IWMI-TATA WATER POLICY RESEARCH PROGRAM

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Does Water Harvesting Help in Water-scarce Regions?

A Case Study of Two Villages in Alwar, Rajasthan

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Abstract

Water harvesting has been a common agricultural practice in India since times immemorial. However, numerous factors seem to have led to a sheer neglect of the system causing devastating effects on agroeconomics of rural India. This paper takes a critical look at the phenomenon of water harvesting technology both from the points of view of supply as well as demand. The basis for the study is Tarun Bharat Sangh's project in the Alwar district of Rajasthan.

Introduction

Water Harvesting has been an age-old phenomenon in our country. Known by various local names such as Jal Talais of Uttar Pradesh, Haveli System in Madhya Pradesh, Khadin, Johads and Paals in Rajasthan etc., these structures have contributed to domestic water security and aided irrigation in most parts of the country. Mapping of the net irrigated area by various sources in India indicates that tank irrigation, which is a type of water harvesting structure, still forms a significant part of the irrigation water supply especially in the Southern states of India.

Though water harvesting structures were an important means of irrigation in many parts of our country till the late 19th century and in some places, as late as the early 20th century, a number of these structures were allowed to deteriorate in favour of modern irrigation systems in the form of dams by the colonial government as well as the Indian government. There is a lot of evidence of neglect of these systems since British times (CSE, 1997). High state subsidies and encouragement by the state in other ways for the Major & Medium projects and increase in groundwater use owing to green revolution technology led to neglect of water harvesting structures and made them seem uneconomical. Further, public control of these structures by village panchayats and irrigation department meant that local communities lost interest in their management. Failure of governing bodies to collect irrigation charges and a general lack of control over the behavior of the users with regard to drawls and rapid siltation due to the failure to carry out desilting etc led to many of these tanks becoming defunct (Shah 1993). An opinion soon grew, to the effect that the days of irrigation through water harvesting structures were over (Pant, Niranjan, 1999). This is substantiated, according to him, by a sustained and pervasive decline in the area under this source of irrigation. Data also clearly show that tank irrigation does not compare favorably with canal and groundwater irrigation with regards to yield per hectare (Robert Chambers, 1988).

Government of India's irrigation policy was biased towards Major and Medium Projects. This led to more than 63% of the irrigation budget of the country being devoted to such projects with an outlay of around Rs. 1,378,088.1 billion at constant 96-97 prices (Thakkar, 1999). Development of these projects followed a political economy of their own leading to the neglect of many areas of the country as far as expansion of irrigated area was concerned.

The lack of public investment in many of the neglected areas was met through increase in private investment in pumps and tube wells to meet the water requirements of irrigation, which had increased manifolds through the coming of High Yielding Varieties. Green revolution had ensured that for the first time agriculture was able to produce surpluses large enough to put the farm economies on a path of progressively increasing farm incomes. However in the semi arid areas the groundwater driven agricultural bubbles began to collapse due to alarming depletion in groundwater levels. To counter these threats water harvesting is being looked upon as a serious option for recharging of the groundwater levels. The quest to sustain groundwater levels and consequently farm incomes has been a major reason behind the upsurge in interest towards water harvesting structures in the last decade

Rajasthan Miracle

The state of Rajasthan seems to have taken a lead in the revival of traditional water harvesting system. The work of two NGO's, Tarun Bharat Sangh (TBS) and PRADAN is notable in this regard. Tarun Bharat Sangh, an Alwar based NGO has done particularly good work covering more than 700 villages in a short span of a little over a decade. The graph below charts their growth path across the years:

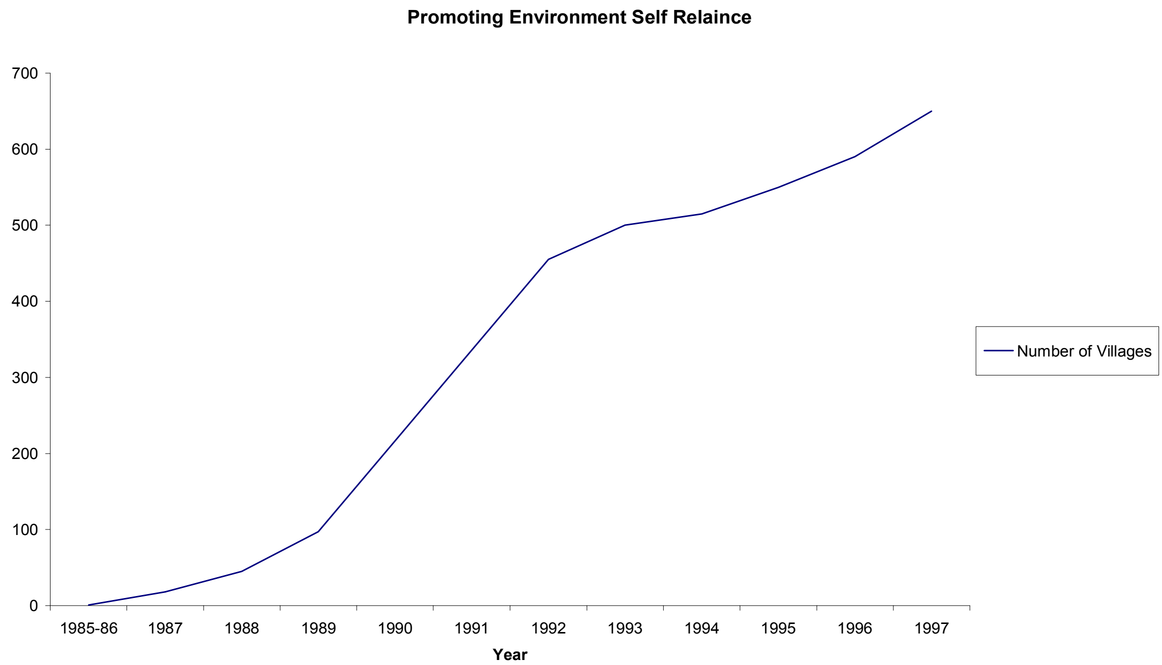


Figure 1: Growth in the Number of Villages Covered
Source: Center for Science and Environment, 2001.

Evaluation of systems built by engineers at Tarun Bharat Sangh (Dr G D Agarwal, former Professor & Head, Dept of Civil Engineering, Indian Institute of Technology, Kanpur) have indicated that over 60 per cent of these systems were compatible with engineering standards of storage construction and cost less (Rs.0.95 per cubic meter of water storage, average for 166 structures). The Engineering soundness of these structures was tested during the monsoons of 1995 and 1996 when numerous government-constructed structures in the adjacent areas were washed away but the TBS structures withstood the vagaries of nature (CSE, 1997). A geophysicist has shown that these structures have enabled an additional recharge of groundwater to the tune of 20 per cent, 17 per cent of additional seepage of rainfall in the non- monsoon period and has reduced the seasonal runoff from 35 to 10 per cent (Mahapatra, 1999:38). At present TBS has constructed more than 2500 *johads* in 500 villages. The expenditure incurred has been Rs. 150 million, with a staggering 73 per cent contribution by the people, in cash and in kind (UN -IAWG - WES, 1998:4). These *johads* have recharged the average groundwater table that was 200 feet below the ground level to 20 feet. It has enabled the farmers to raise food grains like wheat and barley during the rabi season rather than merely dry crops as was the case earlier, as well as corn, *Arhar, jowar, kala jeeree* and vegetables in *Kharif* (Ibid.). In case of wheat, the average productivity has jumped in some areas from 720 kg per acre to 1500 kg per acre (UN - IAWG - WES, 1998:17; Devarajan, in *Business Line*, 4 November 1999).

Objective of the Study

A lot of information has been generated on the supply side effects of the water harvesting structures (mostly speculative but some scientific), However the other part of the equation relating to the demand side has not been studied in depth. Also many point studies seem to have been done where the effect of water harvesting structure at the local level has been analyzed but their effect at the regional (river basin level) has not been analyzed.

One of the scientific studies on water harvesting systems is an ongoing study of PRADAN's work on Paals in Alwar by IWMI. The study involves the assessment of physical as well as socio-economic impact of water harvesting structures. Another study sponsored by Intercooperation measures the impact of a water harvesting structure built by TBS in a village called Suratgarh. Although the Intercooperation study tries to measure the impact of water harvesting structures in nearby villages, the study is essentially flawed because it does not take into account the above average rainfall during the study period. Most other studies on water harvesting structures confine themselves to describing the various kinds of structures, a point I will be making again later in the report. Studies on water harvesting structures are limited and few are based on scientific analysis of issues. The speculative content of many of these studies has given rise to two strands of opinions on the water harvesting debate: one strand which supports the water-harvesting phenomenon rather too enthusiastically, the other questions the value and ability of the structures.

The purpose of this paper is to take a critical look at the phenomenon of water harvesting technology both from the points of view of supply as well as demand. The scope of the paper is an in-depth analysis of some critical issues relating to water harvesting systems enabling an accurate and scientific analysis of the issues. The paper in no way tries to underestimate the achievement of Tarun Bharat Sangh's work that is the focus of the study. For this report we take their work as an exemplary illustration of successful water harvesting.

Methodology

The study involved a formal questionnaire survey for a preliminary assessment of water availability and the pattern of agriculture in the villages under study. The questionnaire also elicited information on wells and water extracting mechanism and formed the basis of a detailed discussion of different issues relating to the agricultural economy of the area in particular and the overall economy in general. In addition to this survey location of wells and johads were marked on the village maps with the assistance of farmers.

Discussion with farmers and informal inspection of the water harvesting structures were used to gain insights into the condition of the structure and the silting therein to understand the modus operandi of these water harvesting structures enabling them continue to give the same yield for years. These discussions were also instrumental in understanding concepts like the links between agriculture and livestock and the phenomenon of migration. A case study of selected families will help in further refining these estimates.

For the purpose of this preliminary analysis two villages in the upper catchment of the Arvari river basin were selected (see map of the river basin at the end of the report). The following considerations were involved in selecting the villages (1) The intensity of water harvesting works in the study area should be very high and (2) A good number of years should have passed since the water harvesting works were undertaken. This would help in getting an idea of what best could be achieved through good water harvesting work. In accordance with this the villages of Bhaonta and Kolyala were chosen for the study.

Profile of the villages

The villages under study are located in the Alwar district of Rajasthan in the Thanagazi block. The terrain is hilly and rocky. The slopes of the hills are generally steep with flat ridges and plateaus of varying widths. The soil is generally dry, impoverished and deficient in humus.

The two villages are situated at a distance of 300 meters from each other and are separated by agricultural lands in the shallow valley between the ridges. The table below shows community wise breakup of the population and the number of families in the village. Large family sizes and hence the concept of joint family becomes evident from the table. This joint family structure plays a significant role in aiding migration.

*Table 1: Population of Bhaonta Kolyala (*Source: Shresth, 2001*)*

VILLAGE	FAMILIES			POPULATION		
	Gujjars	Balai	Rajput	Gujjars	Balai	Rajput
Bhaonta	17	9	3	175	116	50
Kolyala	26	0	0	225	0	0
Total	43	9	3	400	116	50

Nature of Structures Built

While the work of Tarun Bharat Sangh has become famous for the revival of Johads there are actually four different kinds of structures that Tarun Bharat Sangh has built. The first and the major structures in terms of water holding capacity are the Anicuts. These are built on common land plugging the main *nallah.*

The second type of structures is the Paals. They are built on private land on the fields of the farmers and their main purpose is to conserve moisture for the rabi season. The need for irrigation in the rabi season reduces drastically with Paals. Like the Anicuts these structures are also built plugging the main *nallah*.

The third type of structures are the Johads. These are built on common land on the foothills of the mountains and are much smaller than anicuts. Unlike the anicuts they are not built on the nallah and collect water from a small catchment, instead. The major purpose of the johads is to provide water to livestocks. Since the land on which these structures stand are not ploughed the recharge from the johads is much lower as compared to Paals.

The fourth type of structure is medhbandi constructed in the farmers' fields. This again is on private land and involves raising the sides of the fields to store rainwater in them. This helps in retaining moisture from the Kharif season to the Rabi season.

In the Arvari watershed, which we have selected for analysis, a total of 238 structures were built by Tarun Bharat Sangh by 1997, the number being a mix of all the above types of structures. Though no data on the number of structures in the watershed are available, it can safely assumed that their number is well within 300 structures.

Analysis

Rainfall

Since there is no rainfall station in the area under study, the rainfall in the Thanagazi block was taken as a substitute for the rainfall in the area. The rainfall chart of the area shows a mean annual rainfall of 751 mm with a high coefficient of variation of around 40% (data for past 16 years). The number of rainy days during a year varies from 18 to 30. 80% of the rainfall in the year is received during the monsoon (Mahapatra, 1999:38).

The irrigation department uses a figure of 6.631 cubic feet per square mile as the figure for runoff from the area for building their minor irrigation projects in the area. Considering that this is the runoff value with 75% dependability we get 36.54 MCM as the total runoff for the 504 square kilometer Arvari watershed.

The trend of rainfall shows that except for a period of 5 years where the mean rainfall happens to be nearly 1000 mms in a year (1993-97) the average rainfall works out to be 590 mm for the past 17 years. Separating this out in 7 out of 13 years the rainfall is 550 mm or below while in the rest of the 6 years the rainfall is about 700 mms. The conclusion that can be drawn from this is that the maximum rainfall in the region is around 700 mm (mean 720 mm) while the low rainfall may be 550 mm (mean 502 mm) or less. There also seems to be a pattern in the rainfall with a bunch of good rainfall years followed by a spell of bad rainfall years. In figure 2 below the straight line denotes the average rainfall.

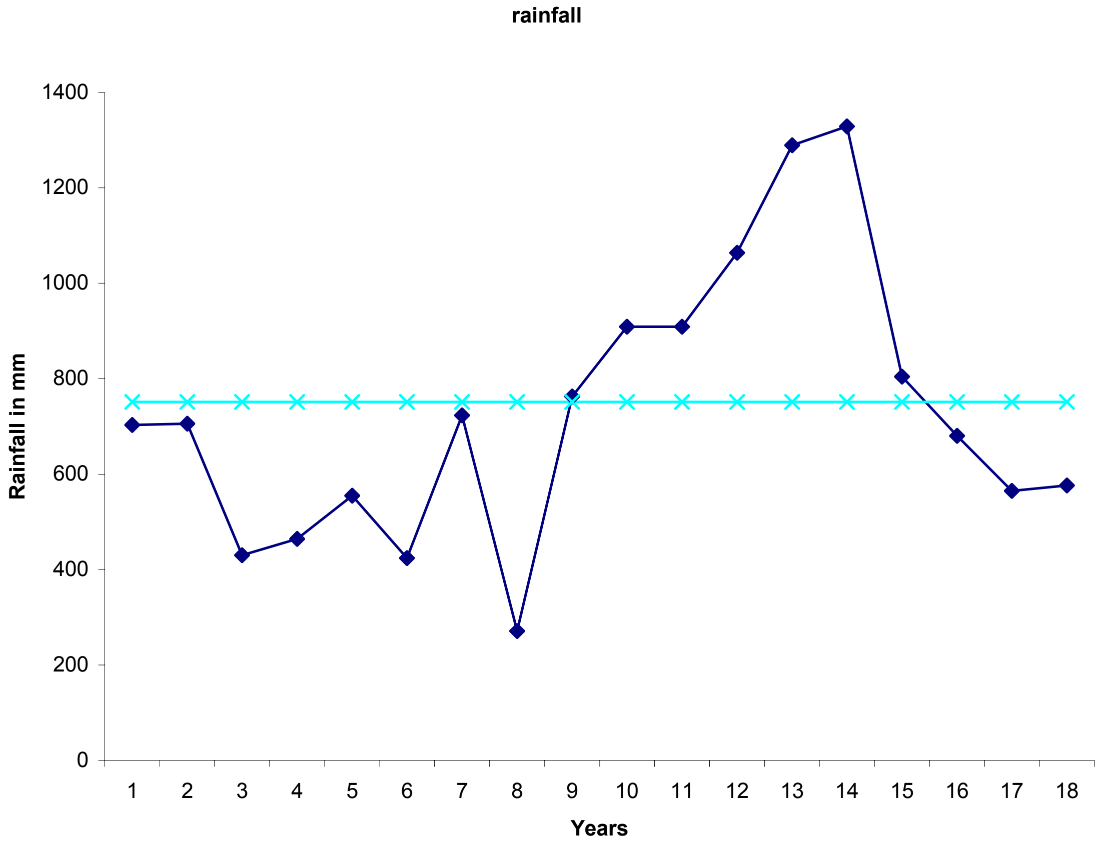


Figure 2: Rainfall Pattern for the Last 17 Years (1984-2000)

Agriculture

Agriculture in the area is a low -input low -output affair. A detailed analysis of the agricultural situation in the area was carried out to determine the total water used by agriculture and also to determine the economic efficiency of agriculture measured in terms of value of output generated per cubic meter of water applied. Other parameters such as net return per capita, yield per acre etc. were calculated in order to understand the state of agriculture in the villages under study. These calculations were then used for the entire river basin with the assumption that the villages were similar in all respects to those in the Arvari basin.

For the agricultural estimation a questionnaire survey of the area was carried out. The cropping pattern of the current year, a poor rainfall year, was noted along with the changes in the cropping pattern in a good rainfall year. The data was collected on the basis of farmer recall. Focus group discussions and farmer interviews were conducted to collect information on the details of pumping in the area. An unusual stroke of luck, which aided the study, in the area was that most of the pumps in the area are 8 Hp diesel pumps. This eased the calculations of demand considerably. This phenomenon is not out of sync with the rest of the villages in the watershed as was borne out by a preliminary study of Hamirpur village.

Table 2, below, shows the amount of irrigation required for different crops grown in the region. The numbers indicate the total number of hours taken by a diesel pump of

8 Hp to supply that quantity of irrigation. All the figures in table 2 show the number of hours of pumping required per bigha of land (0.25 Hectare). Summer crops and wheat come out as the major consumers of irrigation in the area.

Table 2: Amount of Irrigation Required per Bigha

CROP	GOOD RAIN	POOR RAIN
Maize	No Irrigation	6-8 hours (2 irrigation)
Wheat	25 hours (6 irrigation)	30 hours (6-7 irrigation)
Jowar	14 hours (4 irrigation)	16 hours (4-5 irrigation)
Gram	0-4 hours (0 to 2 irrigation)	Upto 6 hours (3 irrigation)
Mustard	0-4 hours (0 to 2 irrigation)	Upto 6 hours (3 irrigation)
Summer Crops	18-20 hours	18-20 hours
Kalajiri	6-8 hours (3 irrigation)	8 hours (3 irrigation)

Table 3 shows the area under each crop in bighas for the two villages. As can be seen from the table, for both the villages the area under wheat encounters the maximum change with decrease in rainfall. The decreased area under wheat goes to less water requiring crops like mustard. The area under summer crops is a small percentage of the total irrigated area and remains more or less constant. This is so because these crops are grown mostly by farmers with sufficient water in their wells throughout the year.

Table 3: Area Under all Irrigated Crops (in bighas)

CROP	BHAONTA		KOLYALA	
	GOOD RAIN	BAD RAIN	GOOD RAIN	BAD RAIN
Maize	112	112	69	69
Wheat	130	96.5	72	42
Jowar	26	6	27	17
Gram	0	0	0	1.5
Mustard	14	59	11	49
Summer Crops	14	14	17	17
Kalajiri	0	0	4	4

Tables 2 and 3 enable us to arrive at the total hours of pumping in the two sample villages. As expected wheat turns out to be the major consumer of irrigation followed by summer crops. High figure for summer crops is despite the fact that they occupy a small percentage of total cropped area.

The returns from mustard works out to be much more than for wheat. Therefore logically speaking farmers should have totally shifted from mustard to wheat. However mustard is reported to be much more vulnerable to termites and frost. Thus only in lands where water is scarce mustard alone is grown despite the risks (Jhunjhunwala for Intercooperation, 1996).

Table 4: Total Pumping Hours for Irrigation

CROP	BHAONTA		KOLYALA	
	GOOD RAIN	BAD RAIN	GOOD RAIN	BAD RAIN
Maize	0	896	0	552
Wheat	3250	2895	1800	1260
Jowar	364	96	378	272
Gram	0	0	0	9
Mustard	28	354	22	294
Summer Crops	500	500	595	595
Kalajiri	0	0	24	32
Livestock	560	560	400	400
TOTAL	4702	5301	3219	3414

The data in table 4 is on the basis of pumping hours of an 8 Hp diesel pump. Different capacity pumps might drastically change the number of hours of pumping. Also the figures stated are rough estimates. The number of hours of actual pumping will depend on several factors such as the age of pumps, water level in the wells, pump Hp etc.

Taking an average value of discharge of 26 m^3 per hour for an 8 Hp diesel pump (this was done by measuring the discharge from three pumps and taking the average) table 5 is obtained.

Table 5 gives the total water pumped in hectare meter for the crops in the region and pumping in summer for the livestock. The total figure gives the volume of water extracted in the village across the agricultural seasons.

Table 5: Total Volume of Water Extracted (Figures in Ha Meter)

CROP	BHAONTA		KOLYALA	
	GOOD RAIN	BAD RAIN	GOOD RAIN	BAD RAIN
Maize	0	2.33	0	1.44
Wheat	8.45	7.53	4.68	3.28
Jowar	0.95	0.25	0.98	0.71
Gram	0	0	0	0.02
Mustard	0.07	0.92	0.06	0.76
Summer Crops	1.3	1.3	1.55	1.55
Kalajiri	0	0	0.06	0.08
Livestock	1.46	1.46	1.04	1.04
TOTAL	**12.22**	**13.78**	**8.37**	**8.88**

Note: (1)The total figures might not match with the sum of parts because of rounding off to 2 digits.

(2) The figures are not net of return flows.

It can be seen from table 4 and 5 that the major change between a good and a bad rainfall year is in the Rabi season when the cropping pattern moves to low water consuming crops like mustard. But despite the shift the overall quantity of water applied remains more or less the same in bad rainfall years because of the need to give irrigation to Maize crop as well as increased amount of irrigation to the wheat and mustard crop (due to the reduced availability of soil moisture).

Tables 6 and 7 give the net returns from agriculture. Table 8 which follows gives the net return per bigha of irrigated crops. Table 6 shows the net returns from agriculture when the opportunity cost of labor from farm operations are not imputed. Table 7 on the other hand takes into account the opportunity cost of labor. The net return figures of the two tables show drastic differences and shows how unviable agriculture is in the presence of opportunity cost of labor. But considering the fact that there is massive hidden unemployment in the agricultural sector in India and hence the marginal value of labor is zero or near zero practicing agriculture is a necessity for much of the rural population. It can be seen from the table that in a low rainfall year the return actually increases. This is primarily the result of shift towards Mustard which gives a higher return per bigha than wheat. However the returns of a bad rainfall year are exposed to a much higher degree of risk as compared to the return in a good rainfall year because of the risks associated with mustard (enumerated earlier in the report).

Table 6 : Net Returns when Opportunity Cost of Labor is not Imputed (All figures in Rs.)

CROP	**BHAONTA**		**KOLYALA**	
	GOOD RAIN	BAD RAIN	GOOD RAIN	BAD RAIN
Maize	218400	218400	134550	134550
Wheat	688090	510774.5	381096	222306
Jowar	85384	19704	88668	55828
Gram	0	0	0	0
Mustard	36400	153400	28600	127400
Summer Crops	112000	112000	136000	136000
Kalajiri	0	0	21500	21500
Total	**1140274**	**1014278.5**	**790414**	**697584**

Table 7: Net Returns when Opportunity Cost of Labor Imputed (All figures in Rs.)

CROP	BHAONTA		KOLYALA	
	GOOD RAIN	BAD RAIN	GOOD RAIN	BAD RAIN
Maize	16800	16800	10350	10350
Wheat	103090	76524.5	57096	33306
Jowar	7384	1704	7668	4828
Gram	0	0	0	0
Mustard	21770	91745	17105	76195
Summer Crops	70000	70000	85000	85000
Kalajiri	0	0	-32500	-32500
Total	**219044**	**256774**	**144719**	**177179**

Table 8: Net Returns in Rs. Per bigha

Crop	Returns in Rs. Per bigha when opportunity cost is not included.	Returns in Rs. Per bigha when opportunity cost is included.
Maize	1950	150
Wheat	5293	793
Jowar	3284	284
Mustard	2600	1555
Summer Crops	8000	5000

Taking tables 3 to 7 in account, it is now possible for us to calculate certain ratios that equip us with a better understanding of the agricultural performance of the region. Table 9 gives 2 such ratios that glance over the land and labor productivity in the area.

Table 9: Sample Performance Indicators

	LAND PRODUCTIVITY	LABOR PRODUCTIVITY
Bhaonta	Rs. 2960 per hectare	Rs. 697 per capita per annum
Kolyala	Rs. 2895 per hectare	Rs. 643 per capita per annum

Land productivity in the region of Rs. 2900 per Ha of GCA and Labor productivity of around Rs. 650 per capita compares with the Land productivity of Rs 2772 per Ha and

Labor productivity of Rs 502 per capita in Jharkhand one of the poorest state in India (Satpathy, 2001).

Calculating the net return per meter cube of water applied we get Rs. 9 /m^3 for Mustard and a low figure of Rs. 1.5/ m^3 for wheat. Observations from Mehsana in Gujarat report a return of Rs. 4.5 / m^3 for wheat which 3 times as high as return from wheat in the two villages (Kumar,2000)

Livestock

The Gujjar community which dominates the two villages as well as the Arvari river basin were traditionally involved in animal husbandry only. Agriculture is a relatively new occupation for them. Even today all families own some form of livestock. Agriculture in the villages is finely meshed with the livestock population of the village. Ploughs supported by animal power is primarily used in the villages and most of the fertilizer used in the villages is organic manure. Wheat, the preferred crop of the area, provides food grain as well as fodder for the cattle. While calculating net returns from wheat fodder was valued at the market rate to take into account the contribution of agriculture to livestock.

The concept of animal wealth is important in the village. Prosperity and prestige is weighed in terms of livestock holdings, specially bovine animals. For villagers livestock is a self perpetuating stock which can be tapped in the times of need. Pastoral production is mostly for the consumption of the family (Shresth,2001). Maintaining livestock is virtually cost free because of the existence of forests for grazing. But this also takes away from the yield of the cattle. Active trade in animals is not seen though sporadic buying and selling does take place.

Migration

Alwar being only 160 kms. from Delhi, there is mass migration from the village to Delhi which offers a comparatively higher wages as compared to other cities. Skilled people also migrate to Jaipur and Ahmedabad for various kinds of job. Compared to agriculture and livestock which are sustenance activities, migration is a surplus generating activity. Most of the family members migrate from the villages with only the necessary number of people needed for maintaining agricultural production remaining in the villages.

The number of months of migration is between 6 to 8 with the peak months being March to mid July. Migration also takes place after the Rabi crop is sown with the family members returning before the harvesting of the crop. The Intercooperation study points to a similar pattern of seasonal migration which reportedly became much higher after the building of water harvesting structures (Jhunjhunwala for Intercooperation, 1996).

The average return per member net of all costs works out to be around Rs. 2,000 per month for unskilled labor. This return however varies with demand for unskilled labor in Delhi.

The information on migration and livestock are on the basis of discussions but no survey was carried out for this. Case study method is proposed to be used for putting figures under the heads of migration and livestock.

Discussion and Conclusion

An analysis of the sources of income in the two villages gives an impression that agriculture is not the primary source of income for the households. This is borne out by the low level of agriculture in the two villages which is comparable to that of Jharkhand. And in such areas due to few local opportunities there is a high rate of seasonal migration (Satphthy Manas, Unpublished) with migration becoming the major source of income. However this does not entail a wholesale shift of families away from agriculture. Agriculture continues to be practiced for providing sustenance and also because it is the traditional occupation. However the relative prosperity of the households is determined by the number of members that can migrate. Migration gives the surpluses for the families to invest in agriculture and the water harvesting structures.

Most studies on water harvesting systems primarily document the different traditional methods of water harvesting practiced in India. After describing the mechanics of the systems these studies move towards expressing hope that the revival of these systems will lead to income augmentation in the project areas. Many of these studies also carry recommendations about the need and mechanics of the revival of these structures. While large irrigation projects are viewed in a critical light no scrutiny is made of the evidences on water harvesting systems (For example Thakkar, 1999 for World Commission on Dams). Logical thinking on these structures would however entail that we view the water harvesting structures in a more critical light. In water short basins agriculture is primarily based on low water requiring crops. If the water level in the wells increased, it should be reflected in a parallel shift from single cropping to double cropping and from low yielding crops to high yielding crops (Jhunjhunwala for Intercooperation, 1996). This would drain away all the extra water recharged by the water harvesting systems. Then in a poor rainfall year there would be a relapse again to a low water intensive cropping pattern. Thus water harvesting structures will result in huge crests and troughs of income coinciding with the highs and lows of rainfall.

Another section of literature also emphasizes the ‘drought proofing’ ability of these systems. It is believed that these structures, by adding to the groundwater in the surplus rainfall years will make water available for the bad rainfall years and thus sustain farmers’ income in a bad rainfall year.

On the other hand, if the water harvesting systems are viewed as income protecting, then the question to address is whether these structures are Drought Proof i.e. can they, by storing excess water, maintain the levels of income in years of drought? And, if yes, then the subsequent question would be that how long can these systems maintain income in the face of successive droughts?

Figure 3 on the next page shows the basic logic of water harvesting structures. It is assumed that water harvesting structures add to the period of recharge thus making available more amount of water for the pure discharge months (rabi season) as well as for the water deficient years. However the basic assumption behind the premise is that the amount of use following a demand remains the same in the face of augmented supply. This seems to be an erroneous assumption because the villagers in many of these semi arid villages are at a low equilibrium so far as water application to the crops is involved. The availability of more water gives them three options: increase the amount of water application to the crops, change the cropping pattern towards more water intensive crops or increase the area under irrigation. This would logically mean that all the extra water stored by the water harvesting structures during seasons of high rainfall will be quickly utilized in the first season of drought. In the areas where inadequate rainfall is experienced for longer stretches of time than just one year, it seems difficult to envisage drought proofing by these structures.

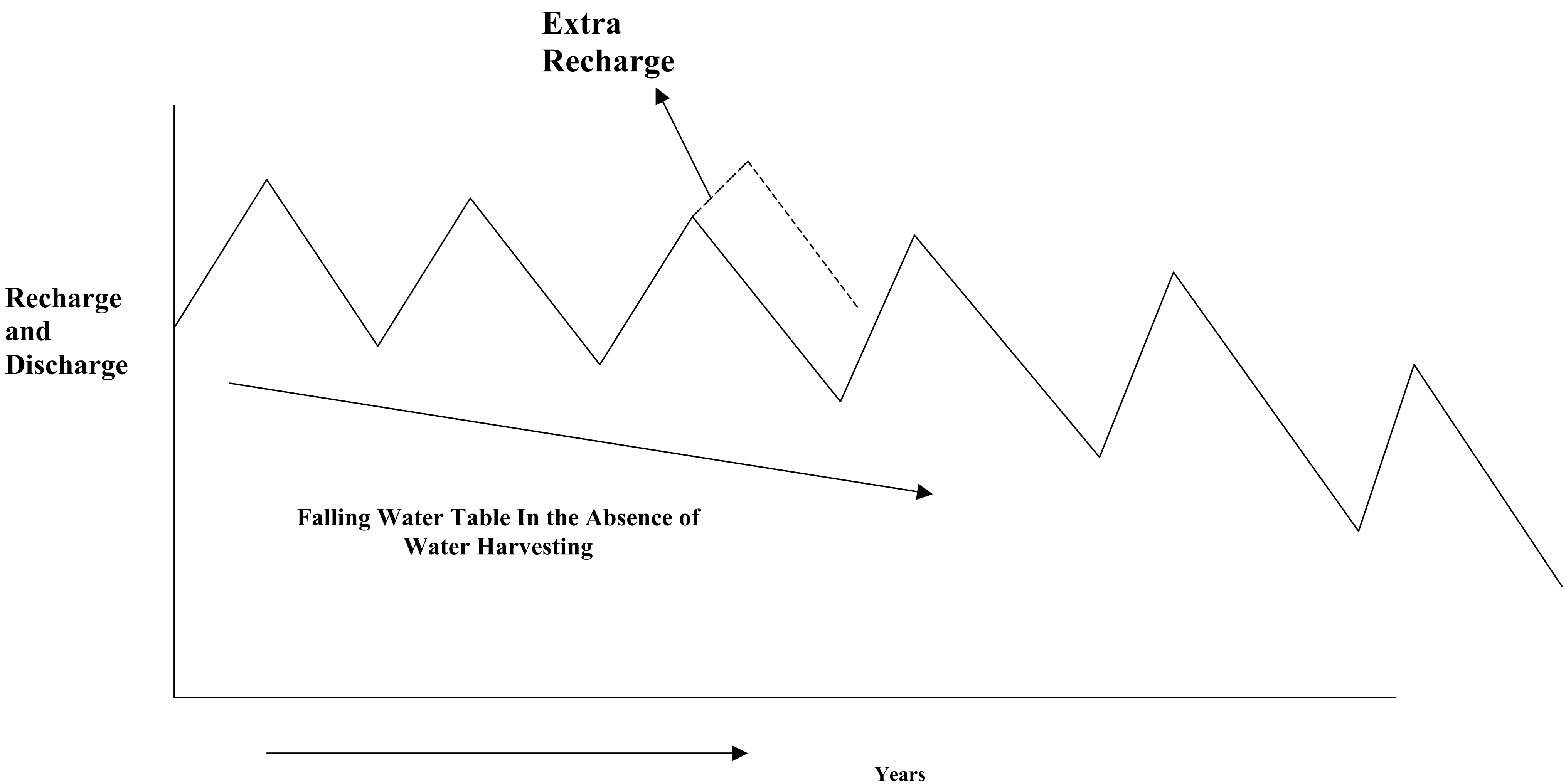


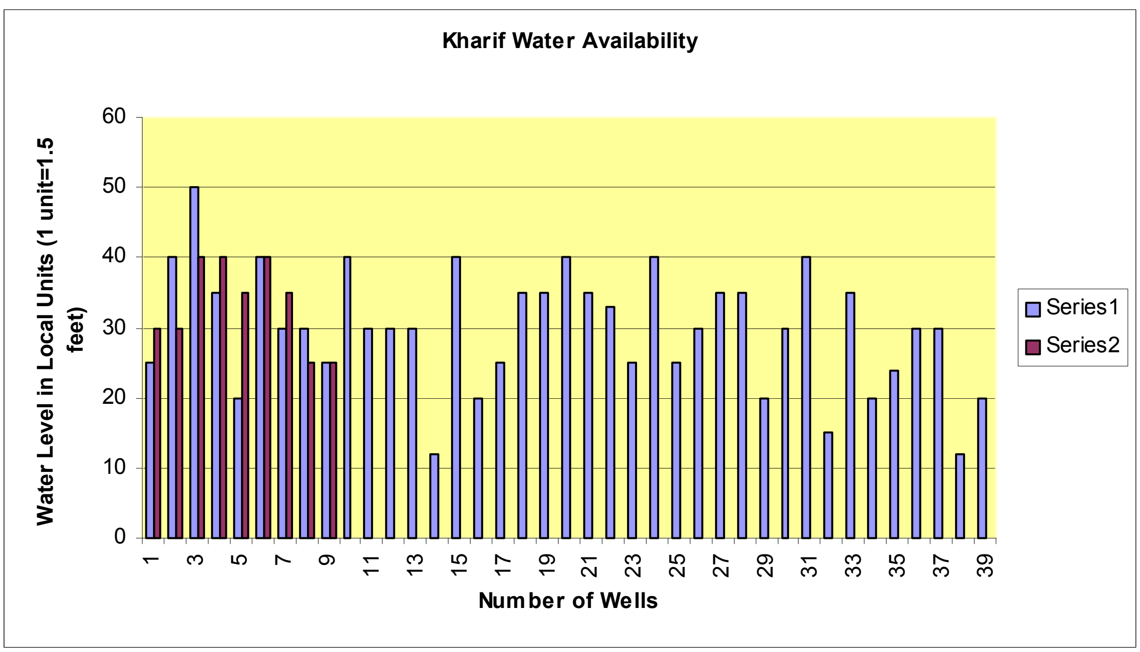
Figure 3: Logic of Water Harvesting

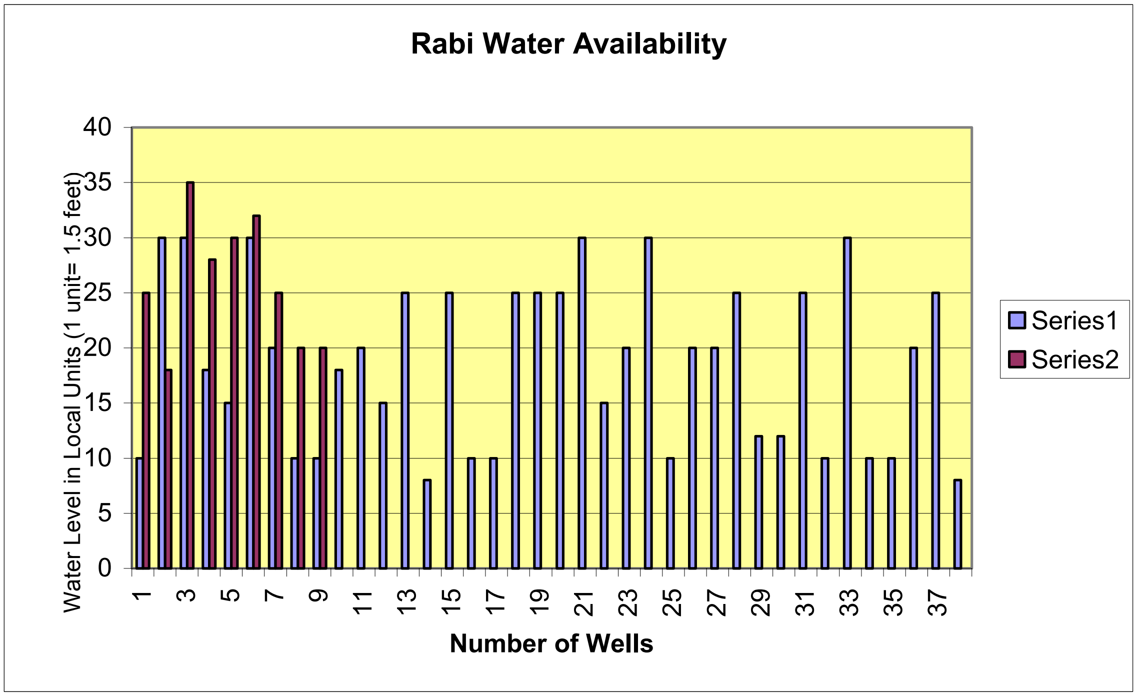
One inverted cone represents a single year. In the absence of water harvesting systems the coming in of pumping technology ensures that the discharge is much more than the recharge resulting in a fall in the water table. The coming in of the water harvesting technology adds to period of recharge thereby stabilizing the water table.

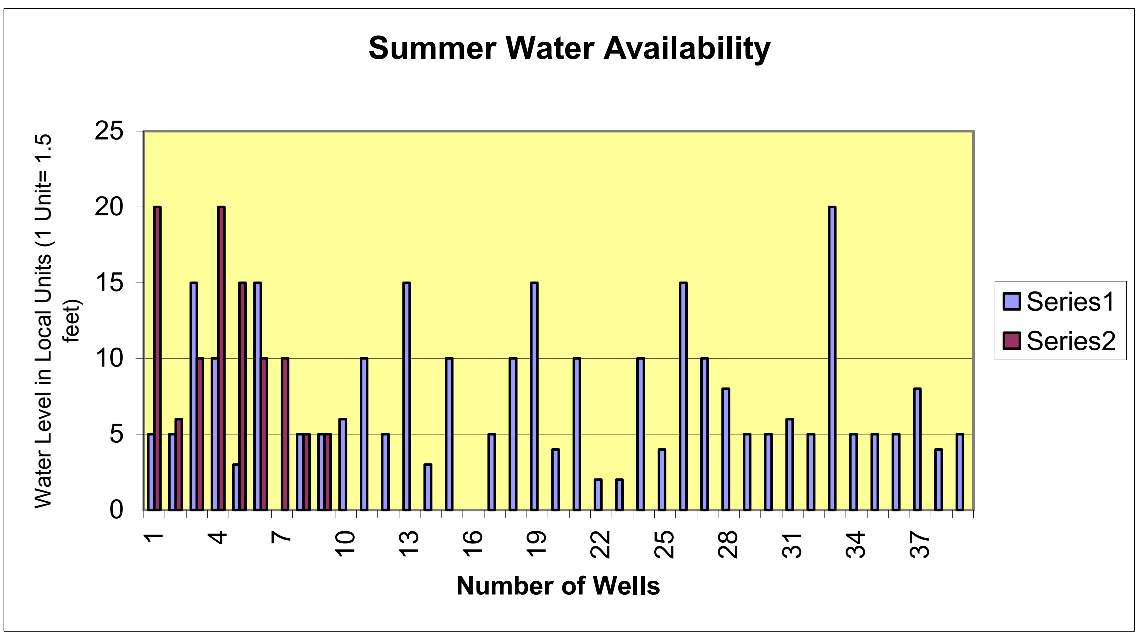
This also comes out with discussions with the farmers. In the poor rainfall years these structures seem to be totally ineffective as far making water available is concerned. A before-after analysis could have shown the effect of water harvesting structures in the drought years. But this effort is defeated in the study because the water extraction regime has changed substantially before and after the water harvesting structures were built in the two study villages. Coinciding with the water harvesting boom in the study villages (around 10 years back) a pump boom also took place (the average age of diesel pumps is 7-8 years). Thus the amount of water extracted increased by at least 10 folds (conservatively) making comparisons of water tables before and after not practical.

However a cross sectional analysis, done for this report, of 48 wells in Hamirpur village in a bad rainfall year showed no significant difference in the water availability in the all the three seasons of Kharif, Rabi and Summer between wells affected by Johads and wells not affected by Johads. The data from the study is presented below in graphical format with series 2 representing wells affected by Johads and series 1 the wells not affected by Johads.

Figure 4: Water Availability in Different Seasons







This idea further gains credence from observations from PRADAN's work in Alwar. The farmers whose wells are affected by water harvesting systems have moved to Onion cultivation that is a water intensive crop (Sakthivadivel, 2001). This supports the contention of the report that in the face of assured availability of water; farmers would like to shift to more remunerative (and higher water consuming crops). If this is so then all the excess water stored in a good rainfall year will be utilized in the same year.

Farmers do claim that in a good rainfall year the water harvesting structures add as much as 3-5 meters to the water level and at least 2-3 hours of continuous pumping. In the table below two scenarios are considered to put some numbers on the functioning of water harvesting systems. In the first scenario which is an optimistic scenario we consider that 50 percent of all the runoff that is generated (50% of 36.54 MCM or around 18 MCM) is put into the aquifer by the water harvesting structures. In the second scenario we take a more pessimistic, and probably realistic too, view that 25 percent of the runoff can be put into the aquifer which comes to 9 MCM of extra water through these structures.

Table 10: Performance of Water Harvesting Systems

	OPTIMISTIC SCENARIO	**PESSIMISTIC SCENARIO**
Runoff Tapped and Put into the Aquifer	18 MCM	9 MCM
Amount of Wheat Equivalent (Considering 1.2 m^3 water is needed to produce 1 Kilogram)	15,000 tons	7,500 tons
Yield per Hectare	4 tons	4 tons
Net Returns per Hectare	Rs. 3172	Rs. 3172
Net value of the extra recharge	Rs. 1,18,95,000	Rs. 59,47,500
Population Density of Thanagazi, 2001. (Estimated from census records)	175 persons/km^2	175 persons/km^2
Area of River Basin	503 km^2	503 km^2
Per Capita Additional Return	**Rs. 135 per capita per annum**	**Rs. 67 per capita per annum**

Storing 50 percent of the total runoff generated water would require a very high density of water harvesting structures. However, the per capita income hike per annum is not very high. Further, in a low rainfall year the return will be lower than even what is shown in the pessimistic scenario because the runoff is an exponential function of the rainfall not a linear function.

These per capita returns are got when all the harvested water is utilised for agriculture in the same year. However if there has to be drought proofing then a part of the water collected in the good rainfall year will have to be left unused for poor rainfall years. This would require judicious demand management on the part of farmers, a feature absent in all the water harvesting sites visited[1].

A third issue of equal, if not greater, importance is that of downstream impact. For achieving significant income or drought proofing impact a high density of water harvesting structures will have to be built. But when such a large number of structures are built, the downstream users of any runoff will experience absolute deprivation during inadequate rainfall years.

The issue of downstream impact being an important one, many research studies have been undertaken in the area. The way they envisage the downstream impact can be seen from the diagram below.

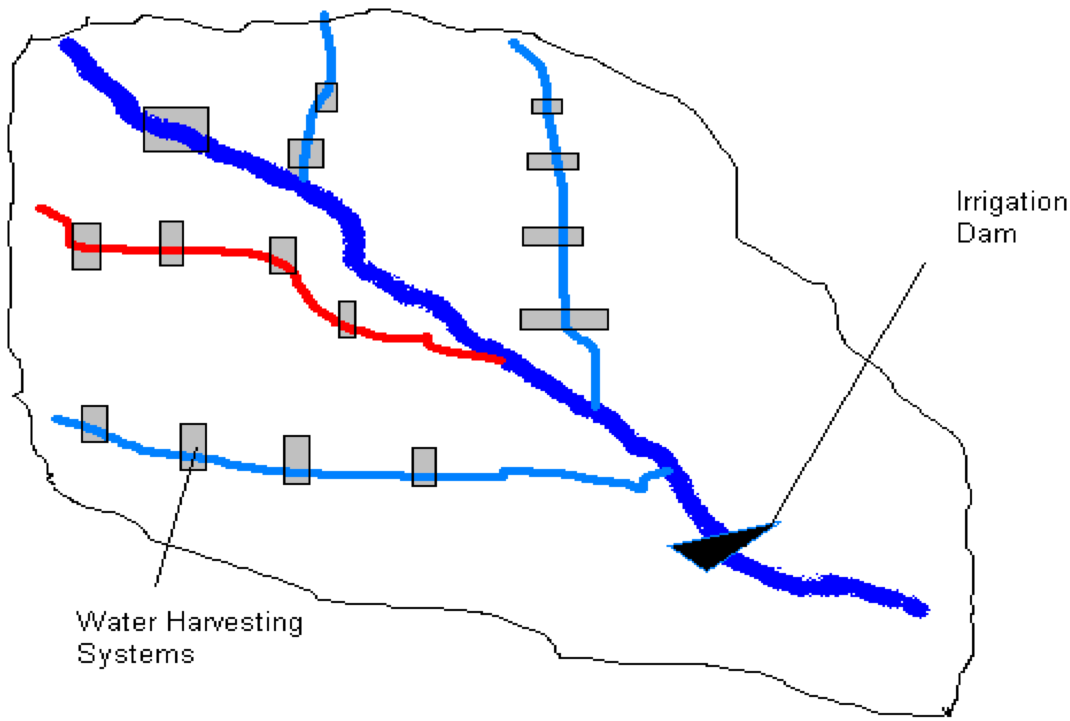


Figure 5: Downstream Impact (The common view)

[1] Tarun Bharat Sangh has tried to incorporate demand management in its strategy for development of water harvesting systems. The guiding resolution of the Arvari Parliament States with regards to Irrigation from Wells states:

- Only crops that require less water should be grown in the areas that are irrigated from the wells near the river.
- Vegetables are to be grown only according to local needs.
- Production should be for local needs.
- People should be penalized for growing rice and sugarcane.
- Digging borewells to draw water should not be allowed in the Arvari catchment.

Despite the existence of the rules for some time most villagers are not aware of these rules nor do they have any intention to follow them.

The diagram shows a large number of water harvesting structures built upstream (shown by grey boxes) which should potentially reduce the inflow in the dam downstream (shown by a black structure at the base). An estimate of the downstream impact is arrived at by seeing the inflow data in the reservoir and if the data on the percentage capacity of the reservoir filled show no significant change before and after the building of the reservoir it is concluded that there is no downstream impact (CSE, 2001 and Nagar, 2001).

This is however an erroneous way to look at the downstream impact. The filling up of the reservoir capacity takes place not only on the basis of quantum of rainfall but also on the distribution of rainfall within the year. Thus if we find that a small amount of rain falls in the year but most of it falls in a day or two then the reservoir will fill up much more than when a large amount of rain falls in the year over a number of days such that the amount of rainfall on a particular day is low. To understand the concept of downstream impact one has to look at the runoff and the reservoir capacity. This can be seen from figure 6.

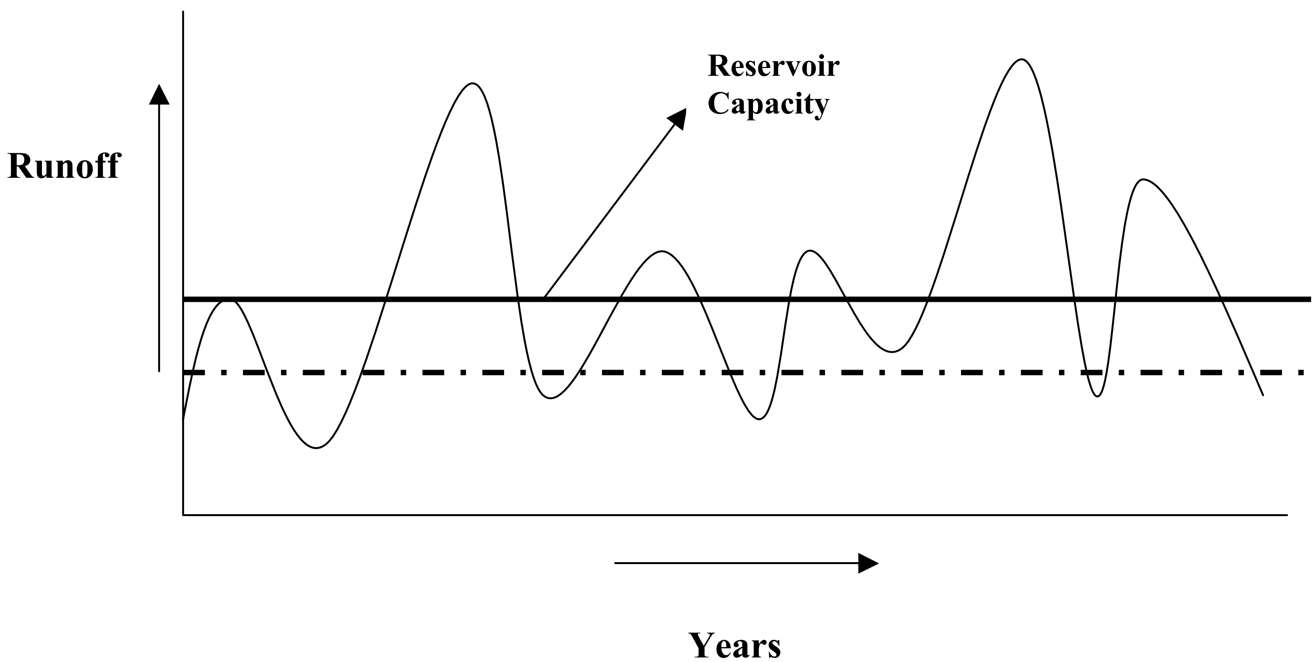


Figure 6: Downstream Impact (Modified View)

In the diagram reservoir capacity is shown by the solid line. If the reservoir capacity is such then for many years water harvesting structures built to tap additional runoff will have a negative impact (shown by the years when runoff is below the reservoir capacity line) because it will take away from the runoff to the reservoir while in a few years the structures will have a positive impact (shown by years when the runoff is above the reservoir capacity line). On the other hand if the reservoir capacity is shown by the dashed line then building water harvesting systems will have a positive impact for most years. To put it simply in closed basins where runoff generated is already being appropriated building water harvesting structures will result in downstream impact. However in open basins the runoff tapped might actually be beneficial.

To complicate the situation further localized downstream impact can take place in a watershed even if the overall downstream impact is minimal. This can be seen from figure 7.

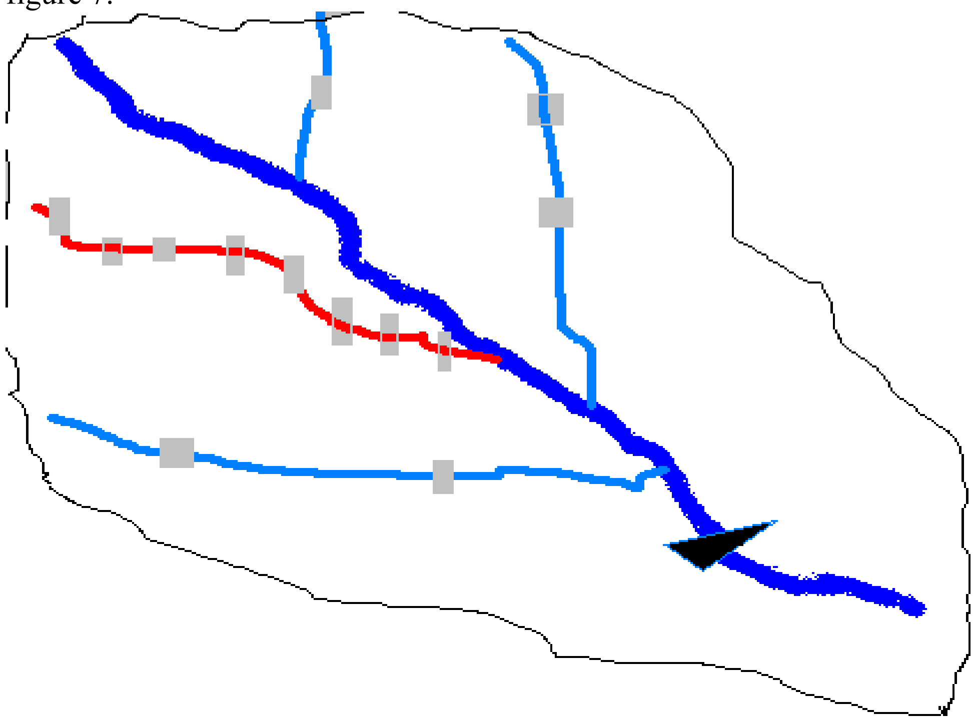


Figure 7: Localized Downstream Impact

Figure 7 is essentially same as figure 5 but here a majority of the structures built only in the watershed are on one stream while there is only a minimal concentration of structures on the rest of the streams. In such a scenario there is downstream impact of a local nature where people dependent on that stream are deprived of the runoff in low rainfall year while for the watershed as a whole the impact is minimal. This seems to be the case in the Arvari watershed where there is impact on the water availability for the villagers lying downstream of the villages of Bhaonta and Kolyala. The villagers of Kolyala themselves subscribed to the fact that building a massive water harvesting structure at the top was substantially reducing the runoff to the village of Bhuriyawas during poor rainfall years (which can be seen from the minor irrigation dam in Bhuriyawas not filling up).

In the final analysis, it is difficult to achieve a simultaneous effect on income, drought proofing and low downstream impact simultaneously during a low rainfall river basin or a heavily appropriated river basin. Trying to significantly augment income in such watersheds would imply low drought proofing potential and high downstream impact. Trying to achieve high drought proofing potential would imply low-income augmentation and high downstream impact. And trying to minimize downstream impact would imply low drought proofing and low-income augmentation. Thus all the three effects are independent of each other.

There is thus a need for a scientific examination of the hydrological credentials of river basins before embarking on programs to establish water-harvesting systems. The questions raised in the report assume immediate relevance when we realize that the state governments of Madhya Pradesh and Karnataka as well as other state governments are embarking on, or have already embarked upon, huge, multi-crore, water shed programs with a heavy bias on water harvesting structures. The analysis in the reports seems to suggest that a reexamination of the rasion d'etre for building water harvesting structures is in order, as there seems to be complex series of value judgments that have to be exercised in relation to these structures.

The debates and issues are all too real to be ignored because water harvesting is a phenomenon which is catching on across the country. However it will not be easy to convince people about the needs of incorporating the gamut of issues involved in constructing these structures unless more concrete and scientific data are available on drought proofing ability and downstream impact of the water harvesting structures. IWMI can play a significant role in this regard by doing a short first cut scientific analysis and then present it to the various stakeholders. Then, if the point drives home, further scientific research can be taken up by the stakeholders themselves in which IWMI can collaborate.

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