Farm level rainwater harvesting for dryland agriculture in India: Performance assessment and institutional and policy needs

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Abstract

The present study was conducted to assess the performance of farm ponds in 5 major rainfed states of India - Andhra Pradesh, Maharashtra, Karnakata, Tamilnadu and Rajasthan, during 2009 and 2010. The data points included sites in the field, farmers, implementing agencies, NGOs, scientists and policy-makers. Rainwater harvested was either used for supplemental irrigation or recharging the open wells. Rainwater harvesting structures of different types and size (10x10x2.5 m, 30x30x3m, 45x45x3m; 82x26x3m) were constructed on individual farms, especially for smallholders. The farmer's contribution to the cost of construction ranged from 10 to 80%. In many cases, farm level rainwater harvesting structures were highly useful for rainfed farming under climate change scenario and had a multiplier effect on farm income. In other situations, it was viewed as wastage of productive land. The farm ponds in Maharashtra resulted in significant increase in farm productivity (12 to 32 %), income and cropping intensity. The ponds were also used for aquaculture for 6-7 months, providing additional net income up to US$ 200 / pond/ annum. Similarly, in Andhra Pradesh farm pond water was useful for supplemental irrigation to mango tree plantation, vegetables and other crops and animals and resulted in significant increase in household income adding net returns of US$ 120 to 320 ha^{-1} annum^{-1}. In spite of its great relevance, the acceptance and adoption of farm pond was not very high except in Maharashtra. The study analysed the factors responsible for success and failure. Though the customization of package and technology were important factors, the institutional mechanism, governance at grass root level and people's participation played greater role in the success. Based on the lessons learnt, different policy and institutional options are proposed for promoting farm-level rainwater-harvesting for dryland agriculture.

Introduction

Rainwater management is the most critical component of rainfed farming, which accounts for about 56 % of the total net sown area in India. The successful production of rainfed crops largely depends on how efficiently soil moisture is conserved *in situ* or the surplus runoff is harvested, stored and recycled for supplemental irrigation. Hence the rainwater harvesting for the past couple of decades has been an important component of rural and agriculture development programmes in India. The importance of rainwater harvesting for agriculture has further been increased as an adaptation strategy in view of increased climatic variability and frequency of extreme weather events.

Research institutions and agricultural universities have worked on designing of efficient rainwater harvesting structures for different rainfall regions and soil types, effective storage of harvested water and method of its efficient use in the Indian context. Since community based initiatives have their own limitations, currently the rainwater harvesting is being promoted at individual farm level. Thousands of farm ponds (dugout pond) have been dug in different rainfed regions of India during the past one decade under different government schemes and to some extent by voluntary agencies. However, the impact of these efforts on agriculture as indicated by the core studies (Rao *et al.* 2009) and press and media has not been very satisfactory especially in terms of enhancing agricultural productivity and farm income. Moreover, no comprehensive study has assessed the performance of rainwater harvesting at farm level in terms of its potential utility and related institutional and policy needs in different agro-climatic regions. Therefore the present study was conducted to assess the performance of farm ponds/rainwater harvesting structures (RWHSs) in five major rainfed states of India representing different agro-climatic regions.

Sampling design and data

Five major rainfed states of India namely; Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu and Rajasthan were selected for the study at first stage. At the next stage sample districts were selected purposively representing diversity from the selected states as presented in Table 1. Thus, the study covered a sample size of 100 farmers with rainwater harvesting structures spread over 5 states under different rainfall and soil situations during the year 2009-2011. Besides farmers, the data points included sites in the field, programme implementing agencies, research scientists, relevant non-governmental organizations (NGOs), policy makers and on-farm trails of All India Coordinated Research Project on Dryland Agriculture (AICRPDA) in different regions.

Table 1: Distribution of sample households across states and districts

State	Districts	No. of block	Rainfall (mm)	Sample farmers	Soil type	Major production system
Andhra Pradesh	Chittoor	2	700	10	Loam	Paddy, sorghum, mango
	Ananthpur	2	500	10	Alfisol	Groundnut, castor, sorghum
Maharashtra	Akola	2	834	20	Vertisol	Cotton, pigeon pea, chickpea
Karnataka	Bangalore rural	2	900	20	Alfisol	Finger millet pigeon pea
Tamilnadu	Vellore	2	795	20	Alfisol	Sorghum, coconut
Rajasthan	Bhilwara	2	650	10	Inceptisol	Maize, groundnut
	Jodhpur	2	350	10	Aridisol	Pearl millet, pulses

Results and discussion

The rainwater harvesting at farm level under scientist managed on-farm trials conducted through All India Coordinated Project on Dryland Agriculture (AICRPDA) centers in their Operational Research Project was found to have good potential under different production systems and soil and rainfall situations (Table 2). The initial investment on construction of farm ponds up to 70 per cent was supported from the project. The additional net returns due to farm pond in different agro-climatic situations ranged from US $ 26-47 to US $ 186-466 per hectare. This assessment clearly substantiates the line of thinking that encourages increased public investment on farm level rainwater harvesting. However, the performance of farm level rainwater harvesting adopted by farmers under different government programmes and areas, has not been same and had shown mixed results.

Table 2: Performance of on-farm trials of farm ponds under different agroclimatic regions

Rain fall (mm)	Major soil types/ order	State	Major production. systems	Type of farm pond	Potential benefits		
					Increment in system's yield (%)	Additional net returns (US \$ ha^{-1} $annum^{-1}$)	Unit cost of structure (US \$)
500 to 750	Alfisols	Andhra Pradesh	Sorghum, castor based	250 m^3 farm pond with lining + sprinkler with 3 hp pump set	15-25 (Increase in cropped area 10-15%)	84-131 per farm pond/ annum	1024
			Groundnut, castor based	Water harvesting and recycling through farm ponds with lining with soil + cement (6:1 ratio)	*20- 24 (*+diversification into vegetables)	72-121	1024
	Inceptisols	Rajasthan	Maize based	500 m^3 farm pond with lining + sprinkler with 3 hp pump set	20- 25 (+diversification + bring waste-land into cultivation*)*	158-224	1397
	Vertisols	Gujarat	Groundnut based	Recharging defunct open wells through filters (Retains 67% sediment load and enhance ground water level) *(*filter and deepening of the defunct well)	15-30	26-47	931
750 to 1000	Alfisol	Karnataka	Finger millet based	250 m^3 Farm pond with lining + sprinkler with 3 hp pump set	15-20 (+10-15% more area under vegetables)	102-224	1024
	Vertisol	Madhya Pradesh	Soybean based	1000 to 4000 m^3 pond without lining mainly for large farmers	20-40 (+diversification into flori-horticulture	149-298 per pond of 1000 m^3	1.6 per m^3
		Maharashtra	Cotton based	500 m^3 farm pond without lining + sprinkler with 3 hp pump set	20-25 (+ 15-20 % increase in cropped area)	149-298 per pond	1397
> 1000	Inceptisols	Jammu & Kashmir	Maize based	250 m^3 farm pond with lining + sprinkler with 3 hp pump set	25 (+ diversification)	84-186 per pond	931
	Oxisols	Jharkhand	Paddy based	1000 m^3 to 4000 m^3 farm pond with lining + sprinkler with 3 hp pump set	30-50	279-381	1862-6518
	Vertisols	Madhya Pradesh	Paddy, soybean based	250 to 500 m^3 farm pond without lining + sprinkler with 3 hp pump set	20-25 (+higher diversification)	130-335	838-1304

Note: 1 US\$ = INR 53.70

Farm level rainwater harvesting in different states

The rainwater harvesting systems (RWHSs) practiced in different states of India through different types and size of individual ponds dugout under different public funded schemes such as Mahatama Gandhi National Rural Employment Guarantee Scheme (MNREGS), Integrated Watershed Management Programme (IWMP), National Agricultural Development Programme (RKVY) and National Horticultural Mission (NHM) were assessed. The farm level rainwater harvesting though was a need-based intervention taken up as part of these programmes but the demand in majority of the cases did not come from the farmers indicating their low level of awareness and participation. The rainwater harvested and stored through farm ponds on individual farmer's field was recycled mainly for supplemental irrigation during dry spells. In some villages in Tamilnadu and Andhra Pradesh these structures were dug in the vicinity of open wells and were used as percolation ponds for their recharging. In Jodhpur, Rajasthan, rainwater was harvested in an underground cistern locally known as *Tanka* which is an age old practice. The harvested water was used for drinking purpose as well as to provide water to few perennial plants near the water source. *Khadin,* which is an ancient method of rainwater harvesting, was practiced in Rajasthan mainly in hyper arid areas with annual rainfall <300 mm, wherein rocky catchments are used to collect runoff which is allowed to percolate in the soil to raise crops in winter (rabi) on the conserved moisture.

The size and initial investment on RWHSs varied significantly in different states (Table 3). The harvested water was not utilized by using micro-irrigation systems in most of the states indicating scope for increasing efficiency of water use. The structures of different types - farm pond, percolation pond and *Tanka* of different size (10x10x2.5 m, 30x30x3m, 45x45x3m; 82x26x3m etc.) - were constructed on individual farms under various government programmes with preference to small holders. The farmer's contribution ranged from 10 to 50%. All were open structures except customised concrete covered structures called '*tanka'* and *'Jal kund'* in western Rajasthan where evaporation losses are very high due to higher temperature and wind velocity. The farm ponds in the black soil area were not lined however the lining with LDPE sheet or other cost effective alternative was required in the red/sandy soil area to minimise seepage loss.

It was critically important to decide the appropriate size and location of the RWHSs depending on the runoff potential and slope of the catchment area and called for the involvement of technically qualified person. Since only some farmers (not more than 30% in a village) opted for the RWHSs, practically the catchment area for the ponds of any farmer was more than his own field. In many cases, except Akola in Maharashtra, Vellore in Tamilnadu and Chittoor in Andhra Pradesh, the location of RWHSs was not technically appropriate and decided either on the basis of convenience of farmer or the contractor who dug these structures. In Akola district, several farm ponds were dug appropriately across the drainage line. In Chittoor the number of fillings were more also because of lateral seepage.

Implementation strategy

The strategy of implementation of the programmes was not same in all the states and to a great extent influenced the usefulness of these structures. In 'better performing districts' such as Chittoor, Akola and Vellore, in the beginning the farmers were sensitized on the importance

Table 3: Details of rainwater harvesting structures in different states, India

District (State)	Average land holding (ha)	Size of farm pond	Purpose	Average initial investment (US $)	Farmer's contribution (% of total)	No. of fillings per year	Access to water lifting device (% farmers)	Extent of recharging open wells (feet)	Method of irrigation	Inlet/ outlet pitching (% pond)	Relevant schemes
Chittoor (Andhra Pradesh	3.31 (2.01-4.0)	100 m^3-700 m^3	Supplemental irrigation, diversification	521	25	6	80	-	In furrow with PVC pipe- 74%; MIS- 26%	75	IWMP
Anantpur (Andhra Pradesh)	3.6 (1.9-5.6)	150 m^3-600 m^3	Recharging, Supplemental irrigation by few farmers	577	10	2	15	10-15	-	10	MNREGS
Bangalore R (Karnataka)	1.6 (1.04-3.5)	100 m^3-500 m^3	Vegetables and perennials on the fringes	410	10	-	5	-	-	10	IWMP, MNREGS
Akola (Maharashtra)	6.0 (2-16)	900 m^3-2500 m^3	Supplemental irrigation, diversification	1527	10	4	100	-	Sprinkler- 100%	85	RKVY, NHM
Vellore (Tamilnadu)	3.05 (2.2-6.4)	500 m^3-1800 m^3	Recharging open wells	801	15	3	75	12-18	In furrow with PVC pipe- 65% MIS- 35%	65	IWMP, MNREGS
Bhilwara (Rajasthan)	6.55 (3.5-9.7)	500 m^3-2200 m^3	Supplemental irrigation	1415	10	1	50	-	In furrow with PVC pipe- 62% Manually- 38%	60	NHM
Jodhpur (Rajasthan)	3.85 (2.1-11.5)	Underground tank (Tanka): 30000 l	Drinking, Supplemental irrigation in fruit plants	1100	50	3	20	-	In furrow with PVC pipe- 43% Manually- 67%	90	IWMP, NHM

Note: 1 US$ = INR 53.70

and potential of rainwater harvesting for enhancing agricultural productivity. Dhan foundation - an NGO in Chittoor – and Agricultural officers in Akola and Vellore played proactive role in creating convergence and helped farmers accessing water lifting pumps, micro-irrigation system (MIS) - sprinkler and drip - and improved seeds. Once the farmers got convinced on the need of RWH structures, the size and location of farm pond was decided together by farmer and the project staff depending on the runoff potential and farmer's need. A series of farm ponds were constructed across the drainage line along with suitable silt trap and inlet and outlet pitching with stone. The harvested rainwater was utilized by using sprinkler/ drip system for supplemental irrigation in crops and perennials by majority of farmers. Within a span of 3 years, 200 farm ponds were constructed in selected village in Akola. Farmers' contribution in cash, kind or labour was mandatory. Organizing farmers into self help groups (SHGs) enabled them to share the water lifting devices and improved technology and grow high value crops. A sustainability fund was created through farmers' contribution. Farmers successfully worked as community and took major responsibility of maintenance and repair of common structures.

On the other hand in 'poor performing districts'- Bangalore rural, Anantpur, Bhilwara and Jodhpur - the farmers' participation was poor and the size of pond was mostly pre-decided and its location was decided in majority of the cases by the contractor on behalf of the department. Majority of the farmers were not able to utilize the harvested rainwater in the absence of water lifting device as reported earlier by Kareemulla *et al.* (2009). The rainwater harvesting was not promoted as complete customized package. Moreover there was no convergence to improve access to water lifting device and MIS. About 20 per cent ponds were dug in such a way that the excavated soil was spread covering area more than the area of actual pond and making that area uncultivable.

Impact on productivity, income and livelihood

Rainwater harvesting and its utilization through farm pond/percolation ponds had a significant impact on farm productivity and household's income, however their performance was mixed one (Table 4). In many cases they were highly useful for rainfed farming and had a multiplier effect on farm income. At the same time these structures were a total failure in other situations and were viewed as wastage of productive land.

The crop and livestock productivity and farm income increased significantly in Akola and Chittoor districts due to farm ponds. Increment in productivity of different rainfed crops in these districts ranged from 8 to 45 per cent. Moreover, the gross cropped area also increased by 20 to 26 per cent. As a result of availability of supplemental irrigation using harvested rainwater, the farmers planted additional fruit plants and it also enhanced the productivity of existing fruit plants namely mango in Chittoor and coconut in Vellore. With the provision of supplemental irrigation, not only the productivity of mango increased but their fruiting was also regularized. For some of the farmers the life got changed due to farm pond in Chittoor. They started earning additional income from higher production of mango and vegetable crops (US$ 120 to 320 ha^{-1} $annum^{-1}$) lifting debt-ridden farm families out of poverty. From the savings they purchased a few sheep and cow and put their children in school. Some acquired diesel operated pumping-set for own use and for renting to others for lifting water from farm-pond. Thus the farm pond had a multiplier effect on farmers' income with additional net returns ranging from US $ 500 to US $ 860 per annum per household.

Table 4: Impact of farm level rainwater harvesting on farm productivity and annual income

District	Increase in gross cropped area (%)	Increase in productivity of different rainfed crops* (%)	Additional fruit plants raised per household (No.)	Increase in existing fruit plant productivity (%)	Increase in fodder availability (ton)	Increase in livestock productivity**	Additional employment generated (Mandays/ annum)	Additional income per household (US$)
Chittoor	19.5	8-35	46	31	2.7	14	232	700
Anantpur	9	5-11	-	-	1.9	-	66	317
Akola	25.8	12-45	7	24	3.5	9	196	927
Bangalore rural	-	0-8	6	-	0.5	4	26	47
Vellore	5	5-13	16	51	1.5	7	93	503
Bhilwara	8.5	4-11	22	19	2.0	7	72	307
Jodhpur	-	-	12	15	1.2	5	38	177

*Increase was due to supplemental irrigation and also due to improved varieties and package of practices

**Increase was due to improved access to fodder and water

Similarly in Tamilnadu, supplemental irrigation to coconut from the recharged wells added net farm income of US $ 370 to US $ 640 per annum. Growing of vegetables on the fringes of farm pond by number of farmers resulted in improved access to green vegetables for home consumption.

In Akola district the crop and variety mix was also changed significantly. There was an increase in *kharif* (rainy season) and *Rabi* (winter season) cropped area and multipurpose plants on the fringes of the pond. The farmers could grow good chickpea crop in winters in large black soil area by providing only one sprinkler irrigation using pond water; the crop otherwise had very low productivity. The farmers shifted from local cotton variety to Bt Cotton with a provision of supplemental irrigation. Some farmers also used ponds for aquaculture for 5-6 months and earned additional net income up to US $ 200 $pond^{-1}$ $annum^{-1}$. The positive impact of farm ponds on agricultural productivity as well as farm income was observed to be highest in case of Akola district followed by Chittoor and Vellore districts and it was least Rajasthan and Karnataka.

The farmers in Chittoor also got organized into self help groups (SHGs) and created sustainability fund through their contributions. Adoption of improved agricultural technologies also increased significantly after the farmers got organized and had increased access to water. In Anantpur, it was not as beneficial, small farm ponds without lining had low acceptance by the farmers because of their poor utility due to high evaporation and seepage loss. Irrespective of the farmers' need, all the ponds excavated under MNREGS were of standard same size. Only 36 percent of the ponds were appropriately located and useful. In Tamilnadu the percolation ponds resulted in recharging of open wells that enhanced farmers' access to irrigation and farm income significantly. The performance of majority of farm ponds in Karnataka was far below its potential mainly because of poor participation and technical soundness of RWHSs, farmers considered the maintenance of farm pond as wastage of his labour and were searching for other employment options. About 47 percent did not get runoff due to wrong location. Inappropriate design, size and location of number of farm ponds in Rural Bangalore, Anantpur and Bhilwara districts resulted in poor rainwater harvesting.

In Bhilwara, the net benefits due to a farm pond ranged from US $ 132 to US $ 345 per annum. Potential benefits could not be harnessed also due to inefficient utilization of harvested water for want of proper water lifting device and MIS and low adoption of improved package of practices for crop and livestock production.

In Jodhpur, where soils are sandy and evaporation losses are high, the rainwater harvested in a covered concrete underground structure (*Tanka)* was mainly used for drinking purpose, animals and supplemental irrigation to fruit plants in the initial stages. The adoption of small *Tanka* by farmers was low mainly because the net benefits from perennial component raised with the help of harvested rainwater in *Tanka* were small but demanded farmer's engagement throughout the year for its maintenance and protection. The high capital requirement was hindrance in adoption of large size '*Tanka*' needed to support an economically viable size of orchard.

A case study of *khadin* system of rainwater harvesting was conducted in Jodhpur district which involved 6 farm households having 12.5 ha land. Besides farmers land, catchment also included nearby rocky wasteland of about 15 ha. Three small check-dams and peripheral bund as part of *khadin* had initial investment of US $ 9500 at current price of year 2012 which had public funding and has life of more than 20 years. As a result the gross cropped area increased by about 90% besides addition of 250 plants of arid fruits – *Zyziphus moritiana* and *Cordia mixa*. Consequently these 6 farmers are earning additional net return US $ 1900 from crops and US $ 850 from fruit plants every year.

Provision of proper inlet and outlet of the pond with stone pitching was needed to ensure longer life and better use of the pond. There was also a need for higher involvement of female members, who actually managed the rainfed agriculture for large number of households, and played role in rainwater harvesting and utilization efforts. The returns observed to be higher in area with black soils and annual rainfall >500 mm as compared to red/sandy soils and annual rainfall <500 mm. Lining of the pond was needed in the red/sandy soils, however was not required in the black soils. Besides tangible benefits the farm ponds provided many intangible benefits like minimizing run off losses, soil losses, nutrient losses, preserving eco- systems and providing drinking water for animals and humans.

Determinants of performance of RWHS

It is clear from the above analysis that the integration of farm pond in the dryland farming systems has a great potential to increase farm productivity and income in these regions. However, its adoption and net benefits varied significantly among different districts/states mainly due to difference in the implementation approach, level of participation, technical soundness, farmer's resources and knowledge and amount and intensity of rainfall. To analyze further the selected districts were grouped into 'Better performing districts' – Chittoor, Akola and Vellore and 'Poor performing districts' – Anantpur, Bangalore rural, Bhilwara and Jodhpur. The critical factors influencing the performance of farm ponds were identified through stakeholders' workshop and PRA. Most of these factors as presented in Table 5 were institutional in nature. For each of the factors an index value was calculated on the scale of 1 to 10 based on the score given to the indicators for each factor. For example the value of index in case of 'farmers participation' was calculated based on the indicators such as farmers contribution in cash or kind, farmer's role in deciding the size, location and design of the farm pond/RWHS, involvement in repair and maintenance of pond, extent of utilization of harvested rainwater, and frequency of interaction among farmers/SHGs and implementing agency for managing farm ponds. Each indicator was allocated 2 marks. The analysis shows that the index value was significantly higher in case of 'better performing districts' especially for 'farmers participation', 'farm pond as part of customize package', regular technical backstopping in initial phase', technical soundness of the structures and its economic viability indicating high importance of these factors in determining the performance of farm ponds.

Non-utilization of harvested water due to non-availability of water lifting devices/micro-irrigation system or lack of appropriate crops/plants discouraged its adoption. The adoption of farm pond by small farmers with less than 2.0 ha land in dryland areas was observed to be very low mainly due to the fact that the small farmer also uses his labour for earning wages to stabilize his household's income and also because the potential of rainwater harvesting and consequent increase in farm returns is low due to small size of the holding. It was also observed that rainwater harvesting in arid regions with <400 mm annual rainfall was more useful for sustaining appropriate number

Table 5: Factors influencing the performance of RWHS (rating index scale: 1 to 10)

Critical factors	Index value		Drivers/Conditions
	Better performing districts	Poor performing districts	
1. Farmers participation	7.5	3.5	• Sufficient efforts for sensitization • Participation of farmers in deciding the size and location of RWHS • Handholding services and liaison work by extension agency in the initial phase • Higher probability of additional net returns
2. Provision of farm pond as part of a complete package (pond, water lifting device, MIS, improved varieties and package of practices, etc.)	7.0	2.0	• Increased usefulness of farm pond and efficiency of resource use and adoption • Multipliers effect on farm productivity and income
3. Convergence of relevant government departments	3.5	2.0	• Bringing them together reduces transaction cost and creates synergy
4. Access to information on technology, market and government support at village level	6.5	3.5	• A person/center is required at village level for knowledge support
5. Regular technical backstopping in initial phase	7.0	3.5	• Building capacity of farmers to use technology independently
6. Easy and cost effective access to technical inputs like water lifting pump, improved seeds, sprinklers, etc.	6.0	2.0	• Reduction in the transactions cost • Higher ease of adoption
7. Technical soundness of RWHS in terms of location, size, design and construction	7.0	3.0	• Catchment: Pond ratio • Drainage lines and location of pond • Inlet and outlet pitching and silt trap • Cost effectiveness
8. Economic viability of farm pond	6.5	2.5	• The net returns should be greater than the opportunity cost of labour and capital
9. Rainfed agriculture as major source of livelihood for farm household	6.5	4.5	• Farm households that did not have alternate source of livelihood took more interest in adoption of farm pond.

of fruit and multipurpose trees to stabilize farm income provided there was provision of fencing, and also water for drinking and animals and for growing *rabi* crops on conserved moisture.

Technology, policy and institutional needs

The analysis has shown that in rainfed semi-arid and arid regions, the farm level rainwater harvesting/pond have tremendous potential to increase the farm productivity and income.

However, construction of farm pond/RWHS is both capital and labour intensive, which poor farmers in drylands may not be able to afford and hence need to be supported through capital subsidy. Though there are provisions for creating farm ponds/RWHS under different public programmes like watershed development, MNREGS, NHM, RKVY, etc; but their poor adoption and realization of low benefits to the farmers were found to be mainly due to lack of proper institutional and policy support. The participation of farmers in true sense was the single most important factor influencing the adoption and potential benefits from RWHSs. The participation of farmers cannot be ensured unless they are sufficiently sensitized and assured of considerable additional net returns by having a farm pond/RWHS. Lack of capital and location specific solutions, high transaction cost, no convergence among multiple actors working for water harvesting, poor access to cost effective water lifting devices, low net returns from dryland agriculture, etc. were the major constraining factors. Though the customization of package and technology were important factors, the institutional mechanism, governance at grass root level and people's participation played much greater role in the success of farm level rainwater harvesting.

The farmers in the drylands especially the small holders do not depend only on crop production, which has high risk and hence allocate their resources and time for other livelihood activities such as livestock, and agricultural and non-farm wages in their village or outside. In such situation the farmer is ready to adopt the farm ponds/RWHS only if it presents a possibility of considerable increase in net returns which are higher than its opportunity cost. Therefore, the following technology, policy and institutional arrangements (Table 6) are needed to promote farm level rainwater harvesting for dryland agriculture:

Table 6: Conditions to be met for adoption of farm level rainwater harvesting

Policy and institutional needs	*Technology needs*
• Major proportion of the initial investment on RWHS has to come from the government by converging different schemes like MNREGS, RKVY, watershed programme etc. • Need to identify points and strategy for such convergence and this should be initiated by the Ministries at national as well as state level from the top. • Operationalization of farm pond/RWHS need to be done as a customized package for rainwater harvesting and utilization (including inlet and outlet pitching and lining of pond, water lifting pump, micro-irrigation system, improved package of practices and varieties etc. • Flexibility in relevant government schemes to decide the size of farm pond as per need • Need to launch awareness campaign through radio, newspaper, electronic media, etc. on the need and benefits of farm level rainwater harvesting • Provision of technical backstopping at village level especially in initial phase: Extension worker/creating service provider farmers (handholding services, equipment, liaison work, follow up until the experimental stage is finished) • Creating water harvesting self-help groups (SHGs) would provide better access to technology and increased opportunity for efficient water harvesting and utilization due to mutual learning and cooperation.	• Low cost and easy to handle water lifting devices and micro-irrigation system matching the needs of different category of farmers needs to be developed. • Location of the RWHS needs to be identified by the technical person by involving the farmers/ community. • Farmers must be properly trained to handle and maintain micro-irrigation systems and make best use of harvested water. • Need to generate maps on water harvesting potential in different regions based on the data on amount and distribution of rainfall, soil, vegetation, temperature etc.

Conclusions

It was seen that the adoption of farm ponds was higher if they were appropriately sized, designed and located to get more water with provisions to use water efficiently. The harvested water should be used not only by efficient methods like drip or sprinkler but should also be used for the crops which optimize the farm returns. The farmers should be suggested with different options for using harvested water along with their package of practices and market opportunities. Hence, there is need to implement RWH as a customized package for harvesting and efficient utilization ensuring effective facilitation in the initial phase by putting technically qualified and trained person at village level. The farm level rainwater harvesting has a great potential to improve productivity and farm income in dryland areas of India and other similar regions provided suggested technology, policy and institutional needs are met.

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Assessment of the agricultural productivity of a traditional agricultural system in Tunisia

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Abstract

The study focused on *Jessour*, a traditional farming system in south Tunisia, which uses water collected from far away in mountainous areas after precipitation there. The study analyzed and estimated the actual agricultural productivity, the productive potential, and the prospects for utilization of the system. Data on crop yields, operation and maintenance cost and farm system expansion and upgrading were collected by a questionnaire to the farmers through a survey. The result shows that Jessour system can permit olive and olive oil production, cereal crops, vegetables, and fruits for domestic consumption throughout the year. However, the crop yields from Jessour are extremely unstable under unsettled meteorological conditions, which have become frequent in recent years. The result also showed that more and more farmers are cultivating fodder crops in upstream catchment area to make up for reduced crop yields in recent years. However, cultivation of catchment area is difficult because of the unfavorable conditions to collect water. Therefore, farmers are cultivating drought resistant plants such as barley and legumes. Cultivation of upstream catchment area may however impact negatively on downstream farmland cultivation.

Introduction

Effective water utilization and water management will become more important in areas facing water shortage. Thus, it is very important to find solutions to overcome water shortage and save water resources. This study focused on an agricultural technique based on a traditional water collection and use on a seasonal stream after rainfall events.

There are various ways of farming using runoff that are practiced in arid regions in North Africa, and 'Jessour' system in Tunisia is one of them. This system can be found in the arid and mountainous zone (El Amami 1984; Mechlia and Ouessar 2004). In seasonal riverbeds, small dams made with earth and stones are constructed. The basic structure of Jessour consists of three main parts. One of them is catchment area which receives precipitation, runoff water, and sediments to the cultivation area. The second part is dyke and spillways which are installed on center of wadi, and the last part is cultivation area to be used as farm field after the gentle slope was formed by sediments. Soil accumulates in front of these dams so that terraces with a soil depth of 1 to 2 m are formed (ILEIA 1986). On the terraces, flood water is impounded and infiltrates into the soil. The infiltrated water makes agricultural activities possible in these arid regions. On the terraces, various kinds of fruit trees such as olives, almonds, dates, and figs, and grain and legume crops are cultivated (Bonvallot 1986). Dams and spillways must be built firmly and their maintenance must be very consistent to make this agricultural system last as long as possible (ILEIA 1986). Mechanism of water collection and holding of Jessour system was studied by Schiettecatte *et al.* (2005). The purpose of this study is to analyze and estimate the actual agricultural productivity, the productive potential and the prospects for utilization of the system.