Groundwater recharge is an important impact of various water harvesting interventions. A direct consequence of increased groundwater recharge in an aquifer is a range of social and economic benefits accruing from it – through improved provisioning of drinking water, irrigation and other uses. One of the visible economic benefits is often through supplemental irrigation to crops and increase in cropping intensity. The question often arising is how much of the agrarian impact is normative, attributable to broader changes in the economy, environment and society; and how much of it can be attributed to the specific intervention of water harvesting resulting in groundwater recharge. Taking an example of river basin scale interventions by AKRSP (I) on decentralized water harvesting, we propose different methodological possibilities to overcome this problem. Since these different methods utilize varied data sets, approaches and assumptions, they potentially provide us an opportunity to triangulate and arrive at ranges of attributable impacts. With increasing availability of remotely sensed images and public data sets, these methods are going to be easier to implement and could present viable alternatives to current methods for attributing impacts.

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HIGHLIGHT

Assessing the Agrarian Impact of Decentralized Water Harvesting at the Basin Scale

A Discussion on Methodology

Shilp Verma and Sunderrajan Krishnan

Assessing the Agrarian Impact of Decentralized Water Harvesting at the Basin Scale

A Discussion on Methodology[1]

Research highlight based on Verma and Krishnan (2012)[2]

In 2002, the Aga Khan Foundation (AKF) initiated a European Commission (EC) supported program *"to stimulate economic development and enhance and protect the livelihoods of the rural poor in resource poor areas of central-west India"*. The key idea behind the program was to build on several years of field experience and contribute to *"effective poverty reduction"* by demonstrating and promoting innovative approaches to community-based natural resource management (AKF 2001). In 2009, as the program started nearing completion, AKRSP (I) approached the International Water Management Institute (IWMI) and INREM Foundation to undertake a review of the work done under the SCALE program in the Meghal River Basin. The 20-month long study thus undertaken looked at various aspects of AKRSP (I)'s work: (1) Hydrological impact; (2) Socio-Economic impact; and (3) Institutional sustainability (Verma and Krishnan 2012). This Highlight presents the results from the socio-economic impact study and discusses methodological complexities and issues faced in the process.

AKRSP (I)'s interventions in the Meghal river basin

The Meghal river basin work of AKRSP (I) involves a range of interventions over the span of a decade. The interventions include: building a river basin identity among the communities; support to the formation of village-level groups congregating into an informal, flat-hierarchy, basin-wide Core Group; and utilizing this basin identity to introduce a variety of concepts in water harvesting and conservation, agriculture water management etc. We envisage that the impacts of these interventions can be understood over different dimensions e.g. crop productivity, labor productivity, water availability etc. The combined effect of all these interventions across the river basin might not be directly the sum of individual impacts; and therefore not simply additive. For example, the use of water savings technologies and practices might lead to expansion of irrigated area and/or gross cropped area. The net impact might be improved efficiency of applied water but might not translate into *real water saving* at the basin level. Likewise, a combination of several interventions might lead to a net impact that is greater than the sum of individual interventions. The secondary and tertiary impacts on the village and basin economy can therefore be difficult to capture and tricky to measure.

The broad objective of the Meghal Basin Socio-Economic study (Verma and Krishnan 2012) was to quantify and understand the impact of AKRSP (I) interventions on the socio-economic welfare of the people. Since the basin is predominantly agrarian, we focused on immediate impacts on basin agriculture directly (through increased productivity and value) and indirectly (via impact on rural banking and agricultural product markets). For this, we conducted a survey in all the villages of the basin. This survey collected data on cropping pattern and cropping intensity; irrigation sources and irrigation intensity; and crop yields and prices (in 2000-01 and 2010-11) to quantify the growth in agricultural production and value. In addition, we collected some data on rural credit from local banks in the basin and visited several agricultural marketing yards. We found that data from local bank branches was difficult to use for our analyses since several of the branches we visited were new themselves and it was not possible to get comparable data for 2000-01. However, the mushrooming of bank branches is itself a qualitative indicator of the growth of the local economy. Likewise, data for business in agricultural marketing yards *(mandis)* was either poorly maintained or inaccessible or both. We have therefore relied only on our primary data for this analysis.

[1]This IWMI-Tata Highlight is based on research carried out by INREM Foundation and its partners with support from AKRSP (I). This is not externally peer-reviewed and the views expressed are of the authors alone and not of IWMI or its funding partners.

[2]This paper is available on request from p.reghu@cgiar.org

Agrarian impact of decentralized water harvesting

Real impact or mere redistribution?

Several studies have been conducted on the localized impacts of decentralized water harvesting and groundwater recharge in Saurashtra. Almost all of them echo a strong, upbeat sentiment about the impact of water harvesting structures on the village agriculture economy. These include: improvements in productivity of irrigation wells (Joshi 2002; Raval 2002), crop output (Joshi 2002; Bhammar 2002), availability of wage labor (Raval 2002), higher cropping intensity (Bhammar 2002) etc. However, it is the impact at the river basin and regional scale that has been an issue of much concern and debate (Shah et al. 2005; Kumar et al. 2008; Verma et al. 2008; Verma 2009).

At the same time, critics and sceptics have argued that chaotic, unplanned growth of decentralized water harvesting structures will cannibalize existing dams and reservoirs downstream. Kumar et al. (2008), for instance, argue that river basins in Saurashtra already have more storage capacity than needed and that the existing 100-odd medium irrigation systems in Saurashtra are over-designed (which explains why several of them don't fill up in most years). The growing profusion of small structures will capture most of the available runoff, especially in drought years, leaving nothing for larger storages downstream. If this were true then it would mean that the benefits of decentralized water harvesting would only be localized and that it would merely redistribute the scarce water resources of a basin without providing significant basin-wide benefits. However, Gohil (2002) offers data on long term rise in static groundwater levels for 30 *talukas* of Saurashtra which shows that the post-monsoon static water tables tend, on an average, to be higher. Recent data from the Central Ground Water Board (CGWB) confirms this over a longer time period and shows that several *talukas* in Saurashtra moved from 'over-exploited' and 'critical' to 'semi-critical' and 'safe' category[3] owing to additional groundwater recharge as a result of the decentralized storages (Jain 2012).

Survey results: Meghal basin

Our survey in all the 50-odd villages of Meghal river basin collected data on land use, season-wise cropping pattern, irrigation, productivity, prices and gross value of output. Table 1 presents a quick summary of the results across the basin.

Table 1 Summarized results of the Basin-wide socio-economic survey

Season	Area (Ha.)		Avg. Price (Rs./Kg.)		Value (Rs. Crore[4])		Value/Ha. (Rs./Ha.)	
	2000-01	2010-11	2000-01	2010-11	2000-01	2010-11	2000-01	2010-11
Monsoon	34166.00	36857.99	12.98	27.86	78.01	209.79	22832.37	56918.40
Winter	20541.00	27543.60	5.50	18.19	63.80	129.58	31060.46	47046.60
Summer	1421.50	7610.00	5.52	27.35	3.03	47.18	21286.80	61991.96
Annual Crops	541.00	1209.00	2.69	4.59	1.79	6.08	33025.88	50314.31
TOTAL	**56669.50**	**73220.59**			**146.63**	**392.63**	**25874.59**	**53622.89**
Cropping Intensity	**1.50**	**1.96**						

The annual gross value of output has grown from ~ 150 crores in 2000-01 to ~400 crores in 2010-11; at an annual growth rate of~10.50 percent. Since these are nominal figures, part of this growth can be attributed to inflation and price rise but the growth in average prices between the two periods also indicates a shift towards higher value crops. Not surprisingly, the (average) value of output per

[3]The CGWB categorizes *talukas* based on the stage of groundwater development and long-term pre and post monsoon levels. A description of what qualifies *talukas* to be categorized as 'over-exploited', 'critical', 'semi-critical' or 'safe' is available on the website of the Ministry of Water Resources (MoWR nd, p.2).

[4]One crore = 10 million

hectare (ha) has also more than doubled (from ~Rs. 26000 to ~Rs. 54000) but part of this growth has also come from expansion in gross cropped area as indicated by a significant increase in Cropping Intensity from 1.50 to 1.96.

The growth varies between seasons and the most significant growth can be seen for the summer season where the gross value of produce has risen from merely ~3 crores to ~47 crores as the summer cultivated area has increased from ~1400 ha in 2000-01 to 7600 ha in 2010-11. Agricultural growth is a function of several farm and market variables but this kind of growth in summer cultivation would not have been possible without improved access to irrigation facilitated by decentralized water harvesting and groundwater recharge.

Growth and attribution: a first-cut assessment

There can be several ways in which socio-economic impact can be measured. We have specifically chosen to focus on the impact of improved water availability on the agrarian economy of the Meghal river basin. Admittedly, some of this analysis is rather *simplistic*. What our data shows is that the agrarian economy of Meghal basin has grown at an average rate of ~10.50 percent per annum. However, this growth may be due to a large number of reasons – better rainfall, improved farming practices, changes in cropping patterns, price rise, better yielding crop varieties, and so on. What our analysis does not show very clearly is what percentage of this growth can be attributed to greater water control resulting from decentralized water harvesting and groundwater recharge.

In this section, we make a first-cut, conservative assessment of how much of this growth may be attributed to improved water control derived from artificial groundwater recharge and owing to decentralized water harvesting; and within that, to AKRSP India's work.

The agrarian economy of Meghal basin is almost exclusively dependent on groundwater for irrigation. Gravity flow irrigation and direct lifting from surface water bodies is negligible. Using results from the Meghal BasinSim hydrological model (Verma and Krishnan 2012), we see that in the Meghal river basin, artificial recharge contributes roughly 32 percent to overall groundwater recharge. This artificial recharge is generated over the entire year and in Table 2, we have calculated how much of the groundwater recharge available will be from artificial recharge in the different agricultural seasons of a year. This way, we can estimate the share of the total value of output generated in the Meghal basin that can be attributed to artificial recharge. Thus, out of the total value of Rs. 392.63 crores generated in 2010-11, Rs. 125.77 crores may be attributed to artificial recharge.

We also know that artificial recharge in the Meghal basin is the result of water storages in the basin. Some of these storages have been created by AKRSP (I) while others have been created by a large number of government and non-government agencies (Table 3). If we assume that artificial recharge and storage capacity have a linear relationship, we can conclude that the contribution of AKRSP (I) to artificial recharge will be in the same proportion as their share of storage capacity in the basin (12.61 percent). We therefore compute the share of value created that may be attributable to the storages created by AKRSP (I). This comes to Rs.15.86 crores (Table 2).

Table 2 First-cut estimates of attribution of agrarian growth in Meghal basin

Season	Gross value of produce (Rs. Crore)		Season-wise availability of artificial recharge	Value attributable to artificial recharge (Rs. Crore)	Value attributable to AKRSP (I) storages (Rs. Crore)
	2000-01	2010-11			
Monsoon	78.01	209.79	27 percent	56.64	7.14
Winter	63.8	129.58	30 percent	38.87	4.90
Summer	3.03	47.18	60 percent	28.31	3.57
Annual Crops	1.79	6.08	32 percent	1.95	0.25
Total	**146.63**	**392.63**	**32 percent**	**125.77**	**15.86**

Table 3 Summary of sub-basin wise storage potential from survey conducted by AKRSP (I) in 2009

Stream	AKRSP(I)		Govt./ Other		Total	
	No. of Structures	Capacity in MCFT	No. of Structures	Capacity in MCFT	No. of Structures	Capacity in MCFT
Lathodariya	58	16.04	140	46.76	198	62.80
Meghal	125	57.08	217	307.01	342	364.09
Vrajami	86	31.47	361	426.72	447	458.19
Kalindri	37	11.02	122	20.20	159	31.22
Total	**306**	**115.61**	**840**	**800.69**	**1146**	**916.63**

Thus we can conclude that the check dams constructed by AKRSP (I) in the Meghal river basin directly contribute to the creation of value in agriculture equal to Rs.15.86 crores in a year. This is roughly 40 percent of the annual growth in value of output and a little over 4 percent of the total value of output in the basin.

It must be noted, however, that this estimate is rough and conservative for several reasons. Construction of check dams and decentralized storages is only one of several interventions carried out by AKRSP (I) in Meghal basin. Any estimate of the overall contribution of AKRSP (I) to agrarian prosperity in Meghal must also account for all the other efforts including (but not limited to): promotion of drip and sprinkler irrigation; improved land and water management practices; construction and management of *boribandhs* to enhance the impact of decentralized storages; support and encouragement for the creation of the Meghal Core Group and the large number of local institutions at the village level; empowerment of village communities through active involvement in decision making; creation and propagation of a river basin identity; capacity building of local village leaders in the management of local and basin water resources and in resolution of upstream-downstream conflicts; promotion of a basin-wide *water ethic*, etc.

Growth and attribution: A discussion

Our estimate of the contribution of AKRSP (I) check dams to agrarian growth in Meghal is based on a large number of simplifying assumptions. It assumes a linear relationship between the creation of storage capacity and the amount of artificial recharge. It further assumes linearity in the relationship between artificial recharge and enhanced water control. Finally, it assumes a simple, direct and positive relationship between water control and value of agricultural output. The estimate represents the scenario of the basin as a whole and does not take into account the large number of variations between and within villages, different crops and across years. These estimates can therefore be refined further by adopting more nuanced approaches. We discuss some alternate approaches that may be employed for doing so.

Irrigated *vs.* non-irrigated growth

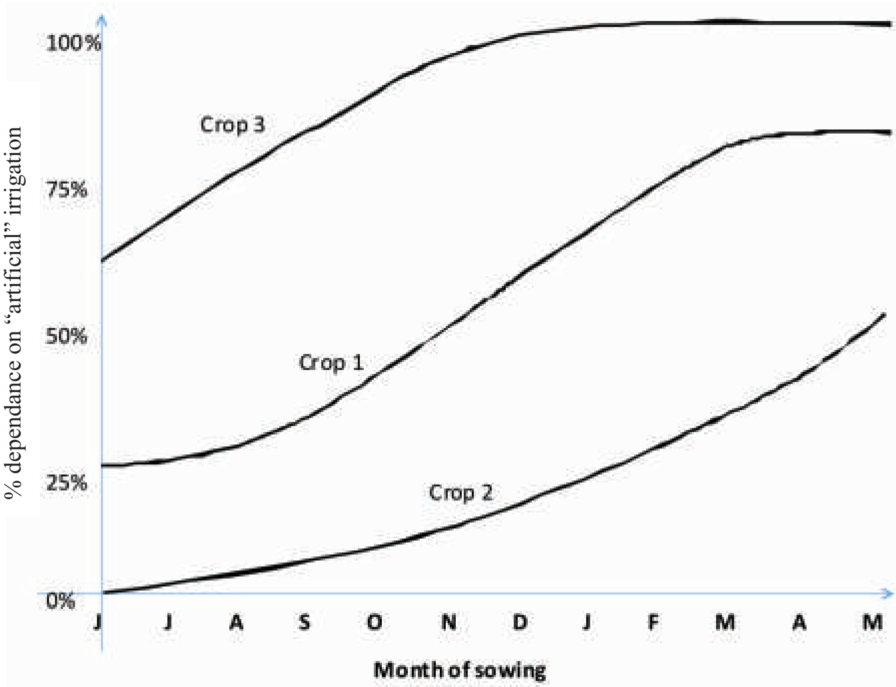
It has been argued that the agrarian growth in Saurashtra may be attributed largely to an improbable spell of good rainfall over the past decade or so. One simple approach to segregating the impact of interventions and that of higher rainfall is to consider only non-monsoon growth. Further, data on the relative dependence of crops on *artificial* water as a function of the month of sowing can be collected. Through this, we can define for each crop, the percentage dependence of that crop on “artificial” water. Each crop can be grown by “natural” water from soil moisture as well as through recharge from normal rainfall. But this percentage dependence of that crop on “natural” water as opposed to “artificial” water will change across seasons – generally this dependence on “artificial” water will increase as we go from June to May for a monsoon rainfall location.

Figure 1 shows this relationship conceptually for three hypothetical crops depicted in Table 4. Note that these curves are different for each crop. For example Crop 2 depends least on artificial water, so it can be grown even in summer with “natural” water, but with only up to 50 percent production. Whereas Crop 3 depends highly on “artificial” water, so as early as in December, it needs “artificial” water to meet its requirements. For example, the summer *Tal* crop (sesame seed) – which has grown significantly in Meghal basin over the study period – may be entirely attributed to “artificial” water, whereas monsoon groundnut would be probably 20 percent due to “artificial” water.

Table 4 Acreage of crops across seasons in a normal rainfall year

	Rains	Winter	Summer
Crop 1	A1R	A1W	A1S
Crop 2	A2R	A2W	A2S
Crop 3	A3R	A3W	A3S

Figure 1 Percentage dependence of crops on artificial water across months of a year



Using these curves, we can generate Dependence Numbers: D1R, D1W, D1S, D2R, D2W, D2S, D3R, D3W and D3S. The curves may be generated using data from different sources: (a) ICAR or Junagadh Agriculture University studies on water requirement for the selected crops; (b) Perceptions from AKRSP (I) field staff; (c) Perception from the farming community; (d) Calculation based on recharge and consumptive water use based on FAO standard estimates; and (e) One can also think of localized curves if such data is available.

Once we have the crop acreage and the dependencies, we can compute an effective acreage attributed to "artificial" water as follows:

Effective acreage attributed to "artificial" water:

$$A1_{eff\text{-}art} = A1R*D1R + A1W*D1W + A1S*D1S$$

$$A2_{eff\text{-}art} = A2R*D2R + A2W*D2W + A2S*D2S$$

$$A3_{eff\text{-}art} = A3R*D3R + A3W*D3W + A3S*D3S$$

If the market prices of these crops are available, MP1, MP2 and MP3, then the total value generated by "artificial" water can be written as:

Total value generated by "artificial" water:

$$V_{eff\text{-}art} = (A1_{eff\text{-}art} * MP1) + (A2_{eff\text{-}art} * MP2) + (A3_{eff\text{-}art} * MP3)$$

In this entire process, we can also have ranges for the parameters, instead of absolute numbers, thereby giving a final range for the computed $V_{eff\text{-}art}$ through a simple Monte-Carlo.

Growth in Meghal *vs.* growth in Junagadh

Another way to segregate the impact of interventions by AKRSP (I) could be to compare the growth in the Meghal villages with the overall level of agricultural growth in villages where water harvesting work has not been undertaken. However, given the popularity and spread of the water harvesting moment in Saurashtra, we are unlikely to find a large number of such villages. Even within Meghal, AKRSP (I) is only one of several agencies that have implemented the construction of water harvesting structures. Nevertheless, one could compare the agricultural growth in Meghal villages with the average agricultural growth in Junagadh district to look at the incremental impact of AKRSP (I) interventions. Such an approach, of course, assumes that AKRSP (I) villages do not, *a priori*, represent villages that would have had better agrarian growth even without AKRSP (I) interventions.

Growth – Storage relationship

As discussed earlier, summer-season *Tal* cultivation made possible due to the improved availability of groundwater for irrigation seems to have contributed significantly to the growth of Meghal basin's agrarian economy. However, as we can see in, some villages perform much better than others in terms of the gross value generated per hectare from summer-*Tal.* While the average for all the villages is ~Rs. 45,000, the value per hectare ranges between ~Rs. 500 to ~Rs. 85000.

Figure 2 Gross value generated (Rs/ha) for summer-*Tal* cultivation across villages

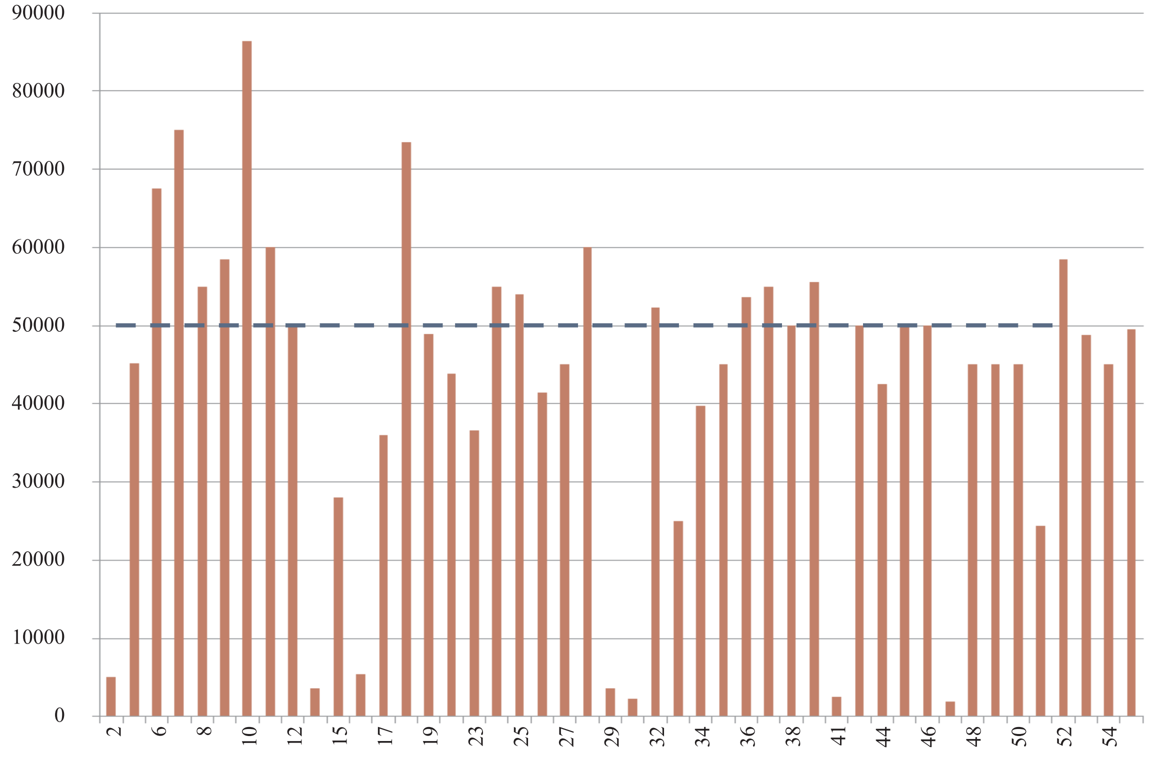
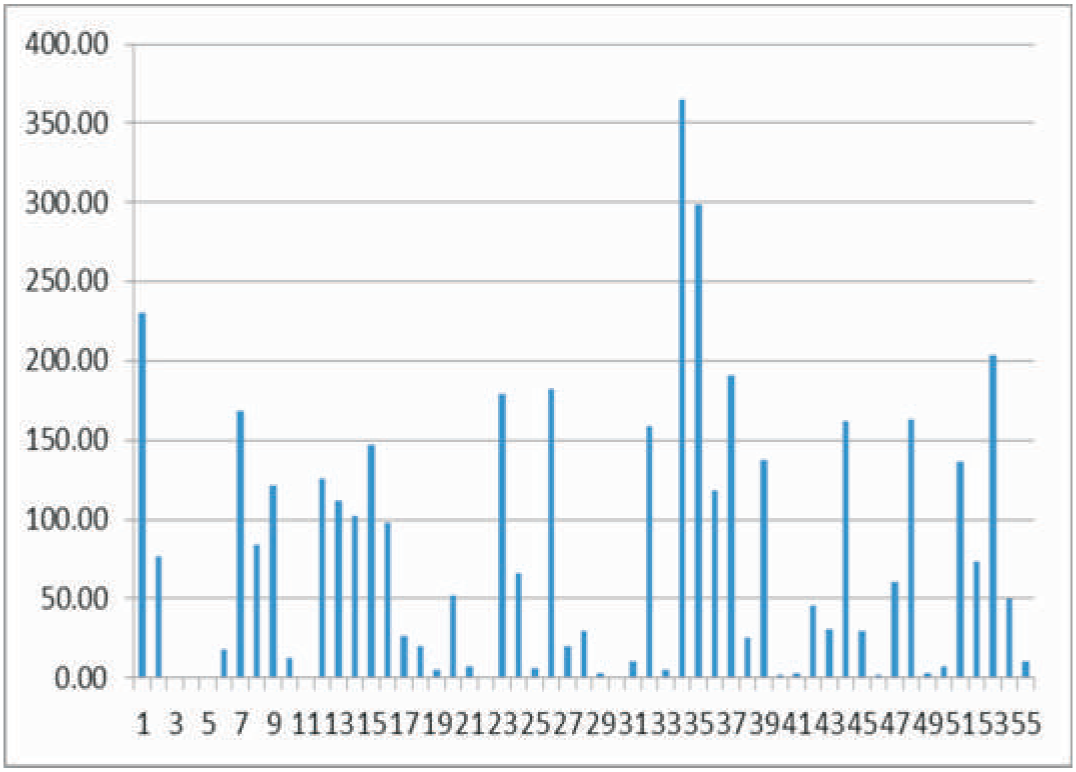


Figure 3 Storage created (m^3/ha) of cultivated area across villages



Likewise, we can see in Figure 3 that the water storage created her hectare of gross cultivated area varies from village to village. Can storage created per hectare of cultivated area explain the differences in value generated? If so, then we can get a more nuanced understanding of the impact of water harvesting on agricultural growth.

Although we have not employed these alternate approaches to estimate the impact of AKRSP (I) interventions, our rough-cut estimates can be made more robust by comparing the results from different approaches.

Conclusions

The impact of water harvesting measures is multitudinous. When we look at the impact from irrigation itself, several methodological challenges are posed, especially when there can be multiple factors contributing to growth. By following different approaches looking at seasonal changes, crop water dependence and by using a dynamic mode of basin water balance, we are able to arrive at rough measures of attributable impact, which in this case is roughly Rs 16 crores annually in the Meghal river basin. This measure can be improved by several other triangulations as discussed in the following sections.

What this study also shows is that a mix of approaches using hydrology, agronomy and economics can help us create hybrid methods that are likely to fare better in capturing the impact and in the tricky process of attributing part of the growth to specific interventions. Though developed specifically for the Meghal assessment, these methods can also be used by similar interventions elsewhere.

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About the IWMI-Tata Program and Water Policy Highlights

The IWMI-Tata Water Policy Program (ITP) was launched in 2000 as a co-equal partnership between the International Water Management Institute (IWMI), Colombo and Sir Ratan Tata Trust (SRTT), Mumbai. The program presents new perspectives and practical solutions derived from the wealth of research done in India on water resource management. Its objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations. Through this program, IWMI collaborates with a range of partners across India to identify, analyze and document relevant water-management approaches and current practices. These practices are assessed and synthesized for maximum policy impact in the series on Water Policy Highlights and IWMI-Tata Comments.

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