Farm ponds for climate-resilient rainfed agriculture

Ch. Srinivasa Rao, R. Rejani, C. A. Rama Rao, K. V. Rao, M. Osman, K. Srinivasa Reddy, Manoranjan Kumar and Prasanna Kumar*

This article summarizes the utility of farm pond technology as an adaptation strategy to overcome water shortage due to several reasons, including climate change. This technology has the potential to increase availability of water for supplemental irrigation, increase in cropped area and productivity leading to increase in net returns from crops. Farm pond offers a solution to overcome the increased frequencies of drought, particularly mid-season and terminal drought under climate change scenario. The article advocates for policy intervention to promote one pond for each farm holding having an area of 2.0 ha at individual farm level or on community-sharing basis. Constraints for large-scale implementation of farm pond technology are also discussed.

Keywords: Climate change, drought management, farm ponds, rainfed agriculture, supplemental irrigation.

RAINFED agriculture in India contributes 40% to the national food basket, supports 40% of the population, 80% of horticulture and 60% of livestock. Fragile agro-ecosystems with low farm productivity are common features of rainfed agriculture largely practised in arid, semi-arid and dry sub-humid zones. Indian agriculture is highly vulnerable to climate change impacts since 58% of the agricultural area is rainfed and more than 80% of farmers are small and marginal (<1 ha land holding) having less adaptive capacity[1]. Rising temperature, occurrence of extreme weather events such as cyclones, droughts and floods, increasing variability in rainfall and rise in sea-water level are evidences of induced risks due to climate change. During 1900–2012, droughts and floods were recurring natural disasters which affected millions of people in the country[2]. In India, the physical impact of climate change is predicted to increase the average surface temperature by 2–4°C, change the distribution and frequency of rainfall, decrease the number of rainy days by more than 15, increase high-intensity rainfall, and frequency and intensity of cyclonic storms[3]. Parts of western Rajasthan, southern Gujarat, Madhya Pradesh, Maharashtra, northern Karnataka, northern Andhra Pradesh and southern Bihar are likely to be more vulnerable in terms of extreme events[4]. Weather aberrations such as delay in the onset of the southwest monsoon, incidence of long, dry spells and early withdrawal of monsoon also affect crop growth and strongly influence productivity levels. The higher average annual temperatures coupled with varying rainfall and water stress (excess or deficit) can have serious implications on crop production in the tropics[5]. In India, significant negative impacts are predicted with medium-term climate change with a reduction in yield by 4.5–9% between 2010 and 2039 (ref. 6). Cereal productivity is projected to decrease by 10–40% by 2100 and greater loss is expected in *rabi*[7]. Hence, concerted efforts are required for mitigation and adaptation to reduce the vulnerability of Indian agriculture to the adverse impacts of climate change, thus making it more resilient.

The authors are at the ICAR-Central Research Institute for Dryland Agriculture, Hyderabad 500 059, India.
*For correspondence. (e-mail: rrejani10@gmail.com)

Impact of supplementary irrigation on crop yield

Rainwater management is one of the most critical components of rainfed farming and the successful production of crops largely depends on how efficiently soil moisture is conserved *in situ* and the surplus run-off is harvested, stored and reused for supplemental irrigation and also for recharging[8,9]. Crops pass through various stages and some growth stages are more critical for optimum productivity. Prolonged dry spells during flowering, pollination and seed formation stages of a crop are highly detrimental to yield. The results of several earlier studies indicated that use of harvested rainwater for one or two life-saving irrigations can increase the average yield of rainfed crops by 40–90% (refs 10, 11).

The rainfall extremes and high-intensity rain events witnessed in recent years are likely to cause large spatial and temporal variation in the amount of surplus run-off available for harvesting; it may even decrease in some areas. Hence, proper planning and design of the rainwater harvesting structures like farm ponds and effective utilization of this stored water through efficient water application systems such as drip, sprinklers, etc. are needed.

Availability of harvestable surplus

Rainfed regions encompass areas with mean annual rainfall of <500 to >2000 mm per annum. In rainfed regions with low rainfall, *in situ* moisture conservation practices are more effective by storing available water in soil profile, while in high-rainfall regions, harvesting excess run-off water in farm ponds and its efficient reuse during mid-season droughts are needed to meet crop water requirements in the *kharif* season. The stored water can also be utilized for pre-sowing irrigation to post-rainy season crops so as to increase the cropping intensity[9]. For building resilience at the regional level, surplus run-off for each district and extent of the area which could be provided supplemental irrigation were estimated for the dominant rainfed districts of India[12].

Farm pond technology

India receives about 4000 billion cubic metres (BCM) of precipitation every year, of which 1869 BCM flows as average annual run-off in various river systems of the country. Due to geographical limitations, only about 690 BCM of surface water can be utilized in addition to 432 BCM of replenishable groundwater, out of which only 63% of the surface water is utilized[4]. Farm ponds when constructed in loose textured soils as in the case of Alfisols require lining to minimize seepage, whereas ponds in clayey soils such as Vertisols having negligible seepage may not require lining. However, unlined farm ponds in soils having higher seepage can be utilized to recharge the aquifers.

Design and construction of farm ponds

For regions having mean annual rainfall varying from 500 to 750 mm, farm ponds of 500 m^3 capacity can be constructed. Black soil regions with mean annual rainfall more than 750 mm need 500–1000 m^3 capacity farm ponds without lining. Selection of the suitable site for a farm pond depends on soil type, infiltration rate, topography/slope of the catchment area, drainage pattern, vegetation, rainfall pattern and its distribution. The farm pond must be located in such a way that water from major portion of the catchment area drains into the structure.

Silt traps are to be constructed at the inlet to control siltation of farm ponds. Black soils with mild to medium slopes (1–10%) having catchment area of 1–5 ha will have an average run-off coefficient of 10–20% and red soils with mild to medium slopes (1–10%) having catchment area of 1–14 ha will have 5–15% in semi-arid regions[13,14]. However, the run-off coefficients are site-specific and their estimation is necessary for ungauged areas.

The pond capacity must be designed considering the critical irrigation requirement of the crops, seepage and evaporation losses. In order to reduce seepage loss from farm ponds, lining using low-density polyethylene/high-density polyethylene (HDPE)/silpaulin plastic film, concrete, etc. is preferred, though each has its own merits and limitations. The use of cement concrete with bricks and stones having a life of 20–40 years is expensive. Presently, HDPE films of 500 μm or cross layer reinforced silpaulin with 300–350 grams per square metre are commonly used. Bureau of Indian Standards (BIS) has recommended polyethylene film (code no. IS 15828 : 200) for design and construction of lined farm ponds[14]. Table 1 presents the estimated cost for construction of farm ponds of different sizes. Water harvesting ponds should be constructed in 2–3% of the watershed area in low to medium rainfall regions and about 5–8% area in high rainfall regions. The depth suggested is more than 3.0 m with side slope ranging from 1 : 1 to 1.5 : 1. It should not be steeper than the angle of repose of the material.

Impacts of farm pond technology: on-farm

A micro-watershed of 4.0 ha was developed at Alfisols of Hayathnagar Research Farm of Central Research Institute for Dryland Agriculture (CRIDA) to study the effect of land use on water yield (Figure 1 *a*). The micro-watershed with slopes ranging from 1% to 5% consisted of crop land (1.47 ha), vegetables (0.13 ha), horticulture (1.43 ha), pasture (0.92 ha) and fallow land (0.05 ha). The conservation measure taken up was graded bunding (0.375 m^2) with a vertical interval of 1.0 m. At the outlet, a farm pond of 540 m^3 (top: 17 m × 17 m, bottom: 12 m × 12 m, depth: 2.5 m, side slope: 1 : 1) was constructed and lined with brick masonry[15]. The actual investment towards pond construction was Rs 51,012 (including Rs 40,000 for lining). The maintenance charges were considered to be Rs 100/year in subsequent years.

The conservation measures (bunding) are effective in reducing the run-off to about 2–4% of the total rainfall and soil loss to 0.18–1.5 t/ha/year. Table 2 presents the temporal variation in hydrologic parameters over a period of five years. The run-off volume was more than 550 m^3 in four years. Hence, a minimum of 500 m^3 can be harvested in a year from a catchment area of 4 ha.

Considering the effective storage capacity of the pond (500 m^3), the pond water was utilized for growing vegetable crops during November–February in 0.1 ha by irrigating at 50% evaporative demand (348.95 mm) for achieving maximum water use efficiency. The water loss due to evaporation during the crop period of tomato was estimated at 94.84 m^3. Hence, the water available for irrigation was 405.16 m^3. When this water was used to

Table 1. Cost of construction of farm ponds

Work component	Description		
Top dimensions of pond (m × m)	20 × 20	27.5 × 27.5	17 × 17
Bottom dimensions of pond (m × m)	11 × 11	17 × 17	8 × 8
Depth of pond (m)	3	3.5	3
Side slopes (*z* : 1)	1.5 : 1	1.5 : 1	1.5 : 1
Capacity of the pond (m^3)	741	1765	489
Cost for excavation of soil (Rs)	19,266	45,890	12,714
Cost of lining (500 micron plastic; Rs)	57,600	1,02,400	44,100
Construction cost of inlet (Rs)	10,000	15,000	10,000
Labour cost for anchoring the lining (Rs)	11,520	20,480	8,820
Cost per unit volume of stored water (Rs/m^3)	133	104	154
Total cost (Rs)	98,386	1,83,770	75,364

Source: Reddy *et al.*[14].

Table 2. Hydrologic data of the micro-watershed at CRIDA farm, Hyderabad, Telangana

Description	1990	1991	1992	1993	1994	Mean
Total rainfall (mm)	778.8	913.1	766.1	755.2	851.3	813.0
Rainy days (>2.5 mm)	54	41	41	48	54	48
Rainfall causing run-off (mm)	429.7	628.6	504.3	360.8	534.4	492.0
Rainfall events causing run-off (no.)	11	12	11	10	14	12
Run-off (mm)	19.2	32.5	13.9	12.1	17.3	19.0
Run-off (m^3)	768	1300	557	485	692	760
Run-off (percentage of rainfall causing run-off)	4.47	5.17	2.76	3.36	3.24	4.00
Run-off (percentage of annual rainfall)	2.46	3.60	2.0	1.95	2.03	2.00
Soil loss (t ha^{-1})	0.95	1.50	0.18	0.34	0.71	0.70
Evaporation loss (m^3)	93.6	96.5	95.3	92.9	95.6	94.8
Irrigable area under tomato (ha)	0.15	0.26	0.11	0.10	0.14	0.15
Net return (Rs)	1931	3268	1400	1219	1740	1911

Figure 1. (***a***) Lined farm pond at CRIDA Farm (red soils) and (***b***) unlined farm pond in Adilabad district (black soil), Telangana.

cultivate tomato in 0.1 ha during post-rainy season, it gave Rs 1.6 for every rupee spent on the farm pond[16]. The irrigable area varied from 0.1 to 0.26 ha, and net returns estimated varied from Rs 1219 in the low-rainfall year to Rs 3268 in the high-rainfall year.

Village-level impacts of farm pond

Seethagondi cluster

Seethagondi cluster of Adilabad district, Telangana is characterized by deep black soil (Vertisols), receives rainfall between 1000 and 1200 mm, and offers good potential for rainwater harvesting and reuse for supplemental irrigation on a large scale. Despite this, farm ponds do not find wide acceptance here, because of the socio-economic conditions prevailing in the area.

An attempt was made by CRIDA to impound a large volume of rainwater in the Seethagondi cluster by digging farm ponds of size 20 m × 20 m up to a depth of 4.5 m using machinery (Figure 1 *b*). Though its acceptance was less in the beginning, its value was seen during the on-farm demonstration, wherein harvested water was used for growing vegetables. Based on several requests from farmers, a detailed ground survey was carried out in all villages in the cluster, and 30 suitable sites were identified where farm ponds were constructed under the National Agriculture Innovation Project of Indian Council of Agricultural Research (ICAR). The success of these 30 ponds led to huge demand for big ponds from many farmers in the region. A few farmers installed pumpsets in these ponds and irrigated their fields. The availability of water in most of these ponds has improved the cropping intensity and diversity in the Seethagondi cluster

(Figure 2). Today this cluster serves as a model for many others in the district in preserving rainwater and using it for mitigating drought. Emphasis is also being laid on scaling up farm ponds through convergence with the other development schemes like Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) and National Horticultural Mission (NHM).

Rainwater harvesting through farm ponds and enhancement of water use efficiency

The farm pond technology was adopted in a cluster in Warangal district, Telangana to mitigate the intermittent drought situation and reduce moisture stress in crops. Thirteen off-stream and on-stream farm ponds were constructed and a total volume of 12,325 m^3 water was harvested. This water was utilized for critical irrigation (5 cm depth) in 32.87 acre land and it increased the cotton yield from 4 to 6 q/ha.

Impact analysis of farm ponds

An economic analysis of farm ponds was conducted by CRIDA in three districts – Adilabad (Telangana), Anantapur and Chittoor (Andhra Pradesh). In each district, 100 farm ponds were selected and data were collected on the cropping pattern, productivity and use of inputs before and after adoption of farm pond technology. Most of these farm ponds were constructed with support from MGNREGS.

Figure 2. (***a***) Cotton and (***b***) *rabi* sorghum with supplemental irrigation from farm ponds at Adilabad.

In Adilabad, the adoption of farm ponds led to significant change in cropping pattern and area under *rabi* crops. The percentage increase in yield was highest in green gram (80) followed by tomato (45). Crops like sorghum, groundnut and soybean showed significant increase in yield after adoption of farm pond technology. Majority of farm ponds in the sample generated returns more than Rs 20,000 per annum. The 100 ponds studied were found to be economically viable.

In Anantapur district, nearly 22,000 farm ponds were constructed during 2009–2012 with support of MGNREGS. These ponds were rarely lined and were used for groundwater recharge. Data from 100 farm ponds showed that the average size of the plot was 1.1 ha. The yield of the main crop, groundnut, increased from 12.2 to 15.6 q/ha due to additional irrigation. Majority of ponds generated additional returns varying from Rs 3000 to 6000 and benefit cost ratio was 2.7.

In Punganur mandal of Chittoor district, around 400 farm ponds were constructed under various schemes. Majority of them received water through subsurface flow in addition to run-off. Farmers used pond water to irrigate rice, groundnut, vegetables and fruits. An impact analysis was conducted using 100 selected farm ponds. All crops of the sampled farmers showed an increase in yield by more than 25%. The highest increase in yield was for mango followed by groundnut and tomato. The additional returns generated by 80 ponds fell in the Rs 5000–20,000 range. In case of more profitable ponds, the BC ratio was above 4 and the average plot-size was higher. Crops like cotton, bajra, chilli and maize in addition to the existing cropping pattern increased profitability.

Features of high-performing and low-performing farm ponds

The cropping intensity in case of five high-performing ponds in Anantapur, Chittoor and Adilabad districts increased to 160.0%, 131.4% and 104.0% respectively, while in case of low-performing farm ponds, it was 100% (Tables 3–5). Better performance of farm ponds was associated with vegetables in Chittoor and Adilabad. The average size of the farm ponds was considerably more in case of the five high-performing ponds and average pond size of 791 m^3 was observed in Adilabad (Table 5). The average size of low-performing ponds in all three districts ranged from 148 to 200 m^3. Considerable increase in yield of various crops ranging from 78% to 100% was noticed in plots with five high-performing farm ponds in Chittoor, whereas it ranged from 16.6% to 100% in Adilabad with more diversity of crops. In case of

Table 3. Impact of high-performing (top 5) and low-performing (bottom 5) farm ponds in Anantapur, Andhra Pradesh

Major crops	Plot size (acres)	Pond size (m^3)	Digging cost (Rs)	Cropping pattern changed (Y/N)	Cropping intensity (%)	Bore well (Y/N)	No. of fillings	Additional returns (Rs)
Five most profitable farm ponds								
Groundnut + red gram + sunflower + bajra	7	240	32,000	Y	200	Y	2	27,024
Groundnut + red gram + sunflower + bajra	4	240	32,000	Y	200	Y	1	27,050
Groundnut + red gram + sunflower	3	128	14,000	Y	100	N	1	27,687
Groundnut + red gram + sunflower + bajra	6	240	32,000	Y	200	Y	1	28,063
Groundnut + red gram + orange	5	240	32,000	Y	100	Y	2	41,612
Mean	5.0	217.6	28,400		160		1.4	30,287
Five least profitable farm ponds								
Groundnut + red gram + paddy	3	200	24,000	N	100	N	2	867
Groundnut + red gram + paddy	0.5	200	23,000	N	100	Y	2	1645
Groundnut + red gram + paddy	3	200	26,000	N	100	N	1	1675
Groundnut + red gram + paddy	5	200	27,000	N	100	N	1	1828
Groundnut + red gram + paddy + sunflower	4	200	28,000	N	100	Y	1	1976
Mean	3.1	200	25,600		100		1.4	1598

Table 4. Impact of high- and low-performing farm ponds in Chittoor, Andhra Pradesh

Major crops	Plot size (acres)	Pond size (m^3)	Digging cost (Rs)	Cropping pattern changed (Y/N)	Cropping intensity (%)	Bore well (Y/N)	No. of fillings	Additional returns (Rs)
Five most profitable farm ponds								
Tomato + tomato	3	200	12,800	Y	200	Y	6	96,993
Mango	4	288	12,800	Y	100	N	3	65,735
Groundnut + tomato	3.5	200	12,800	Y	157	Y	2	59,853
Tomato	3.5	128	8,300	N	100	Y	3	59,523
Tomato	3.5	200	12,800	Y	100	Y	6	57,917
Mean	3.5	203.2	11,900		131.4		4.0	68,004
Five least profitable farm ponds								
Groundnut	1	288	25,400	N	100	N	3	633
Tomato	1	200	12,800	Y	100	N	3	1279
Paddy	0.5	72	4,000*	Y	100	N	3	2585
Tomato	1	288	25,400	N	100	N	4	3105
Groundnut + ridge guard	2	128	8,300	N	100	N	3	3396
Mean	1.1	195	15,180		100		3.2	2200

*Farmer's own pond characterized by high seepage into it.

low-performing farm ponds it ranged from 16.7% to 100.0% in both districts, but the diversity of crops was less. Yield improvement was relatively low in Anantapur with 18% to 32% in high-performing category and 3.1% to 15.4% in low-performing category. The additional area brought under cultivation was higher in Adilabad.

An analysis of individual farm ponds in high- and low-performing category was carried out. The individual farm ponds of high-performing category in Anantapur resulted in additional returns ranging from Rs 27,050 to 28,063 (Table 3). In case of low-performing category, the additional returns ranged from Rs 867 to 1976. Among the five selected farm ponds, the size was 240 m^3 in four high-performing ponds and it was 200 m^3 in low-performing category. In case of high-performing farm ponds in Chittoor, the additional returns ranged from Rs 57,917 to Rs 96,993, whereas in low-performing category, it ranged from Rs 633 to Rs 3396 (Table 4). In case of high-performing farm ponds in Adilabad, the additional returns obtained ranged from Rs 58,120 to 1,07,400 and in case of low-performing category it ranged from Rs 3600 to 8200 (Table 5). The larger farm pond or plot size coupled with pumping of available water might have resulted in higher returns.

Constraints in the implementation of farm pond technology

Marginal and small farm holdings: In dryland semi-arid regions, the number of small and marginal farmers is more and their land holdings are less (<2 ha). Most of them depend on their land for livelihood and thus in majority of the cases, these farmers are hesitant to spare even 2–5% of their land for the farm pond. They believe that sufficient rainfall may occur once in 3–4 years and hence using part of their land for farm ponds may not be economical. The initial investment for the construction of individual farm ponds is around Rs 30,000–80,000

Table 5. Impact of high- and low-performing farm ponds in Adilabad, Telangana

Major crops	Plot size (acres)	Pond size (m^3)	Digging cost (Rs)	Cropping pattern changed (Y/N)	Cropping intensity (%)	Bore well (Y/N)	No. of fillings	Additional returns (Rs)
Five most profitable farm ponds								
Tomato + cotton + tomato + jowar	5	1395	35,000	Y	120	N	6	58,120
Tomato + soyabean + cotton	5.5	198	17,000	Y	100	Y	5	73,935
Cotton + ridge gourd	2.2	1280	27,000	N	100	Y	4	74,252
Tomato	9	198	17,000	N	100	N	4	105,399
Tomato + cotton	5	884	35,000	Y	100	N	4	107,400
Mean	5.4	791	26,200		104		4.6	83,821
Five least profitable farm ponds								
Tomato + cotton	4	72	7,000	Y	100	Y	5	3500
Soyabean	4	198	17,000	Y	100	Y	4	4700
Dry paddy	4	72	7,000	Y	100	N	5	5200
Cotton + ridge gourd	2	198	13,000	N	100	Y	3	7800
Cotton + ridge gourd	2	198	18,000	N	100	N	8	8200
Mean	3.2	148	12,400		100		5.0	5880

per pond without lining. Hence, small and marginal farmers may not come forward to invest in farm ponds. In case of successful farm ponds, farmers must diversify their routine crops to high-value crops for maximizing profits. It needs extra care, investment and also experience in adopting such new crops. If majority of farmers in a locality come forward to invest in the same high-value crops, surplus production could result in less market price. Run-off harvesting and supplementary irrigation to high-value crops can overcome the loss incurred towards the land and can reduce the payback period of farm ponds to two years from the normal five years.

Some of the remedial measures to overcome these constraints are to develop large community farm ponds with water-sharing and custom-hiring facilities with pump sets and micro-irrigation accessories. Such type of group activities will encourage the farmers to help each other by sharing their knowledge, develop skills for adoption of drip and sprinkler irrigation, and for availing subsidies for micro-irrigation system. In case of individual farm ponds, increasing the depth of ponds by 1 m (from 3.0 to 4.0 m) will reduce the exposed area by approx. 65%, as well as evaporation loss.

Evaporation and seepage loss: In case of farm ponds utilized for supplemental irrigation to *kharif* crops, evaporation loss from them is less due to lower evaporation during rainy season. In case of *rabi* crops, retaining farm pond water for life-saving irrigation is one of the major challenges. In order to minimize the evaporation loss, indigenous technical knowledge (ITK) like covering solar panels, asbestos floats, oil cover and shade nets can be explored. Black soils may not need lining for farm ponds, while red soils need lining to retain water.

Investment: High initial investment at individual level is one of the most important constraints in large-scale adoption of farm ponds. Maintenance of farm ponds with lining, and desiltation of silt traps and farm ponds are other issues. In case of large community ponds, collective usage of water, sharing of water and maintenance of water-diversion channels give rise to equity issues in some cases. The diversion channels can be effectively utilized by bringing water and storing in large community ponds, and their preparation and maintenance can be done through Government-sponsored schemes to make the process sustainable.

Involvement of the Government: At present, the Government is involved in the upliftment of small and marginal farmers by constructing farm ponds and check dams, desilting and renovating existing tanks through schemes like IWMP, NHM, MGNREGS, etc. The subsidies for micro-irrigation are given to farmers through Agriculture and Horticultural Departments under the State and Central Government schemes.

Once the Government-sponsored schemes cease, the structures constructed by them remain unattended and and hence, the sustainability of these projects is an issue. In order to overcome these problems, nowadays, an exit policy is followed by these schemes to train the local people to get involved in these activities. Also, a fund will be generated/allotted for farm-pond maintenance and responsibility will be delegated to the user groups for its maintenance before the withdrawal of these schemes from the area.

Several social issues are associated with the implementation and scaling-up of farm ponds on a large scale. Lack of awareness among farmers, relatively high initial investments and moderate benefits during 'normal' years are some of the constraints. Hence, farmers must be made aware of the concept that farm pond construction is one of the climate change adaptation strategies in rainfed areas and they should be encouraged to access technical and financial support. Agriculture research institutions under state and central governments should guide the farmers in optimal crop planning for effective utilization of the harvested water to maximize net returns. Facilitating the farmers by providing technical support and networking with developmental agencies, NGOs and village panchayats, besides state line departments like Krishi Vigyan Kendras is crucial for scaling-up the implementation of the farm pond development programme to avoid crop failure.

Potential of rainwater harvesting using farm ponds based on surplus run-off available in India

Sharma *et al.*[12] estimated the rainwater harvesting potential or surplus run-off available across the rainfed districts of India. It was reported that about 27.5 m ha of rainfed area in the eastern and central states has the maximum potential to generate run-off of 114 BCM of water. Out of this, 28 BCM can be used to provide one supplemental irrigation to about 25 m ha of rainfed area during a normal year and 31 BCM for one irrigation to about 20.6 m ha area in a drought year using 50 million farm ponds. This strategy would not only control erosion, but also contribute to climate change adaptation by rainwater harvesting and supplemental irrigation. Rainfed production could be increased by 50% by a single supplementary irrigation along with improved agricultural practices. In addition, these ponds can retain soil amounting 5–10 t/ha/year and 10–20 t/ha/year in red and black soil regions respectively. The collected sediment, rich in nutrients can be recycled within the catchment area to enhance productivity.

Conclusion

Farm pond is an option for rainwater harvesting and to provide life-saving irrigation to standing crops when they are exposed to mid-term/terminal drought and also for pre-sowing irrigation in post-rainy crops in rainfed areas. Ponds may be lined in light textured soils, while unlined farm ponds in soils having higher seepage can be utilized to recharge. In a watershed, a series of ponds may be constructed in farm fields and across the water courses/ first- and second-order drainage channels to intercept run-off, reduce peak flow, control erosion and store water for supplemental irrigation and to recharge groundwater. Selection of crops and cropping systems based on profitability and irrigation requirement is needed to efficiently utilize the harvested water. Modern methods of irrigation like drip and sprinklers may be adopted for increasing water-use efficiency. Insufficient awareness among farmers, small farm holdings, relatively high initial investments, evaporation and seepage loss, and moderate benefits during 'normal' years are some of the constraints that impede adoption of farm ponds on a large scale in rainfed ecosystems of India.

1. Srinivasarao, Ch., Ravindra Chary, G., Mishra, P. K., Subba Reddy, G., Maruthi Sankar, G. R., Venkateswarlu, B. and Sikka, A. K., Rainfed Farming – a compendium of doable technologies. AICRPDA, ICAR–CRIDA, Hyderabad, 2014, p. 194.
2. NRAA, Contingency and compensatory agricultural plans for droughts and floods in India – 2012. Position paper No. 6, National Rainfed Area Authority, Planning Commission, Government of India, 2013, p. 87.
3. Ranuzzi, A. and Srivastava, R., Impact of climate change on agriculture and food security. ICRIER Policy Series 16, Indian Council for Research on International Economic Relations, New Delhi, 2012.
4. Mall, R., Singh, R., Gupta, A., Srinivasan, G. and Rathore, L., Impact of climate change on Indian agriculture: a review. *Climatic Change*, 2006, **78**, 445–478.
5. Prasad, Y. G. *et al.*, Smart practices and technologies for climate resilient agriculture. ICAR–CRIDA, Hyderabad, 2014, p. 76.
6. Jasna, V. K., Som, S., Roy Burman, R., Padaria, R. N. and Sharma, J. P., Socio-economic impact of climate resilient technologies. *Int. J. Agric. Food Sci. Technol.*, 2014, **5**(3), 185–190.
7. Venkateswarlu, B. and Rao, V. U. M., Climate change and its impact on Indian agriculture. In *Climate Change Modeling, Mitigation, and Adaptation*, (ed. Rao, K. V. *et al.*), American Society of Civil Engineers, 2013, pp. 419–453.
8. Rao, K. V. *et al.* (eds), In Proceedings of National Workshop-cum-Brain Storming on Rainwater Harvesting and Reuse through Farm Ponds: Experiences, Issues and Strategies, ICAR-CRIDA and ICRISAT, Hyderabad, 2010.
9. Srinivasarao, Ch., Ravindra Chary, G., Mishra, P. K., Nagarjuna Kumar, R., Maruthi Sankar, G. R., Venkateswarlu, B. and Sikka, A. K., Real time contingency planning: initial experiences from AICRPDA. All India Coordinated Research Project for Dryland Agriculture, ICAR-CRIDA, Hyderabad, 2013, p. 63.
10. Mustapha, A. B., Effect of dry spell mitigation with supplemental irrigation on yield and water use efficiency of pearl millet in dry sub-humid agro-ecological condition of Maiduguri, Nigeria. In International Conference on Environment Science and Biotechnology, IACSIT Press, Singapore, 2012, vol. 48, p. 46.
11. Pathak, P., Sahrawat, K. L., Wani, S. P., Sachan, R. C. and Sudi, R., Opportunities for water harvesting and supplemental irrigation for improving rainfed agriculture in semi-arid areas. Rainfed agriculture: unlocking the potential. In *Comprehensive Assessment of Water Management in Agriculture Series 7* (eds Wani, S. P. *et al.*), CAB International, ICRISAT and IWMI, 2009, pp. 197–221.
12. Sharma, B. R., Rao, K. V., Vittal, K. P. R., Ramakrishna, Y. S. and Amarasinghe, U., Estimating the potential of rainfed agriculture in India: prospects for water productivity improvements. *Agric. Water Manage.*, 2010, **97**(1), 23–30.
13. Adhikari, R. N., Mishra, P. K. and Muralidhar, W., Dugout farm pond – a potential source of water harvesting in deep black soils in Deccan plateau region. In Proceedings of National Workshop-cum-Brain Storming on Rainwater Harvesting and Reuse through Farm Ponds: Experiences, Issues and Strategies (ed. Rao, *et al.*), ICAR-CRIDA and ICRISAT, Hyderabad, 2010.
14. Reddy, K. S. *et al.*, Farm ponds: a climate resilient technology for rainfed agriculture; planning, design and construction. Technical Bulletin: 3/2012, ICAR-CRIDA, Hyderabad, 2012.
15. Mishra, P. K., Manjunath, B. L., Rao, J. V. and Subba Reddy, G., Farm pond – a potential source for vegetable production. *Indian J. Dryland Agric. Res. Develop.*, 1993, **8**(2), 171–172.
16. Mishra, P. K., Rama Rao, C. A. and Siva Prasad, S., Economic evaluation of farm pond in a microwatershed in semiarid Alfisol Deccan Plateau. *Indian J. Soil Conserv.*, 1998, **26**(1), 59–60.

Received 4 March 2015; revised accepted 15 September 2016

doi: 10.18520/cs/v112/i03/471-477