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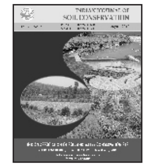

Community water harvesting structures' status, management and socio-economic impacts : Case studies in Shivaliks foothills, Northern Himalayas, India

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ABSTRACT

There has been an increasing participation of communities for management of common property water resources (CPWRs) as a means to reduce pressure on government finances, and to improve efficiency and sustainability of irrigation systems. Drawing on qualitative and quantitative surveys conducted during 2010 and 2012 of 406 households in five villages located in foothills of Shivalik region in Northern Himalayas, this paper analyses impact of community based water storage structures on productivity, economic efficiency and social aspects. Majority of surveyed beneficiary farmers (88%) belonged to marginal and small categories owning less than 2 ha of cultivated land, and are heavily dependent upon CPWRs for agriculture, animal husbandry and domestic needs. Dependence on CPWRs for irrigation was noticed to be higher of marginal farms than small farms indicating that dependence on CPWRs decreased with increase in landholding size. Marginal farmers' dependence on CPWRs for animal needs was absolute as this category of farmers do not own private water source. The results evinced that community based rain water harvesting structures have effectively contributed to close existing gap between demand and supply of water for its multiple usages. Augmentation of ground water recharge resulted in installation of tube-wells which paved way for informal local water markets by reallocation of water from surplus to scarcity farms and they are taken as a coping strategy for managing water scarcity.

1. INTRODUCTION

With limited water resources, vagaries of monsoon and looming water scarcity in many parts of India, water conservation and its use through community managed micro water harvesting structures have assumed great significance. Increasing participation of communities in management of CPWRs, which are resources to which all members of an identifiable community have in-alienable use rights, is being tried as a means to reduce pressure on government finances and to improve efficiency and sustainability of irrigation systems (Arya and Samra, 2001; Raju and Sarma, 2004 and Dasgupta, 2005). Community-managed participatory watershed projects continue to be recognized in India and various parts of the world, because not only they have successfully helped local communities to cope with water stress and scarcity, but also have performed significantly well both in terms of efficiency and administration (Aggrawal and Narain, 2002; Arya and Samra, 2006; Marcus, 2007 and Vaidya, 2015).

In addition to drinking and sanitation, rural areas depend on reliable water supply for agriculture, animal husbandry and fishing to be productive. Till recent past, a number of state governments in India conducted varying degrees of institutional reforms in the water sector, particularly in relation to irrigation, rainwater harvesting, and tapping of traditional and indigenous water resources, which are non-exclusive resources to which rights of use are distributed among a number of co-owners generally identified by their membership of a community or a village. There are numerous cases, where rainwater harvesting has been used to improve livelihoods and environment by providing water for domestic purposes, for income generation activities, for recharging groundwater, and for establishing woodlots to reduce deforestation (Farrington *et al.*, 1999; Biswas, 2005; Pathak *et al*., 2013 and Singh *et al*., 2016). In essence, these projects augmented water supply to accelerate social and economic development, by alleviating poverty, and generating income for farmers by enhancing crop yields by means of supporting production methods as well as promoting environmental conservation. But over time, due to neglect, these resources have suffered a decline in quality and the replenishment efforts made by governments have been inadequate. Alongwith neglect of these resources, demand for water (both for domestic and non-domestic purposes) has tremendously increased leading to over exploitation of these resources. Therefore, the status of these important resources needs to be highlighted.

Although, numerous micro-level studies have been performed on utilization of CPWRs for non-domestic livelihood-related purposes (such as irrigation, livestock rearing, fishing, etc.), little has been discussed about the degree and nature of dependency of different social and economic sections of rural population on these resources for basic life-sustaining activities (mainly, drinking and domestic usage) that are intimately related to the user's overall quality of life.

Equity and management aspects of non-domestic utilization of CPWRs have notable social relevance in the present Indian context. CPWRs are economic resources subject to individual use but not individual possession. Thus, CPWRs are strongly linked to the livelihood of small and marginal farmers as well as landless, yet are not possessed by any of them individually. This makes coordination of various individual users of different kinds for sustainable use important. Further, the emerging technology-driven scenario in Indian agriculture sector contains grave implication for traditional institutional arrangements for sharing of benefits as per contribution towards caring of CPWRs. The resultant local water markets are a case in point.

Present study, aimed to investigate the status of existing CPWRs in Shivalik foothills region of the country is based on data collected from eight communities managed surface and sub-surface water harvesting structures (CPWRs) in Panchkula district of Haryana state. Dependency of different socio-economic groups for various usages of selected CPWRs, impact on crop and livestock productivity, and their institutional management were studied. An attempt was also made to examine resultant water supply-demand scenario, ground water recharge and water markets, alongwith policy prescriptions for sustainability of these community based structures.

2. MATERIALS AND METHODS

Study Area

The study was undertaken by the ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Chandigarh in Panchkula district (Haryana), which lies in Shivalik foothills. The Shivalik foothills region, sandwiched between the Himalayas and Indo-Gangetic Alluvial Plains, is spread over an area of 3.33 Million ha (M ha) over states of Punjab, Haryana, Himachal Pradesh, Jammu and Kashmir, Uttarakhand and Uttar Pradesh (Yadav *et al.,* 2015). Out of Shivaliks land in Haryana, 60% is under agriculture, 30% under forests and 10% under miscellaneous uses (Statistical Abstract of Haryana, 2012-13). The farm lands in Haryana Shivaliks are generally rainfed. Inadequate distribution of precipitation, poor soil fertility, erosion hazards and small landholdings have lowered farmland productivity to one-third that of irrigated areas (Yadav *et al.*, 2005).

Approximately an area of 0.2 M ha of Shivalik foothills falls in districts of Panchkula, Ambala and Yamunanagar of Haryana state, and is ecologically highly degraded. In order to prevent and reverse the degradation process of Shivalik hills, Integrated Watershed Development (Hills) Project, also popularly known as 'Kandi' project, was implemented in different stages during the last three decades. The project aimed at providing a uniform integrated rural development platform to address social and natural resources problems of the Shivalik region. Local communities were motivated for development and effective utilization of water resources. Various field studies indicated that communities-led watershed development projects in this region have been instrumental in environmental preservation, management of common property resources, and above all, harnessing the best out of private property resources (Mishra *et al.,* 1980; Chopra *et al.*, 1990; Grewal *et al.*, 1995; Arya and Samra, 2001; Arya and Aggarwal, 2004; Arya and Singh, 2006; Arya and Yadav, 2014; Singh *et al.,* 2016).

Methodology

Multistage stratified random sampling technique was used for data collection. The first stage of data collection involved purposive selection of Panchkula district out of the three districts based on preponderance of Shivalik area (74.8%) in the district, the other two being Ambala and Yamunanagar belonging to Haryana state, India. The second stage comprised of selection of Pinjore and Raipur Rani blocks of Panchkula district (Haryana), where extensive watershed development activities were carriedout. Selection of villages was the third stage of sampling. Five villages namely, Mallah, Jabrot, Bunga, Mirpur and Sambhalwa, having surface and sub-surface water harvesting structures (which in total are eight) were selected. All these structures are being solely maintained by local communities.

Data was collected from all households in selected villages on a pre-structured schedule. A list of water users was prepared and stratified sample of water users based on land holding size was finalized for detailed survey. Comprehensive data was collected from 406 households between 2010 and 2012. Data was collected about dependence on water, quantum of water drawn from the structures, details of water use, etc. The benefits from water storage structures such as details of agricultural and livestock production, benefits from utilizing harvested water, groundwater recharge, etc. were ascertained through the personal survey. Hydrological survey of selected water storage structure was also carriedout to assess the status of water storage structures, catchment characteristics, design aspects, etc. The historical and present institutional arrangement of management, benefit sharing and conflict resolution mechanisms was also investigated. Data on multiple uses and sectoral distribution of available water from the community-based water storage structures, levels of participation in maintenance and management of these structures, water productivity in different sectors (in crop equivalent yield per unit of water), and status of water supply-demand gap were also collected.

Crop and Livestock Water Productivity

The methodology adopted by Palanisami *et al*. (1997) and Jacob *et al*. (2003) was used to estimate crop and livestock productivity from water utilized from community managed CPWRs. Crop water productivity is defined as ratio of the grain yield (usually measured in kg or its monetary value in Indian rupees) and amount of water utilised (usually limited to crop evapo-transpiration, measured m^3). In the context of supplemental irrigation, productivity is estimated based on applied irrigation water. For estimation in monetary terms, the grain yield is converted into monetary value based on its market rate before estimation.

Crop water productivity = Grain yield (kg) / water used (m^3) or Monetary value of grain yield (₹) / water used (m^3).

Similarly, water productivity of livestock was estimated based on milk yield.

Livestock water productivity = Milk yield (lts) / water used (m^3) or Monetary value of milk (₹) / water used (m^3).

3. RESULTS AND DISCUSSION

Selected CPWRs, Status and Their Utilization

As per Table 1, the catchment of all the eight structures is reserved forest which varies from 10 ha to 155 ha. Two out of selected eight structures are subsurface structures and rest six are surface water storage reservoirs. The water is being utilized for irrigation, cattle drinking, cloth/utensil washing and groundwater recharge. The height of the structures varies from 13 to 16 m and the top length in case of community check dams varies from 60 to 215 m. The command area receiving supplemental irrigation from these structures varied from 19 to 120 ha at initial stage, which has decreased considerably, varying from 6 to 60 ha (Table 1). Water distribution to agricultural fields is through pipelines and open channels. The maintenance of the subsurface structures was excellent, whereas, it was not so apparent in the case of surface structures.

CPWR Beneficiaries and Irrigation Water Dependency

Among the sampled beneficiaries, majority (56%) belonged to marginal category, followed by small (32%), medium (6%) and large (6%) categories (Table 2). The cultivated land ownership of surveyed marginal farmers was about 141 ha, of which 53% was irrigated. Of this, 79% was irrigated from CPWRs. Small farmers owned 96 ha, half of which 50% was irrigated. The contribution of CPWRs in the irrigated area was 56%. Among surveyed medium farmers, out of total cultivated area of 62 ha, 47% was irrigated (CPWRs contribution to total irrigated area-47%), and in case of large farmers, 60% of cultivated land was irrigated (CPWRs contribution to total irrigated area-28%). Average irrigated area from CPWRs varied from 28% to 79% of the total irrigated area. Dependence on CPWRs for irrigation was observed to be higher of marginal and lowest of large farms indicating that dependence on CPWRs decreased with increase in landholding size. This was because marginal and small categories of farmers do not own private water source. The average employment from crop production varied between 82 mandays holding^{-1} year^{-1} on marginal holdings and 384 mandays holding^{-1} year^{-1} on large ones.

Livestock Ownership and Water Dependency

The community managed water storage structures have also contributed to livestock production, affecting the overall village livelihood. Farmers in this region raise livestock as an essential enterprise for

Table: 1
Salient features of sampled community managed water harvesting structures

Particulars	Surface structures						Sub-surface structures	
	Bunga			Mirpur		Sambhalwa	Jabrot	Mallah
	Dam 1	Dam 2	Dam 3	Dam 1	Dam 2			
Type of structure	Surface	Surface	Surface	Surface	Surface	Surface	Sub-surface	Sub-surface
Year of construction	1983-84	1986-87	1988	2002-03	2004-05	1996-97	2001-02	2001-02
Catchment (ha)	155	101	10	70	54	101	NA	NA
Command area (ha)								
Initial	120	109	19	60	60	58	115	105
At present	35.63	25.51	Nil	24.5	18.4	46	60	58
Total number of beneficiaries surveyed	99	85	Nil	21	16	90	57	38
Purpose / utility of the structure	Irrigation, fish-culture	Irrigation	Cattle drinking	Irrigation	Irrigation	Irrigation,	Irrigation, cattle drinking, clothes washing	Irrigation, cattle drinking, clothes washing
Managing agency	WUA*	WUA	WUA	WUA	WUA	WUA	VDC**	VDC
Whether societies constituted	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Water availability status	September to February	September to February	September to February	September to February	September to February	September to February	July to April	July to April

**WUA - Water Users Association; **VDC - Village Development Committee*

Table: 2
Land holding details of sampled CPWR villages

Land holding size (ha)	No. of sampled beneficiaries	Total cultivated area (ha) of sampled beneficiaries	Irrigated area (ha)	Percentage of irrigated area by CPWRs	Average size of holding (ha)	Average employment for crops (mandays year^{-1} holding^{-1})
Marginal (< 1 ha)	229 (56)	140.7	74.4 (53)	79	0.6	82
Small (1-2 ha)	129 (32)	191.3	96.0 (50)	56	1.5	154
Medium (2-4 ha)	24 (6)	61.7	29.3 (47)	47	2.6	255
Large (> 4 ha)	24 (6)	113.9	68.8 (60)	28	4.7	384
Total	406 (100)	507.6	268.5 (53)	59	0.7	216

Figures in parentheses indicate percentages to respective total supplementing their family income due to small landholdings. Ownership of milch animals was higher than draught animals, and farmers in all the categories owned more buffaloes than cows among the sampled beneficiaries. This livestock population, estimated in terms of average number of cattle units (ACU) per farm by using conversion factors depicted by Kumbhare *et al*. (1983), was maximum on small farms (4.4 units) and it decreased with the increase in size of land holding (Table 3). The marginal and small farms owned larger number of cattle units than medium and large farms. It indicated the importance of animal husbandry as a source of livelihood for small and marginal farmers. In contrast to the livestock ownership, the water consumption for animal husbandry increased with the increase in size of land holding. Average water use for livestock production varied from 67 litres day^{-1} farm^{-1} on marginal farms to 141 litres day^{-1} farm^{-1} on large farms. But the dependency of the holdings on CPWRs for livestock needs was observed to be inverse, where it increased with the decrease in land holding size. The share of community water resource in livestock production varied from 66% on large farms to 100% on marginal farms in the sample farms surveyed, which again indicated the importance of CPWRs for small and marginal farmers having animal husbandry as an important source of livelihood. Marginal farmers' dependence on CPWRs for animal needs was absolute as this category of farmers do not own private water source. The average employment for livestock production varied from 160 mandays annum^{-1} farm^{-1} to 286 mandays annum^{-1} farm^{-1} with an average of 181 mandays annum^{-1} farm^{-1}.

Impact on Crop and Livestock Productivity

Since water supply from subsurface galleries was assured for six to eight months in a year in comparison to Bunga and Mirpur where irrigation is given only to *rabi* crops, beneficiary farmers could grow high value crops like tomato, ginger, chillies, etc.; hence, returns were higher. Contrarily, in case of the surface water harvesting structures, farmers cultivated low value crops like wheat, mustard and *berseem* due to limited water supply for supplemental irrigation. The net returns from crops as a result of differential water supply from CPWRs varied from ₹ 49,958 ha^{-1} annum^{-1} (Jabrot) to ₹ 54,292 ha^{-1} annum^{-1} (Mallah) as compared to ₹ 23,901 ha^{-1} annum^{-1} (Bunga) to ₹ 53,027 ha^{-1} annum^{-1} (Sambhalwa). As a result, the subsurface systems (Mallah and Jabrot) recorded higher crop productivity per unit of water (₹ 13 m^{-3} and ₹ 10 m^{-3}, respectively) than earthen dams (Bunga, Mirpur and Sambhalwa) (Table 4). Contrary to crop water productivity, livestock water productivity was maximum in Sambhalwa (₹ 1054.78 m^{-3}) and Bunga watersheds (₹ 704.96 m^{-3}). The net returns from livestock as a result of CPWRs varied from ₹ 41,166 cattle unit^{-1} annum^{-1} (Bunga) to ₹ 53,768 SLU^{-1} annum^{-1} (Sambhalwa) as compared to ₹ 21,796 (Mallah) to ₹ 23,272 (Jabrot). The study indicated that farmers in these watersheds supplement their low income from agriculture by keeping more number of animals and devoting more area to fodder crops.

Status and Working of Community Based Management Institutions of CPWRs

Water management is often a social and moral dilemma for the local people as it requires

Table: 4
Crop and livestock productivity (₹ m^{-3}) in CPWR villages

CPWR structure	Type of structure	Crop productivity (₹ m^{-3})	Livestock productivity (₹ m^{-3})
1. Jabrot	Sub-surface	10.00	258.51
2. Mallah	Sub-surface	13.01	119.68
3. Bunga	Surface Structure	7.34	704.96
4. Mirpur	Surface Structure	7.16	37.22
5. Sambhalwa	Surface Structure	8.50	1054.78

Table: 3
Livestock ownership details in CPWR villages

Land holding size	Cow	Buffalo	Bullock	Standard cattle units	Average number of cattle units per farm	Average water used for livestock (litre day^{-1} farm^{-1})	Dependence on CPWR (%)*	Average employment for livestock (mandays year^{-1}farm^{-1})
Marginal	181	512	182	717	3.1	67.6	100	160
Small	170	446	96	572	4.4	85.9	89	192
Medium	41	110	33	147	1.7	102.7	75	223
Large	37	132	42	171	1.5	141.5	66	286
Average					3.9	82.8	81	181

**Remaining livestock water requirement is being met through government supplied water, such as through taps.*

participatory approach which is a difficult choice that has to be made between the two or more alternatives, which may be equally undesirable. Nevertheless, the beneficiary farmers of the studied watersheds participated in planning of all functions of the structures transferred to them, including distribution of water, resource mobilisation, operation and maintenance, decision making, enforcement of decisions, and conflict resolution etc., through Water Users Associations (WUAs) registered as "Hill Resource Management Societies" (HRMS). The scope of responsibilities transferred, physical conditions of the services and institutional elements of the transfers varied from case to case. Data given in Tables 5 and 6 revealed the scope of working of HRMS in the villages in terms of activities managed. In case of Bunga, Mirpur and Sambhalwa watersheds, the HRMS have been collecting subscriptions through sale of irrigation water, fishing rights, usufructs, and collection of fines and fees from members. The functioning of these societies was enlarged by subsuming investment activities for maintaining flows from stocks of common property resources.

In case of Mallah and Jabrot, farmers' participation in operation and maintenance of subsurface drainage and consequently recovery of maintenance costs was the most important issue to start with, because these subsurface drainage networks are on land in possession of farmers. However, before the subsurface structures were constructed, water users in these two villages had evolved a wealth of expertise from managing a *kuhl* system (open water distributing channels) that was in operation in these villages over 100 years for providing water to agricultural fields. They evolved a common set of norms for participation in management of *kutcha* (without cement lined) *kuhl* system.

The subsurface structure is a source of good quality water because the water gets filtered automatically while crossing various layers of the Earth. In addition, there is no risk of silting or drying up, though the volume may reduce during off-season. It can be utilized downstream under gravity by using Un-Plasticized Polyvinyl Chloride (UPVC), High-Density Polyethylene (HDP), and Reinforced Cement Concrete (RCC) pipelines.

Water Allocation Rules

In case of water harvesting structures in Bunga, Mirpur and Sambhalwa, water rights have been established for all members of the societies. Each society fixed the charges for water on hourly basis and gave

Table: 5
Status of community based management institutions of water storage reservoirs

Particulars	Surface structures			Sub-surface structures	
	Bunga	Mirpur	Sambhalwa	Jabrot	Mallah
Name of managing agency/water users association	Hill Resource Management Society	Hill Resource Management Society	Hill Resource Management Society	Jabrot Kissan Club	Village Development Committee
Year of formation	1985	2004	1998	2003	2003
Membership criteria of General Body	All beneficiaries	All beneficiaries	All beneficiaries	All households	All households
Executive committee constitution	10 (two women members)	8 (two women members)	11 (two women members)	12 (two women members)	12 (two women members)
Meetings held	Regularly	Occasionally	Regularly	As and when needed	As and when needed
Source of fund	Water charges, fish cultivation in pond	Water charges, fish cultivation in pond	Water charges	Beneficiaries contribute as and when needed	Beneficiaries contribute as and when needed

Table: 6
Expenditures and fund sources of HRMS of community managed water storage structures

Watershed	Operation period of Society	Activity	Expenditure (₹)	Farmers' contribution (%)	Source of fund
Bunga	1985-86 to 2012-13	a) Dam / pipeline repair	523715	100	a) Sale of grass from community forest area
		b) Investment on community works	529970	100	b) Irrigation charges
		c) Salary of watchman	312939	100	c) Renting reservoir for fish production
		d) Miscellaneous	219742	100	d) Membership fee and fines
Mirpur	2004-05 to 2012-13	a) Lease amount paid to Haryana Forest Department contribution (%)	101425	100	a) Sale of grass from community forest area
		b) Repair and maintenance of dam and pipeline	202680	100	b) Irrigation charges
		c) Village development work	85507	100	c) Membership fee and interest from bank
		d) Travelling and other administrative expenditure	31824	100	
		e) Salary of watchman	59000	100	
Sambhalwa	1998-99 to 2012-13	Repair and maintenance of dam	246780	100	Irrigation charges and membership fee
Jabrot	2003-04 to 2012-13	a) Purchase of pipeline	47900	100	Money was collected from each beneficiary.
		b) Repair, maintenance of tank, pipeline and kuhl	114300		Besides, farmers also contributed 3910
		c) Repair of cattle pond	30800		mandays of labour.
Mallah	2003-4 to 2012-13	a) Repair, maintenance of pipeline	27500	100	Money was collected from each beneficiary.
		b) Construction of pucca *kuhl* and extension of pipeline	35800		Besides, farmers also contributed 2695
		c) Cleaning of channels	17600		mandays of labour

selling rights to those who could not utilize their share themselves. The rates varied according to the size of pipeline, which was typically between ₹ 15 $hour^{-1}$ (80 mm pipeline size) and ₹ 30 $hour^{-1}$ (133 mm pipeline size). The creation of water tanks also enabled the villagers to reap benefits from selling of fish by auctioning it to a contractor. In case of sub-surface structures, water is allocated *sami*-wise (shareholders in the land) and is free of charge. There are three *samis* in village Mallah and 10.5 in Jabrot. Each *sami* is allocated 24 hours of water in Mallah, and 12 hours in Jabrot. Again, the process is repeated after distributing the water to all the *samis.* After the construction of infiltration galleries in these villages, Village Development Committees were formally reconstituted. There is a President, a Secretary, a Cashier and seven Members in the Executive-Committee, which includes two women. The Chairman of the committee is always the *Sarpanch* (*i.e.* Head) of the village to avoid conflict and smooth functioning of the society. Since no rates are fixed for water usage, repair and maintenance costs of the system, they are being shared equitably by all the *samis* by contributing labour and cash**.** The maintenance objective is to sustain a reliable system for the future. Government provided a small amount of assistance in the past, and in rare instances provides technical advice for now. Table 6 indicated that the societies incurred the maximum expenditure on repair and maintenance of pipelines. Besides, society of Bunga has also invested on developmental works like construction of school, *dharamshala* (social welfare place), temple, tube-well, veterinary hospital, community centre, to name a few.

Ground Water Recharge Impact and Resultant Water Markets

An attempt was made to study the impact of CPWRs on groundwater recharge in the surveyed villages. As scope of our present investigation is limited to indicate the unseen role of reservoirs in creation of local water markets through ground water recharging, we focused on the socio-economic impact, and not on quantifying volume of water recharged.

There were no open wells in the studied area as such. Hence, the numbers of tube-wells which have come up in over a period of time after construction of community managed water harvesting structures were listed to quantify the impact of the structures on groundwater. In Bunga watershed, over a period of 22 years (1988-89 to 2010-11), 13 tube-wells had been installed and the area from tube-wells increased from 11 ha to 108 ha. In all three watersheds together, Bunga, Mirpur and Sambhalwa, 55 tube-wells have been installed by farmers in the recharge zone of the structures. Whereas, no tube-wells have been installed in Jabrot and Mallah (subsurface watersheds) because water supply was available for 6 to 8 months in a year from the structures.

Installation of the tube-wells near surface structures has been possible mainly due to efforts of the community in conserving water and recharging of groundwater. Surplus pumping capacity created for these tube-wells by the community-managed water harvesting structures is being used for augmenting economic benefits of the tube-well owners, and other farmers who are not in a position to invest in extraction of groundwater. Over a period of time, these dams have silted up and more than half of their water holding capacity has been lost. In absence of any other assured source of irrigation water, recharging of individual tube-wells, which has resulted into building private property water resources, has created informal ground water markets that have gradually expanded in the study area, and are taken as a coping strategy for managing water scarcity and reallocation of water from water surplus to the water scarcity farms.

The ground water markets ensure that the surplus pumping capacity is being profitably utilized. This increases economic benefits for the tube-well owners. The markets furthermore allow farmers, who are unable to make the necessary investments in tube-wells, to meet their irrigation water demand, offering them opportunity to benefit from improved agricultural productivity due to irrigation (Shiferaw *et al.*, 2008). Consequently the water markets appear to be beneficial for the society as a whole (Saleth, 2004). Groundwater markets in India are mostly informal and have usually emerged from farmers' initiatives. They are enforced through users' cooperation, and water rights in these markets are often not explicitly defined (Zekri and Easter, 2007).

However, the use of tube-well extracted water is guided by private resource regime, and is not equitably shared by tube-well owners with the others in society. The survey revealed that the tube-well owners are selling water for irrigation in the range of ₹ 40 hour^{-1} to ₹ 60 hour^{-1} in contrast to ₹ 6 hour^{-1} from the dams. Paddy was being grown by farmers who have their own tube well. All the other households were buying water for wheat and *berseem* only. It was estimated that tube-well owners in Bunga are providing irrigation water to their own fields in a year worth ₹ 2,95,800 in contrast to other users worth only ₹ 1,26,798.

Profile of Tube Well Owners and Water Buyers in Studied Watersheds

For an in-depth analysis of these local water markets, 311 households in Bunga, Mirpur and Sambhalwa villages were surveyed (Table 7). Land holding profile of studied villages revealed that 18% of the farmers owned tube-wells and remaining were water buyers. All the farmers with land holding >3.0 ha owned tubewell. The average land holding size of tube-well owners was estimated to be 2.29 ha as compared to 0.97 ha of the buyers. The relatively high investment required in water extraction mechanism (WEM) explains scale bias in land ownership in these villages. A farmer needs to invest ₹ 5 to 6 lakh for a complete WEM, which clearly reflects direct correlation with owner's land size. Out of the 55 tube-well

Table: 7
Land holding profile of tube-well owners and water buyers in Bunga, Sambhalwa and Mirpur villages

Land holding category (ha)	No. of house-holds	Tube-well owners			Water buyers		
		No. in sample	Total land (ha)	Average land ownership (ha)	No. in sample	Total land (ha)	Average land ownership (ha)
0.0-1.0	168	3 (1.8)	2.19	0.73	71	39.76	0.56
1.0-2.0	114	34 (29.8)	54.42	1.60	84	99.69	1.19
2.0-3.0	17	6 (35.3)	15.90	2.65	9	18.99	2.11
> 3.0 ha	12	12 (100.0)	53.59	4.47	Nil	Nil	Nil
Total	311	55 (17.7)	126.10	2.29	164	158.44	0.97

Figures in parentheses are sample percentage of number of households in a land category owners, all have surplus pumping capacity, except large farmers (>3.0 ha), and are selling irrigation water to their neighbouring farms.

Further, watershed-wise analysis was done with survey data for understanding other dimensions of water markets in these watersheds. Differences were observed across the watersheds in numbers of tube-well owners selling pumped water, average number of buyers per seller, average season area of buyer's land irrigated per seller, hours of sale per year, number of hours of waters used per acre and own area irrigated by tube-well owners (Table 8). On an average, a seller supplied water to 2.98 buyers, in addition to irrigating his own land. Average number of buyers per seller varied from 1.23 in Sambhalwa village to the highest 6.46 in Bunga village. Most of these belonged to small and marginal categories to which food security always remains the first priority. Fodder for animals is their next priority as livestock are an integral part of the farming system in these areas because more than 50% of the farming income is contributed by livestock sector. In Sambhalwa and Bunga, 81% and 16% of gross cropped area is cultivated with cereals and fodders, respectively, and 65% and 67% of total farming income is earned through cereals and livestock, respectively. Since dam water is available in limited quantity, and water rates charged by tube-well owners are not always fixed due to informal nature of the market (charge rate depends upon need and demand from buyers), these farmers are buying water from tube-well owners for wheat and *berseem* cultivation because they are not in a comfortable situation to pay the heavy water charges. However, tube-well owners are growing paddy, in addition to wheat and *berseem*. They are also growing small amount of vegetables like potato, tomato etc. Average season area of buyers' land irrigated per seller varied from 2.24 ha to 4.10 ha indicating the surplus pumping capacity generated by the structures (Table 8) which is 2.88 ha for the 3 watersheds together. Similarly the surplus pumping capacity is indicated by a number of irrigation hours sold per year, which varied from 332 to 884. The average annual hours of sale/seller for the 3 watersheds was 33 hours.

Water Supply-Demand Scenario

Water demand of two major sectors - crop and livestock - was estimated on the basis of crop water requirement and livestock requirement. The crop water requirement was the amount of water being used for irrigation, whereas livestock water requirement was for drinking and washing purpose. The supply status of water included water from CPWR structures, cattle ponds and tube-wells. Since tube-wells in these villages have come up exclusively as a result of ground water recharge, so water availability from tube-wells was also taken into account. The estimate revealed that the water supply in all the watersheds exceeded demand, more so in Mallah and Jabrot due to perennial flow throughout the year (Fig. 1). However, without considering water supply from tube-wells, it was observed that the surface structures could meet out only 36% of water requirement of both crops and livestock indicating deficiency of water supply purely from CPWR structures, thus highlighting role of tube-wells in the water scenario of the studied area.

Policy Implications

Community management, however, is not a 'magic wand' for solving problems in water sector, or

Table: 8
Dimensions of water markets in studied watersheds

Particulars	Bunga	Sambhalwa	Mirpur	Total
Number of tube well owners selling irrigation water	13	35	7	55
Number of buyers	84	43	37	164
Average number of buyers per seller	6.46	1.23	5.28	2.98
Area irrigated with purchased water (ha)	53.2	78.6	26.6	158.4
Average season area of buyers' land irrigated per seller (ha)	4.10	2.24	3.80	2.88
Number of irrigation hours sold per year	599	884	332	1815
Average annual hours of sale/seller	46	25	47	33
Average hours of water used by buyers per acre	11.25 (4.5 hrs/acre)	11.25 (4.5 hrs/acre)	12.5 (5 hrs/acre)	11.66
Total tube well owners irrigation of own field (ha)	34.8	73.7	17.6	126.1

Weighted average cost of irrigation to buyers: a) ₹ 180 acre^{-1} = ₹ 450 ha^{-1}; b) ₹ 50 on an average; c) ₹ 3 hp-hours^{-1} (if pump is of 20 hp) for governments who are keen to decentralize or privatize water provision. Neither is it a recipe that can be replicated wholesale as a blueprint. In every community, the process has been very different, in terms of both pace and content. Although in each case, the communities are now better able to manage their water supply systems, the institutions, rules and structures that have underpinned this enhanced capacity are also diverse. This diversity again demonstrates that the communities have designed their own management systems, rather than follow a blueprint provided by support agencies. Certain observations from the field that can form basis of future policies are mentioned below:

(1) State support to community action, both in technical and financial terms, is a pre-requisite for effective harnessing and management of water resources at local level. The relevant government agencies need to be more encouraging in their approach in involving community members in maintenance of irrigation infrastructure. Timely and appropriate support on the part of state agencies would have resulted in decreased rate of siltation in the reservoirs, thereby increased water availability in case of both Bunga and Mirpur watersheds.

(2) The study indicated that although water supply exceeded due to availability of tube-wells in case of surface structures, but total area under irrigation decreased over the years due to maximum use of tube-well water by owners themselves for sowing water intensive crops such as paddy, sugarcane and *berseem*. Many scholars and policy makers believe that rights to groundwater should be those of use and not of ownership (Vaidyanathan, 1996). If the state recognizes these institutions and gives them authority to manage groundwater resources, then chances are good that these will work efficiently. The State should facilitate functioning of the community and efforts to harness and conserve water resources, by providing technical and financial inputs for monitoring groundwater and status of water balance in the zone. It would require some special efforts to organize communities around water resources in such a manner.

(3) Informal water markets, as evident from the study, are playing a crucial role in the nature of agricultural development in the region. Monopoly over water resources by a few has led to inefficient allocation of water affecting land productivity and keeping crop yields low for village as a whole. Therefore, ground water, a valuable natural resource, should not be left unmanaged, as it is prone to overexploitation. There is a need to change the status of groundwater recharged due to CPWR structures from private property resource to a co-operative or joint property of the users through creation of co-operative usufruct rights and vesting them in water users' co-operative societies.

(4) An integrated water management practice consisting of three main components - rainwater harvesting, water-saving micro-irrigation, and highly efficient crop production - should be adopted. There is a need to create awareness about effective cultivation practices, efficient use of water through drip and sprinkler systems and crop rotations, etc.

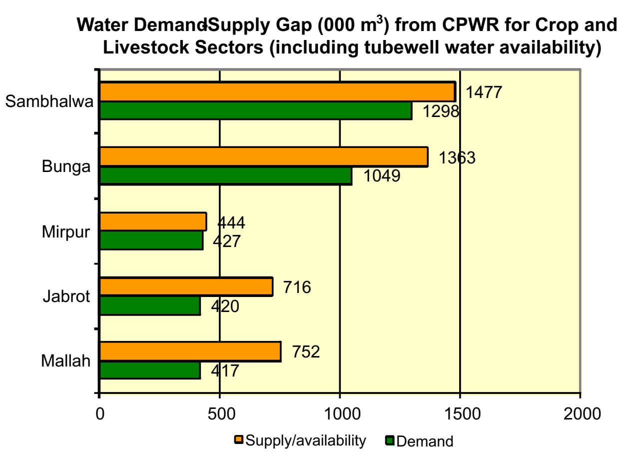

Fig. 1. Water demand-supply difference for crop and livestock sectors from CPWRs

4. CONCLUSIONS

The status and management of eight community managed water harvesting structures in Panchkula district of Haryana state in India in terms of dependency, productivity, socio-economic aspects and groundwater recharge was assessed. All the eight structures are being solely maintained through community based institutions regarding distribution of water, collection of repair charges and maintenance of pipelines, etc. Majority of beneficiary farmers (88%) of CPWRs belonged to marginal and small categories each owning less than 2 ha land. Their dependence on CPWRs was mostly for irrigation and livestock, which decreased with increase in landholding size due ownership of private water source by larger land holdings. Subsurface systems recorded higher crop productivity per unit of water than surface earthen dams due to better water supply of 6 to 8 months from former compared to only during winter from latter. On the other hand, farmer's dependence on surface CPWRs had higher livestock productivity apparently to compensate for lower crop productivity from lesser irrigation water supply from their CPWRs. The case studies discussed are innovative community water resource management models, which have proven to be beneficial to user groups. As literature suggests scarcity of and dependence on resources, the non-availability of alternative resources, high perceived benefits, and homogeneity of user groups play a major role in ensuring durable collective action for management of water resources (Chopra and Kadekodi, 1990; Kumar and Vashisht, 2005; Gupta, 2004 and Singh, 2008). All these factors were found to be intrinsic to the discussed models. The major impact of the surface water harvesting structures has been creation of local water markets in the respective villages by installing tube-wells. But they are informal markets guided by private resource regime leading to inequitable distribution of pumped groundwater recharged due to the CPWRs established by contribution of all the villagers. Though, these groundwater markets provide resource poor farmers access to irrigation water, giving them opportunity to raise their productivity, but the economic benefits derived by the tube-well owners from the resultant surplus pumping capacity of their water extraction mechanisms are far higher than that of have-nots.

REFERENCES

Aggrawal, A. and Narain, S. 2002. Community and household water management: The key to environmental regeneration and poverty alleviation. In: Marothia, D.K. (eds.), *Institutionalizing Common Pool Resources*. Concept Publishing Comp., New Delhi.

Arya, S.L. and Aggarwal, R.K. 2004. Organizational structure, membership pattern and present status of hill resource management societies in Haryana Shivaliks. *J. Soc. Econ. Dev.*, 6(1): 1-22.

Arya, S.L. and Samra, J.S. 2001. *Re-visiting Watershed Management Institutions in Haryana Shivaliks, India*. Central Soil and Water Conservation Research and Training Institute, Dehradun, 361 p.

Arya, S.L. and Samra, J.S. 2006. Impact analysis of watershed development projects in Shiwalik foothill villages in Haryana state. *Agric. Situa. India*, 62(2):711-722.

Arya, S.L. and Singh, P. 2006. Capacity building of informal institutions through integrated wasteland development project in villages of Punjab. *Indian J. Exten. Edu.*, 42(1&2): 136-142.

Arya, S.L. and Yadav, R.P. 2014. Joint forest management in Haryana: Assessment of performance and evaluation of impacts. *Ind. J. Soil Cons.*, 42(3): 314-321.

Biswas, A.K. 2005. *Integrated Water Resources Management in South and South-East Asia*. Oxford University Press, New Delhi.

Chopra, K. and Kadekodi, G.K. 1990. *Participatory Development - People and Common Property Resources.* Sage Publications India Private Limited, New Delhi, 163 p.

Dasgupta, P. 2005. Common property resources: Economic analytics. *Econ. Polit. Weekly*, 40(16):1610-1622.

Farrington, J., Turton, C. and James, A.J. (eds). 1999. *Participatory Watershed Development: Challenges for the Twenty - First Century*. Oxford University Press, Delhi.

Grewal, S.S., Samra, J.S., Mittal, S.P. and Agnihotri, Y. 1995. *Sukhomajri Concept of Integrated Watershed Management.* Technical Bulletin No. T-26/C-5. Central Soil and Water Conservation Research and Training Institute, Research Centre, Chandigarh, India, 157 p.

Gupta, R.K. 2004. Water governance in Gujarat state, India. *Water Resour. Dev.*, 20(2):131-147.

Jacob, W.K., Barker, R. and Molden, D. 2003. Improving water productivity in agriculture: Editor's overview. In: Kijne, J., Barker, R., Molden, D. (eds.). *Water Productivity in Agriculture: Limits and Opportunities for Improvement, Comprehensive Assessment of Water Management in Agriculture.* CABI Publishing, UK in association with International Water Management Institute, pp xi-xix.

Kumar, C. and Vashisht, U.S. 2005. Redefining community state partnership in natural resource management: A case from India. *Dev. Prac.*, 15(1): 28-38.

Kumbhare, S.L., Sharma, K.N.S. and Patel, R.K. 1983. Standardization of bovine units. *Indian J. Animal Sci.*, 53(2): 547-550.

Marcus, R.R. 2007. Where community-based water resource management has gone too far: Poverty and disempowerment in southern Madagascar. *Cons. Soc.*, 5(2): 202-231.

Mishra, P.R., Grewal, S.S., Mittal, S.P. and Agnihotri, Y. 1980. *Operational Research Project on Watershed Development for Sediment Drought and Flood Control - Sukhomajri*. Central Soil and Water Conservation Research and Training Institute, Research Centre, Chandigarh, India, 57 p.

Palanisami, K., Rajagopal, A. and Mohamed, Ali. A. 1997. *Productivity Per Unit of Water Under Various Land Uses Mixes in Tamil Nadu.* Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore, 12 p.

Pathak, P., Chourasia, A.K., Wani, S.P. and Sudi, R. 2013. Multiple impact of integrated watershed management in low rainfall semi-arid region: A case study from eastern Rajasthan. *Indian J. Water Resour. Protec.*, 3(5): 27-36.

Raju, K.V. and Sarma, C.V.S.K. 2004. *Water Rights in India and Water Sector Reforms in Andhra Pradesh.* Working Paper No 149, Institute for Social and Economic Change, Bangalore, pp 1-20.

Saleth, R.M. 2004. *Strategic Analysis of Water Institutions in India: Application of a New Research Paradigm*. IWMI Research Report 79, IWMI, Colombo, Sri Lanka, 38 p.

Shiferaw, B., Reddy, R.V. and Wani, S.P. 2008. Watershed externalities, shifting cropping patterns and groundwater depletion in Indian semi-arid villages: The effect of alternative water pricing policies. *Ecol. Econ.*, 67(2): 327-340.

Singh, N. 2008. Indigenous water management systems: Interpreting symbolic dimensions in common property resource regime. *Soc. Natural Resour.*, 19(4): 357-366.

Singh, O., Sharma, T. and Singh, J. 2016. Farmers' perceptions and satisfaction levels on the performance of watershed development activities in the Morni hill area of Shivalik Himalayas in India. *J. Human Ecol.*, 43(6):1-14.

Vaidya, R.A. 2015. Governance and management of local water storage in the Hindu Kush Himalayas. *Int. J. Water Resour. Dev.*, 31(2): 253-268.

Vaidyanathan, A. 1996. Depletion of groundwater: Some issues. *Indian J. Agric. Econ.*, 5(1&2): 184-192.

Yadav, R.P., Aggarwal, R.K., Arya, S.L., Singh, P., Prasad, R., Bhattacharyya, P., Tiwari, A.K. and Yadav, M.K. 2005. *Rainwater Harvesting and Recycling Technology for Sustainable Production in Small Agricultural Watershed - Johranpur*. Bulletin No. T-50/C-11, Central Soil and Water Conservation Research and Training Institute, Research Centre, Chandigarh, 165 p.

Yadav, R.P., Panwar, P., Arya, Swarn Lata and Mishra, P.K. 2015. Revisit of Shivalik region in different states of north-western India. *Geolog. Soc. India*, 86(3): 351-360.

Zekri, S. and Easter, K.W. 2007. Water reforms in developing countries: Management transfers, private operators and water markets. *Water Policy*, 9(6): 573- 589.