higher water levels in wells in the area surrounding the Khadin bed and reduced energy charges for pumping water, due to higher water levels in wells.

Costs and Benefits

Costs

Capital cost for rennovation of a Khadin is Rs 5,39,894. The life of the system is assumed to be 15 years and the capital cost was annualized considering a discount rate of 5%. The maintenance cost for these 15 years, which is undertaken 5 times i.e every three years, is Rs 53,989. The net present worth of the costs is Rs 7,35,875.

Benefits

Incremental income from crop production in the command area of the Khadin over irrigated cultivation is Rs 5,17,311. The Net Present Worth of the Private Benefits considering a discount rate of 5% is Rs 18,79,888, which is accrued once in three years. The positive externality as a result of saving in cost of energy for pumping groundwater is Rs 29,257, which is also accrued once in three years. Net Present Worth of the Indirect Benefits is Rs 94,897. Social benefit, which is the sum of the private benefit and positive externality, is Rs 19,74,785. For a discount rate of 5%, the private benefit-cost ratio is 2.55 and the social benefit-cost ratio is 2.68.

Expansion of Irrigation		
Attributes	Unit	Value (at 2017 prices)
Net cultivated area (western Rajasthan)	M ha	11.99
Net area irrigated by surface and groundwater sources	M ha	2.845
Total sprinkler irrigated area (ha)	ha	456.86
Weighted average of net income from crop production under traditional method of irrigation for the whole cropped area	Rs	1,11,15,088
Weighted average of net income from crop production under micro sprinkler irrigation for the whole cropped area	Rs	1,14,31,664
Incremental income with sprinklers per ha of irrigated crop	Rs/ha	33900
Water saving benefit/ha of sprinkler irrigated crop	M3/ha	1736
Annualized Capital Cost (private)	Rs/ha	15,069
Annualized Capital Cost (economic)	Rs/ha	16,747

Rejuvenation of Khadins		
Attributes	Unit	Value (at 2017 prices)
Average command area of the Khadin	Ha.	41
Incremental income from crop production in the command area of the Khadin over irrigated cultivation	Rs/ha.	5,17,311
Net Present Worth of the Private Benefits considering discount rate of 5%	Rs	18,79,888
Saving in cost of energy for pumping groundwater	Rs	29,257
Capital cost (of rennovation of Khadin)	Rs	5,39,894
Maintenance cost (once in three years during lifetime of 15 years)	Rs	53,989
Net Present Worth of the Costs at discount rate of 5%	Rs	7,35,875

BCR Table

Summary Table

Interventions	Benefit Rs/ha at 2017 prices	Cost Rs/ha at 2017 prices	BCR	Quality of Evidence
Expansion of Irrigation				
Private benefit-cost Ratio	33,900	15,069	2.25	Strong
Economic benefit-cost Ratio	33,900	16,747	2.02	Strong
Social benefit-cost Ratio	48,886	16,747	2.92	Strong
Renovation of Khadins				
Private benefit-cost Ratio	18,79,888	7,35,875	2.55	Strong
Social benefit-cost Ratio	19,74,785	7,35,875	2.68	Strong

Notes: All figures assume a 5% discount rate.

BCR Table for Discount rates of 3%, 5% and 8%

Interventions	Discount	Benefit at 2017 prices (INR/ha per year)	Cost at 2017 prices (INR/ha annualized)	BCR	Quality of Evidence
Private benefit-cost					
Expansion of Irrigation	3%	33900	13562	2.50	Strong
	5%	33900	15069	2.25	
	8%	33900	16576	2.05	
Renovation of Khadins	3%	2123290	761250	2.79	Strong
	5%	1879888	735875	2.55	
	8%	1592467	705911	2.26	
Economic benefit-cost					
Expansion of Irrigation	3%	33900	15072	2.25	Strong
	5%	33900	16747	2.02	
	8%	33900	18421	1.84	
Social benefit-cost					
Expansion of Irrigation	3%	48886	15072	3.24	Strong
	5%	48886	16747	2.92	
	8%	48886	18421	2.65	
Renovation of Khadins	3%	2230474	761250	2.93	Strong
	5%	1974785	735875	2.68	
	8%	1672855	705911	2.37	

1. Introduction

Rajasthan is characterized by low to very low rainfall and excessively high aridity due to high temperatures affecting large parts of the state. This is compounded by high inter-annual variability in climate parameters especially rainfall. The state has one of the lowest per capita renewable water resources in the world with an average annual per capita renewable freshwater availability of 532 cubic meters which is only slightly more than the international minimum of 500 cubic meters needed to avert what is referred to as a condition of absolute water scarcity. However, the natural environment (hydrology, geohydrology and climate), the characteristics of the physical systems of water supply, the socio-economic conditions and cultural environment vary remarkably from region to region. Such variations have significant implications for the water supply, irrigation potential and hence agricultural productivity of the different regions of the state.

The state has limited renewable surface water resources which is concentrated in the Southern and South-eastern parts. The only major surface water source for western and northwestern Rajasthan is the Indira Gandhi canal, which irrigates roughly 1 million hectares (m ha) of arid land in four districts from the region and also provides water for several drinking water supply schemes. All the rivers originating in the state, including the major rivers, are seasonal in nature. Some of the west flowing rivers of the state are highly ephemeral in nature and carry stream flows for only for a few days in a year, during the rainy season. In western Rajasthan, in most of the areas (except that of Luni river basin), drainage is internal, and streams are lost in the desert. The average annual renewable water availability varies from a lowest of 304 m3 per capita per annum in Shekhavati river basin to a highest of 1536 m3 per capita per annum in Chambal river basin.

In terms of availability, the entire region comprising the northern and northwestern parts of the state has abundant groundwater. However, the quality of native groundwater is very poor in most parts (except in pockets in the vicinity of large surface reservoirs and canal networks), with high levels of salinity and fluoride making it unfit for drinking while in most parts it is unsuitable for irrigation also due to excessively high salinity.

The gross groundwater irrigated area in the state is 2.96 m ha, which accounts for 54.2 per cent of the total irrigated area in the state. Livestock farming is the backbone of the rural economy in the dry regions of Rajasthan. It accounts for nearly 15% of the net state domestic product. The livestock holdings include cows, bullocks, small ruminants and camels. The total utilizable groundwater in the state has been estimated to be 8034.7 MCM, against which the total groundwater draft for various uses was estimated to be 11,599 MCM. Even at the aggregate level, groundwater is over-developed with the level of average annual abstraction exceeding the average annual recharge in 21 out of the 32 districts in Rajasthan.

2. Expansion of Irrigation

2.1 Description of intervention

A substantial increase in area under irrigation and economic outputs from irrigated production would be possible with the help of efficient irrigation technologies which result in the rational use of the imported surface water. The Indira Gandhi Nehar Project, which imports water from Sutlej in Punjab to the dry desert of western Rajasthan had led to vast expansion in area under crop production and improved the economic conditions of farmers in this region.

Indira Gandhi Canal

(Source: India Today)

The intervention considered is the expansion of surface water irrigation in the desert region of Rajasthan. Construction of diggies to store water, irrigation using sprinkler systems and choosing crops that are low water-intensive would enable farmers to take up crop production even in undulating land having saline groundwater, with low water application requirements. A major driver for adoption of efficient irrigation technologies would be 'rationing' of volumetric water allocation to the command areas by the irrigation agency.

2.2 Data

Net cultivated area (western Rajasthan) and net area irrigated by surface and groundwater sources are used in the analysis. Information about crops grown, triggers for improving water use efficiency and drivers of change in crop economics were obtained from primary data and analysis thereof. Weighted average of net income from crop production under traditional method of irrigation for the whole cropped area was estimated from actual field data, using standard methodology as explained in Kumar (2016). Weighted average of net income from crop production under micro sprinkler irrigation for the whole cropped area, as well as the total sprinkler irrigated area were established using primary data. Other information includes primary data regarding the use of water post irrigation adoption and the initial capital investment.

2.3 Literature Review

The Water Resources Department of the Government of Rajasthan has taken up two strategies to increase irrigated area.

Creation of new command area by tapping the surplus surface water from other basins

As per the Water Resources Departement (WRD), Rajasthan, the total cultivable land in the State is 257 lac ha, out of which 38.2 lac ha land has been covered through canal irrigation, 68.7 lac ha has been covered by tube wells/open wells or traditional irrigation systems like talabs and the remaining 150 lac ha is under rain fed agriculture. At present about 58% cultivable land is under rain fed agriculture.

The schemes by WRD intend to utilize surplus water and these include the Narmada Major Irrigation Project covering 246,000 ha of Canal Command Area (CCA), 6 Medium Irrigation Projects covering 40,031 ha of CCA and 49 Minor Irrigation Projects covering 46,846 Ha of CCA. The department has started work on the "Four Waters Concept" to use the surplus water from the Mahi, Chambal, Luni, Sukli and West Banas basins through construction of 267 minor irrigation tanks and 413 check dams to create additional command. By 2020, 110,000 ha of additional land area is expected to be covered through canal irrigation through these ongoing projects.

The new projects in the pipeline are Kalisindh Phase II and Parwan major irrigation projects, three medium irrigation projects, four proposals for inter linking rivers to transfer water from surplus basins to deficit basins and new works under Four Waters Concept of the Sabarmati Basin

Works for improving water use efficiency

In the past, the Rajasthan Water Sector Restructuring Project (RWSRP) and Japan International Co-operation Agency (JICA) had taken up many projects on Repair, Rennovation and Restoration (RRR) of old water bodies, Environmental Resources Management (ERM), farm development and Command Area Development (CAD), for improvement of water use efficiency. The department has implemented pilot sprinkler irrigation projects in 24 minors of IGNP (Indira Gandhi Nahar Pariyoyana) Stage II lifts in 287,32 ha of CCA.

The activities taken up by the department, for improvement of water use efficiency, are repair of 32 old water bodies under the RRR project of the Government of India (GoI) amounting to Rs. 90 crore, CAD Water Management (WM) works in 1.6 lac ha of CCA, revamping of Chambal Canal System amounting to Rs. 1,274 crore, 113 numbers of works under ERM and designing the Narmada Irrigation Project on sprinkler irrigation covering 2.46 lac ha of CCA.77 projects under RRR of GoI, 5 projects under ERM under State Plan and 22 projects under ERM of GoI are in the pipeline. An area of 3.2 ha from 6 lift schemes of IGNP stage II will be covered by pressure irrigation technology with an estimated cost of Rs. 2,012.56 crore partially funded by the Ministry of Water Resources (MoWR), GoI, under Command Area Development and Water Management (CADWM).

A policy is being prepared to cover the command of existing irrigation projects by pressure irrigation in a phased manner by making it mandatory in new irrigation projects. 433 projects have been proposed under JICA II. A separate policy for desilting of dams/tanks to ensure full storage capacity utilization of the structures is also being proposed. Other activities include the construction of lined watercourses in CCA of 113,420 ha of Bhakhra canal systems, construction of lined watercourses in CCA of 164,337 ha of Ganga Canal Project and relining of Indira Gandhi Feeder (Punjab Portion) and Sirhind Feeder. A hydrology project funded by the World Bank has been sanctioned for scientific study of rainfall to determine accurate availability of water.

Issues have been identified relating to the financing of implementation, and operation and maintenance of projects of the central and state governments and also the Panchayati raj institutions which need to be addressed (Amarasinghe et al, nd).

Diggis and Warabandi System in IGNP

Groundwater is virtually the only source of irrigation in the southern plateau and arid region of the west (93% and 92% respectively) and dominates irrigation in southern and eastern plain regions (79% and 65% respectively). However, canals provide almost all the irrigation in the arid north region. The IGNP project, popularly known as the Rajasthan canal, is the largest surface irrigation project in arid northwest. The warabandi is the system of water deliveries in the IGNP project to promote equitable distribution of water, but water deliveries at times become unreliable or inefficient.

A diggi is a small pond to store the canal water supply that addresses the reliability issue through a self enforcement mechanism and corrects the allocation inefficiency of water use. With diggis, farmers are able to irrigate all their cultivated area compared to only two-thirds of the area before diggi construction. The increase is significant and is uniform across all reaches in canal command and groundwater irrigated areas. Due to significantly lower number of hours of canal water supply, the farms without diggis in the middle reach irrigate only 79 per cent of the cultivated area. Farmers with diggis use sprinkler irrigation systems to irrigate their crops, and this allows them to irrigate even the undulated land, which the direct canal irrigation did not allow, and as a result it increases the irrigation coverage substantially. Overall, the crop area has increased by 33 percent with diggi construction. A similar increase is evident in groundwater- irrigated areas where farms with diggis irrigate almost all the cropped area.

The average gross value of output of farms with diggis is significantly higher than of those without diggis. It is 39 per cent higher in kharif season, and 21 per cent higher in Rabi season. However, there are significant differences of increments in different canal reaches. Even in the groundwater-irrigated areas, benefits of introducing a diggi far outweigh the cost. A farmer can recover the full cost of constructing a diggi on a farm with land holding size 10 ha, after 3 years. (Amarasinghe et al, nd)

The Rajasthan Water Sector Livelihood Improvement Project (RWSLIP), under the Water Resources Department, Government of Rajasthan, was intended to increase and stabilize agricultural production in Rajasthan State. The Government of Rajasthan implemented the Rajasthan Minor Irrigation Improvement Project (RAJAMIIP) from 2005 to 2015 under a JICA official development assistance (ODA) loan. In addition to the rehabilitation of the irrigation facilities, the project enhanced and organized Water Users Associations (WUAs) which are the main actors in the operation and maintenance of the facilities rehabilitated under the project. In addition, farming support activities were implemented in collaboration with the Department of Agriculture (DoA) and contributed to the improvement of agricultural production (JICA and NKL, 2017).

2.4 Calculation of Costs and Benefits

The incremental return per ha of (gross) irrigated area was compared against the incremental cost. The incremental return from surface irrigation per ha of irrigated area was analysed for both direct gravity irrigation and pressurized irrigation using diggie and sprinkler. This estimation was done in such a way that the effect of increase in gross cropped area due to irrigation was captured along with that of irrigation on crops in the form of yield, etc. Incremental return from surface water irrigation was evaluated by estimating the difference in current net return from irrigation over the net return that pre- surface water import (under rainfed condition or well irrigation) produced.

Since micro irrigation is practised by farmers under a scenario of sharply reduced water release, a straight comparison of net income from the area under sprinkler irrigation and that from the area under traditional method of irrigation will be meaningless. As such, the net income from a sprinkler-irrigated plot was compared against that from plots irrigated under traditional method with the same of volumetric water as under sprinkler method.

In addition to the direct benefits, the positive externality associated with water saving was estimated. In order to estimate water saving, the amount of water required to attain the same income in irrigated plot under traditional irrigation method was compared against the actual water consumption in the sprinkler-irrigated plot (Kumar, 2016). This is the only method to estimate water saving, as the area under irrigation post adoption, and the income are different.

In the case of benefit cost evaluation of micro irrigation systems in western Rajasthan, the methodology adopted is very different from what has normally been used for evaluating the benefits of MI systems. In the normal case, the water supply situation remains the same (between pre and post adoption), and the extent of increase in crop yields and reduction in water use per unit area of land resulting from the use of MI technology are estimated and economic value of these benefits are quantified. However, in this case, the water allocation had dramatically changed from the pre-MI adoption scenario and a sharp reduction in water allocation through canals had promoted the farmers to adopt MI systems on a large scale. The availability of subsidies for micro sprinklers had enabled this. The irrigated cropped area and income per ha under the post adoption scenario did not correspond to the same amount of water use as that of pre-adoption scenario. Hence for estimating the incremental income post adoption, the net income for pre-adoption scenario had to be adjusted to make it correspond to the same amount of water use as that of post-adoption. The incremental income provided the basis for estimating the direct benefit. However, there is a hidden indirect benefit, which cannot be ignored. In spite of a large reduction in water allocation, which is the major and perhaps the only constraint to increasing crop production and raise the income of farmers in the region, the MI technology had enabled enhanced production of crops and net income leading to a remarkable increase in water use efficiency. Had the technology not been used, it would have led to farmers depleting the scarce surface water resources to increase the production as other sources of water are not available in the region to achieve the same crop and economic outputs. Therefore, the water equivalent of the substantial additional income obtained for the same dose of water cannot be ignored. The approach used for estimating this water saving benefit was ‘water use efficiency gain’.

Reviewers from Copenhagen Consensus suggest that only one of the benefits can be counted. Either water allocation is fixed, and the benefit is the change in net income between the two technologies; or net income is fixed, and the benefit is the change in value of water used. I do not agree with this framing.

This methodology draws its theoretical foundations from virtual water trade concept. We examined how much water it would have taken to generate the net income obtained by farmers under MI system, had traditional method been employed and compared it against the actual amount of water used under MI system. This is same as the water equivalent of the incremental net income produced through the use of MI technology in a scenario wherein the precision irrigation technology is assumed to be absent. However, such an approach would have led to 'double counting' of benefits, if the aggregate water use by farmers in the region was less than the estimated water use, or if the region doesn't have extra water to produce the additional crop and income outputs obtained through MI use in which case the water saving that we estimate would be unreal. That said, the economic value of this virtual water saving was estimated by taking the average economic value of use of the same water for crop production. Now this technology has a potential for scalability in western Rajasthan situation, where a large amount of water from Sutlej river is transferred for crop production and yet a large proportion of the irrigated area is still under traditional method of irrigation. Rationing water allocation in the existing command areas supported by intermediate storage systems and micro sprinklers and drips can lead to vast expansion in area under cultivation, with the agency being able to take water to new areas which are currently not under irrigation. The current study is based on empirical data on water use, yield, input use and income obtained from plots irrigated by micro sprinklers and has shown substantial benefits. If the sprinklers are replaced by drips (with the introduction of high value fruits, vegetables and flowers), the yield gain and water use efficiency gain (through reduction in water use and increase in yield) would be even larger, though the area under such crops can be quite limited at the regional scale in lieu of the market constraints. Some of the high value crops that are now grown in western Rajasthan and which have very good local market are chillies, tomatoes, cauli-flower, capsicum, brinjal, marigold, seedless cucumber, berries and *kinnow* orange.

The total cultivated land (in 1000 ha) in the ten districts of Western Rajasthan is 11,989. The gross irrigated area (in 1000 ha) is 4,666 and net irrigated area (in 1000 ha) is 2.845. As on 2010, the area under sprinkler irrigation is 8, 66,592 ha and area under drip irrigation is 1,70,098 ha in Rajasthan (Sanakaranarayanan et al, 2011).

2.4.1 Calculations

Private benefit-cost ratio was calculated as the ratio of incremental income with sprinklers per ha of irrigated crop to the annualized private capital cost (with subsidies), while the economic benefit-cost ratio was calculated as the ratio of the incremental income with sprinklers per ha of irrigated crop to the annualized economic capital cost (without subsidies). Social benefit-cost is the ratio of social benefit (private benfit plus externalities) to the annualized economic capital cost.

The irrigated area considered for estimating income under traditional method of irrigation was adjusted to the amount of water available in the sprinkler irrigation scenario, which is 37% of the base case. The initial annual private capital investment and the annual economic investment without the subsidy component were amortized using the discounting technique, the discount being 5%. Social benefit was calculated as the sum of private benefit and positive externality, the positive externality being from water saving. The economic value of water was estimated as Rs.8.64/m^3 under traditional method of irrigation.

Net cultivated area is 11.99 M ha and net area irrigated by surface and groundwater sources is 2.845 M ha. Total sprinkler irrigated area is 456.86 ha. Incremental income with sprinklers per ha of irrigated crop ((Total net income under sprinker -Total net income under TMI X RF)/area under sprinkler irrigated crop) worked out to Rs 33900/ha. Positive externality affected by water saving is Rs 14986.

The following values were obtained for the benefit-cost ratios:

Private benefit-cost Ratio – 2.25

Economic benefit-cost Ratio – 2.02

Social benefit-cost ratio – 2.92

Intervention	Discount	Benefit (INR/ha per year)	Cost (INR/ha annualized)	BCR	Quality of Evidence
Private benefit-cost					
Expansion of Irrigation	3%	33900	13562	2.50	Strong
	5%	33900	15069	2.25	
	8%	33900	16576	2.05	
Economic benefit-cost					
Expansion of Irrigation	3%	33900	15072	2.25	Strong
	5%	33900	16747	2.02	
	8%	33900	18421	1.84	
Social benefit-cost					
Expansion of Irrigation	3%	48886	15072	3.24	Strong
	5%	48886	16747	2.92	
	8%	48886	18421	2.65	

2.5 Assessment of Quality of Evidence

Data on crops grown and water saving benefit/ha of sprinkler-irrigated crop were obtained from primary data. Data on triggers for improving water use efficiency was obtained from farmer interviews while data on drivers of change in crop economics and net income from crop production under traditional method of irrigation for the whole cropped area were obtained from analysis of primary data. Hence the level of confidence on the quality of evidence for all these attributes is high. As for water saving, the average economic value of water use in agriculture in the area is taken for estimating the positive externality due to water saving, which is the minimum level of benefit that can be expected and hence the confidence in the quality of evidence is 100%.

2.6 Sensitivity Analysis

A sensitivity analysis was performed to understand the impact of external factors on the profitability of the intervention. For the purpose, B/C ratio was estimated for three different discount rates (3%, 5% and 8%) as this is one major external factor which is controlled by market. The range of selected discount rates captures the lows and highs that a market may experience. The social benefit cost ratio at 3% discount rate was estimated to be 3.24, at 5% discount rate 2.92 and at 8% discount rate 2.65. Even at a high discount rate of 8%, the intervention seems to be valuable. Hence, the assumtions considered for the economic assessment of irrigation expansion in western Rajasthan through lifting canal water into diggies and using it for irrigation through sprinkler system and selection of crops that are less water-intensive are quite robust.

3. Renovation of Traditional Water Harvesting Systems

3.1 Description of intervention

Rajasthan is historically known for several types of traditional water harvesting systems including Khadins, Nadi, tankas and Johads, for both rainwater harvesting and runoff harvesting for drinking water, domestic and livestock uses and irrigation. Khadins are runoff harvesting systems which store water from the rocky catchments in the soil profile of the reservoir bed, for later use in crop production. Western Rajasthan, especially Pali and Nagaur districts, have thousands of traditional water-harvesting systems. Renovation of Khadins for runoff harvesting is expected to increase crop production particularly in the non-rainy season.

Khadin

Source: Scroll.in

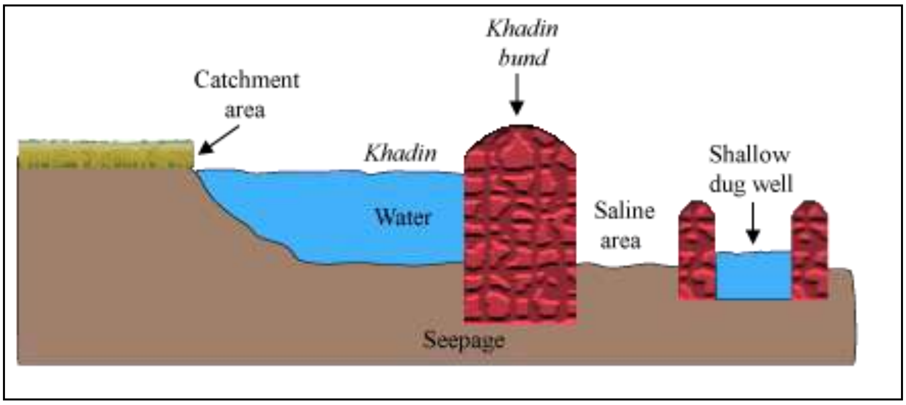
3.2 Data

Data on total cultivable area and net area irrigated by surface and groundwater sources were obtained from official sources of the Government of India. Average command area of the Khadin and data of the drivers of change in crop economics was obtained from fieldwork carried out in Pali and Nagaur districts. Primary data was collected on the differential water level fluctuations in the influence area of Khadins. The capital cost for renovating the Khadins and the maintenance cost incurred every three years were based on actual cost figures from the project implementing agencies.

3.3 Literature Review

In Rajasthan, there are various traditional water resource systems like Khadin, nadi, talab, johad, bandha, sagar, samanad and sarovar, to name a few.

Khadins: The khadin system is the runoff agricultural system. The runoff water from high catchment areas is stored with the help of khadin bunds. It is impounded during the monsoon season. The system is mainly based on the principle of rainwater harvesting on farmland and subsequent use of this water enriched land for crop production. The khadin soils remain moist for a long period because of water storage, and chemical weathering and decomposition along with the activities of microbes eventually raise the organic and other nutrient content of the soil.



Khadins have functioned efficiently for centuries maintaining the soil fertility. Khadins are mainly found in the districts of Jaisalmer, Jodhpur, Bikaner and Barmer of Rajasthan. There are still 500 big and small khadins covering an area of 12,000 Ha in the Stat.

Case Study on Socio-Economic Analysis of Water Harvesting Structures in Rajasthan (Bassi and Vedantam, 2013)

This case study analyzes the hydrological and economic impacts of traditional water harvesting structures in Western Rajasthan. The Khadin selected for the case study was rehabilitated in the year of 2008 at a cost of Rs 3.50 lakh. The rehabilitation of the khadin consists of construction of an embankment with a waste weir. The structure has a total catchments area of 1700 ha and an earthen embankment of about 1.3 km length. The intervention has led to increase in cropped area and well recharge benefits in the immediate vicinity. After the construction of Khadin, nearly 41 hectares of land belonging to 5 households have been brought under crop cultivation. It is estimated that the farmers were able to get 36% higher yield for jowar and 25% higher yield for green gram inside the khadin in comparison to the cropped land outside the khadin. Also, the mean net returns (Rs/bigha) were higher for all the three crops grown inside the Khadin; for bajra it was nearly 9%, for jowar it was 42% and for green gram it was 54% higher in comparison to the crops grown outside the khadin area.

It was observed that the selected khadin was able to provide a recharge benefit to the 11 wells located in its direct influence area. Out of these 11 wells, one was located in the upstream and 10 were located in the downstream with reference to the Khadin. Recorded data from these observation wells show an average rise of 2.31 m in the water level between pre- and post-monsoon months.

3.4 Calculation of Costs and Benefits

Western Rajasthan had large number of traditional water harnessing systems, for both runoff -harvesting for direct irrigation and drinking water supply and conserving water in the soil profile for crop production after the short monsoon period. The benefit cost analysis provided in the paper is based on a study of khadins, which were renovated by an NGO in western Rajasthan. The khadins were lying completely defunct due to non-repair of the waste weir and bunds. There are several thousands of such structures lying in dilapidated condition in western Rajasthan. They can be taken up for renovation. These structures have very good rocky catchments, and they produce sufficient runoff during high rainfall years, though they do not yield any benefit during drought years, which are very common in the region due to the high variability in the rainfall. The renovation of the structure helps not only in raising the production of crops in the khadin bed but also in raising water table in the area. In a water-scarce region like western Rajasthan (having all the river basins there remaining 'closed'), the water captured in the khadin would otherwise be available to the downstream area for irrigation through groundwater recharge from the stream channels, and hence there is an opportunity cost of using water from the system. This opportunity cost would be approximately equal to the net income benefits from well irrigation in the region. Because of this reason, the direct benefits from irrigated crop production in the khadin bed were not considered for benefit cost evaluation. Instead, the incremental benefit over irrigated crop production in the neighbouring well irrigated areas was considered. The analysis which shows high economic benefit from *khadin* renovation, however doesn't suggest that the scheme can be replicated everywhere in western Rajasthan. For the scheme to be successful, there is a need for sufficient catchment area that is capable of producing sufficient amount of un-committed runoff for harvesting in the sense that it creates no downstream negative impacts. Hence it is advisable that only the existing khadins that are lying in dilapidated condition be taken up for renovation.

The direct income benefits of enhanced crop production in the khadin bed were compared against irrigated production in the neighbouring areas to estimate the incremental economic benefits due to khadins. This is the difference between net income per ha under khadin bed over net income per ha under irrigated cultivation outside khadin, multiplied by the total area under cultivation in the khadin bed. As explained in the previous paragraph, The reason for taking the incremental income over irrigated cultivation is to internalize the negative externality of harvesting rainwater in the khadin on downstream water availability and irrigation. The average command area of the Khadin is 41 ha.

In addition, the indirect benefits of improved recharge of groundwater in the shallow aquifer due to large water storage in the khadin were also considered in the benefit-cost calculations. The positive externality arises from a reduction in energy use for pumping groundwater due to rise in water levels in 11 wells in the surrounding area.

It is assumed that the khadins will be productive only once in three years (1, 4, 7, 10 and the 13th year). This is based on field research, and primary data collected from the farmers in Pali district.

3.4.1 Calculations

The private benefit-cost ratio was calculated as the ratio of the net present worth of the private benefits to the net present worth of the costs. The life of the Khadin system is assumed to be 15 years with need for maintenance every three years. Social benefit-cost ratio was calculated as the ratio of social benefit to the net present worth of the costs. Social benefit is the sum of private benefit and positive externality. The discount rate considered was 5%. The following values were obtained for the private and social benefit-cost ratios.

The average command area of the Khadin is 41 ha. Incremental income from crop production in the command area of the Khadin over irrigated cultivation is Rs 517,311 per hectare.

Private benefit-cost ratio - 2.55

Social benefit-cost ratio - 2.68

Interventions	Discount	Benefit (INR/ha per year)	Cost (INR/ha annualized)	BCR	Quality of Evidence
Private benefit-cost					
Renovation of Khadins	3%	2123290	761250	2.79	Strong
	5%	1879888	735875	2.55	
	8%	1592467	705911	2.26	
Social benefit-cost					
Renovation of Khadins	3%	2230474	761250	2.93	Strong
	5%	1974785	735875	2.68	
	8%	1672855	705911	2.37	

3.5 Assessment of Quality of Evidence

Data on total cultivable area and net area irrigated by surface and groundwater sources were obtained from official sources of the Government of India. Therefore, the confidence level on the quality of evidence on these attributes is strong. Data on the drivers of change in crop economics is based on fieldwork carried out in the districts of Pali and Nagaur and the average command area of the Khadin was obtained from primary survey. The differential water level fluctuations in the influential area of Khadin were also based on primary data obtained from the field. As such the confidence level on the quality of evidence for these data is also strong.

3.6 Sensitivity Analysis

A sensitivity analysis was performed to understand the impact of external factors on the profitability of the intervention. For the purpose, B/C ratio was estimated for three different discount rates (3%, 5% and 8%) as this is one major external factor which is controlled by market. The range of selected discount rates captures the lows and highs that a market may experience. The social benefit cost ratio at 3% discount rate was estimated to be 2.93, at 5% discount rate 2.68 and at 8% discount rate 2.37. Even at a high discount rate of 8%, the intervention seems to be valuable. Hence, the assumtions considered for the economic assessment of renovation of traditional water harvesting structures such as khadins are quite robust.

4. Conclusion

The arid region of Western Rajasthan has vast amounts of arable land but due to very low rainfall with high inter-annual variability, and extreme aridity, crops cannot grow well in this region without external water inputs. Two interventions are suggested for the state of Rajasthan as solutions to this problem and an analyis of the benefits and cost of these developmental interventions were undertaken.

The suggested interventions are: 'Expansion of Irrigation through improvements in Water Use Efficiency' and 'Renovation of Traditional Water Harvesting Systems'.

Expansion of surface water irrigation in the desert region of Rajasthan is possible through construction of diggies, irrigation using sprinkler systems and choice of low water intensive crops. This would enable farmers to take up crop production even in undulating land having saline groundwater, with reduced water application requirements. The incremental return per ha of (gross) irrigated area due to the intervention was compared against the incremental cost of the intervention. Private benefit-cost ratio was calculated as the ratio of incremental income with sprinklers per ha of irrigated crop to the annualized private capital cost (wuth subsidies), while the economic benefit-cost ratio was calculated as the ratio of the incremental income with sprinklers per ha of irrigated crop to the annualized economic capital cost (without subsidies). Social benefit-cost is the ratio of social benefit (private benefits plus positive externalities) to the annualized economic capital cost. The private benefit-cost ratio, economic benefit-cost ratio and the social benefit-cost ratio work out to be 2.25, 2.02 and 2.92, respectively for a discount rate of 5%.

The renovation of Khadins for runoff harvesting not only enables crop production in the non-rainy season but also raises the water level in wells in the Khadin influence area, leading to reduced energy costs for pumping ground water. The direct income benefits of enhanced crop production in the khadin bed as compared to irrigated production in the neighbouring areas, and the indirect benefits of improved recharge of groundwater in the shallow aquifer due to large water storage in the khadin, are considered for calculating the benefit-cost ratios of the intervention. The private and social benefit-cost ratios work out to be 2.55 and 2.68 respectively, for a discount rate of 5%.

The table below summarises the benefits and cost at discount rates of 3%, 5%, and 8%. The benefit cost ratio reduces as discount rate increases. In the case of Rajasthan, for both the proposed interventions, the benefit cost ratios are greater than 2 even for a discount rate of 8% except in the case of economic benefit cost ratio which has a value of 1.84 for a discount rate of 8%. Even this is higher than 1.25 below which the intervention is considered to be not advantageous.

Summary Table

Expansion of Irrigation		
Attributes	Unit	Value (at 2017 prices)
Net cultivated area (western Rajasthan)	M ha	11.99
Net area irrigated by surface and groundwater sources	M ha	2.845
Total sprinkler irrigated area (ha)	ha	456.86
Weighted average of net income from crop production under traditional method of irrigation for the whole cropped area	Rs	1,11,15,088
Weighted average of net income from crop production under micro sprinkler irrigation for the whole cropped area	Rs	1,14,31,664
Incremental income with sprinklers per ha of irrigated crop	Rs/ha	33900
Water saving benefit/ha of sprinkler irrigated crop	M3/ha	1736
Annualized Capital Cost (private)	Rs/ha	15,069
Annualized Capital Cost (economic)	Rs/ha	16,747

Rejuvenation of Khadins		
Attributes	Unit	Value (at 2017 prices)
Average command area of the Khadin	Ha.	41
Incremental income from crop production in the command area of the Khadin over irrigated cultivation	Rs/ha.	5,17,311
Net Present Worth of the Private Benefits considering discount rate of 5%	Rs	18,79,888
Saving in cost of energy for pumping groundwater	Rs	29,257
Capital cost (of rennovation of Khadin)	Rs	5,39,894
Maintenance cost (once in three years during lifetime of 15 years)	Rs	53,989
Net Present Worth of the Costs at discount rate of 5%	Rs	7,35,875

BCR Table

Interventions	Discount	Benefit at 2017 prices (INR/ha per year)	Cost at 2017 prices (INR/ha annualized)	BCR	Quality of Evidence
Private benefit-cost					
Expansion of Irrigation	3%	33900	13562	2.50	Strong
	5%	33900	15069	2.25	
	8%	33900	16576	2.05	
Renovation of Khadins	3%	2123290	761250	2.79	Strong
	5%	1879888	735875	2.55	
	8%	1592467	705911	2.26	
Economic benefit-cost					
Expansion of Irrigation	3%	33900	15072	2.25	Strong
	5%	33900	16747	2.02	
	8%	33900	18421	1.84	
Social benefit-cost					
Expansion of Irrigation	3%	48886	15072	3.24	Strong
	5%	48886	16747	2.92	
	8%	48886	18421	2.65	
Renovation of Khadins	3%	2230474	761250	2.93	Strong
	5%	1974785	735875	2.68	
	8%	1672855	705911	2.37	

5. References

Bassi, N. and Vendantam, N., (2013). Traditional and modern systems for addressing water scarcity: impacts of khadins and sub-surface dykes in arid environment of western Rajasthan. *Review of Development and Change, 18*(2), pp. 131-148.

Bhalge, P. and Bhavsar, C., (2007). Water management in arid and semi arid zone: traditional wisdom. International History Seminar on Irrigation and Drainage, Tehran-Iran, pp. 423-428.

Bhattacharya, S., (2015). Traditional water harvesting structures and sustainable water management in India: a socio-hydrological review. *International Letters of Natural Sciences*, pp. 37.

CGWB, (2011). *Select case studies rain harvesting and artificial recharge*. Central Groundwater Board, Ministry of Water Resources, New Delhi.

Directorate of Agriculture, (2016). Rajasthan Agricultural Statistics at a Glance 2014-15. DoA, Government of Rajasthan, Jaipur, Rajasthan, India.

Dhiman S. C. and Gupta S., (2011). *Rainwater harvesting and artificial recharge*. Central Ground Water Board, Ministry of Water Resources, New Delhi.

Japan International Cooperation Agency (JICA) and Nippon KOEI Co Ltd., (2017). *The preparatory survey on Rajasthan water sector livelihood improvement project*. Final Report Advance Version, Volume I. Water Resource Department, Government of Rajasthan.

Kumar, M. D., (2016). 'Wet' water saving and social benefits from micro irrigation: a study from IGNP command area in Rajasthan. In Viswanathan et al. (Eds), *Micro irrigation systems in India: emergence, status and impacts*. Springer, Singapore.

Ministry of Rural Development, (2004). *Water harvesting and artificial recharge*. Rajiv Gandhi National Drinking Water Commission, Government of India, New Delh

Rajasthan is the largest Indian state. It has a diversified economy, with mining, agriculture and tourism. Rajasthan has shown significant progress in improving governance and tackling corruption. However, it continues to face acute social and economic development challenges, and poverty remains widespread. What should local, state and national policymakers, donors, NGOs and businesses focus on first, to improve development and overcome the state's remaining issues? With limited resources and time, it is crucial that priorities are informed by what can be achieved by each rupee spent. To fulfil the state vision of "a healthy, educated, gender sensitive, prosperous and smiling Rajasthan with a well-developed economic infrastructure", Rajasthan needs to focus on the areas where the most can be achieved. It needs to leverage its core competencies to accelerate growth and ensure people achieve higher living standards. Rajasthan Priorities, as part of the larger India Consensus – a partnership between Tata Trusts and the Copenhagen Consensus Center, will work with stakeholders across the state to identify, analyze, and prioritize the best solutions to state challenges. It will commission some of the best economists in India, Rajasthan, and the world to calculate the social, environmental and economic costs and benefits of proposals.

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