Ind. Jn. of Agri. Econ.
Vol.74, No.4, Oct.-Dec. 2019

Levels and Determinants of Economic Viability of Rainwater Harvesting Farm Ponds

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ABSTRACT

Improving the productivity, profitability and stability in rainfed agriculture is critical to achieving the goals of inclusive growth and enhancing farmers' incomes given the demographic and geographic importance of rainfed agriculture. Rainwater management through dug out farm ponds is an important part of strategy for enhancing productivity of rainfed agriculture. Therefore, considerable emphasis was given to support rainwater harvesting farm ponds in programmes such as MGNREGA, watershed development, etc. This paper attempts to analyse the impact of farm ponds in three districts: Anantapur and Chittoor in Andhra Pradesh and Adilabad in Telangana. The profitability of farm ponds was found to vary across districts and across farm ponds within each district. Profitability was found to be high in Adilabad receiving higher annual rainfall with 69 per cent of ponds generating an additional income of more than Rs. 20000 per year as compared to 8 per cent in Anantapur with less annual rainfall. The factors associated with varying profitability of farm ponds were identified for policy implications.

Key words: Farm pond, rainwater, rainfed agriculture, viability

JEL classification: Q12, Q25

I
INTRODUCTION

The current emphasis of the development planning is on inclusive growth of the economy. There is an explicit target of doubling incomes of farmer households by 2022 (Chandra Sekhar and Mehrotra, 2016). Achieving both these objectives requires a considerable increase in productivity and income from rainfed agriculture which is practised in nearly 60 per cent of the net sown area. Rainfed agriculture is practiced largely in arid and semi-arid environments wherein evapotranspiration exceed precipitation and also in dry sub humid regions to some extent. Rainfed agriculture is

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This paper is an output of the project, "Economic analysis of rainwater harvesting structures" at ICAR-CRIDA, Hyderabad. The efforts of P. Sudhakar Reddy, Dr. D. Yella Reddy and E. Ravindranath in collecting data are gratefully acknowledged. The authors are also thankful to the anonymous referee for his comments in improving the paper.

a significant contributor to production of coarse cereals, rice, pulses, oilseeds and cotton. However, rainfed agriculture is characterised by poor natural resource base in terms of low and erratic rainfall, poor soils, shorter growing period and more importantly, the poor economic status of the farmers (Venkateswarlu and Rama Rao, 2011). As a result, the productivity levels in rainfed agriculture are considerably less than those achieved in irrigated agriculture and are also less than what can be achieved in rainfed environments (Rama Rao *et al*., 2010).

By definition, rainfed agriculture is dependent on rainfall with little access to irrigation facilities. Rainfall in these regions is quantitatively inadequate in relation to evapo-transpiration demand, uncertain and unevenly distributed within a season resulting in long dry spells and drought like situations during crop growth period. Also, inter-annual variation is also observed in the seasonal rainfall. The productivity of rainfed crops can be significantly increased and protected if rain water can be harvested and used to irrigate crops (Rao et al., 2010). In fact, such an approach of harvesting rain water for using as a source of irrigation is recognised as an important part of strategy for betterment of rainfed agriculture. Rainwater management assumes further importance when the implications of changing climate are considered (Rama Rao et al., 2016).

Harvesting of rainwater through smaller structures called farm ponds constitutes an important component of watershed development programmes and is also largely supported through programmes such as Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) (MoRD, 2013). These farm ponds are generally dug out small scale water harvesting measures across the slope to capture run-off water. Water so collected in these dug out structures is meant to protect a crop during a dry spell and provide drinking water for livestock. Their life and utility can be enhanced if lined as recommended in red soil regions (CGWB, 2000, Reddy et al., 2012). When water is not used for irrigation, they can also help recharge groundwater (Christy and Lakshmanan, 2017).

This paper attempts to analyse the impact of adopting rainwater harvesting through farm ponds at the farm level in terms of changes in cropping pattern, cropping intensity and crop incomes in three districts. The paper also examines the extent and determinants of profitability or viability of farm ponds.

II

DATA AND METHODOLOGY

Study Area

The study was conducted in two districts, Anantapur and Chittoor of Andhra Pradesh and Adilabad district of Telangana state. The districts present a wide range of rainfed situations in terms of rainfall, cropping pattern and socio-economic situation. A large number of farm ponds were dug with the support of programmes

such as MGNREGA and watershed development programmes in these districts. A brief description of the agro-climatic features of these districts is given below:

Anantapur District

This is one of the districts with least annual rainfall (553 mm) in the country and presents arid climate. The normal rainfall for the south west monsoon period is 338.0 mm which forms about 61.2 per cent of the total rainfall for the year. The soils in the district are predominantly red, though there are a few black soil pockets. The gross sown area of the district is 1.1 m ha out of which 0.98m ha is under k*harif* and 0.13 m ha is sown during *rabi* season. Groundnut is the most predominant crop in the district. The district occupies the lowest position with respect to irrigation facilities with only 15.43 per cent of the gross cropped area. Nearly 70 per cent of farmers are small and marginal (Kareemulla *et al*., 2008; DAC, 2017).

ChittoorDistrict

The major portion of the district is covered by red soils with portions of alluvial soil in erstwhile *talukas* of Chittoor and Bangarupalem. The major crops grown are rice, groundnut, sugarcane, tomato, mango etc. The district has a cropping intensity of 108 per cent. The average rainfall of the region is 934 mm (DAC, 2017).

Adilabad District

The climate of the district is characterised by hot summer and is generally dry except during the south-west monsoon season. The average annual rainfall is about 1100 mm. Despite receiving higher rainfall, the district often experiences severe drought like situations. About 60 per cent of the soils are black. About 75 per cent of the cultivated area in the district is under rainfed conditions. The principal crops of the district are sorghum, rice, cotton, maize and soybean. More than 70 per cent of the farmers are small and marginal (Kareemulla *et al.,* 2008; DAC, 2017)

Data and Analytical Methods

In order to estimate the impact of farm ponds, primary data was collected from farmers with farm ponds in the three districts. Farm ponds were dug with support from the Mahatma Gandhi National Rural Employment Guarantee Programme during the last three years in these districts. From each district four mandals were selected which had relatively higher number of farm ponds and from each mandal five villages were selected. The analysis was done using primary data collected during 2013 from 100 farmers having farm ponds in their farms. Data on cropping pattern, yield and profitability were collected from the sample farmers for 'before' and 'after'

farm pond situation. The impact of farm ponds in terms of changes in cropping pattern, yield and crop income was examined by comparing the changes in these variables with a 'before farm pond' situation. The economic feasibility of farm ponds was analysed through benefit cost ratio (BCR) and net present value (NPV) assuming a life of 15 years for each pond and the flow of economic benefits are uniform over years as done in Kumar *et al.* (2017), Reddy *et al.*, (2012) and Malik *et al.* (2013). Initial digging cost and maintenance cost were included in the cost computation and additional returns accrued compared to 'before pond' situation were taken as benefits attributable to farm pond. These additional returns were a result of a combination of changes in crop yields, cropping pattern, cropping intensity and additional area brought into cultivation. Multiple linear regression analysis was done to identify the major determinants of profitability farm ponds. It is to be noted here that the flow of returns would vary with intra-seasonal and inter-annual variation in rainfall and change in crop choices by farmers over time.

III

RESULTS AND DISCUSSION

The impact of farm ponds on the cropping pattern of the farm, yield of crops grown and area under cultivation for all the 100 ponds in each of the three districts and additional returns attributable to use of harvested water in farm pond are given in Table 1.

Anantapur District

After farm ponds were dug, the farmers in Anantapur increased the area under sunflower (3.2 ha), pearl millet (1.6 ha) and rice (0.6 ha), while there was decrease in the area of groundnut + pigeonpea. An additional area of 2.1 ha was brought under cultivation with farm ponds. The proportionate area sown to groundnut decreased by 4 per cent compared to 'before farm pond' situation.

Chittoor District

The area under cereal crops such as rice, pearl millet and maize increased after ponds were dug. With farm pond, area under tomato increased by 12.8 ha. Only *rabi* tomato showed a marginal decrease in area. There was significant decrease in the area of groundnut by 9.7 ha. With access to irrigation enabled by harvested rain water through farm pond, some of the farmers started growing crops like cotton, chilli, pearl millet and maize. These 100 farmers brought an additional 9.2 ha of land after having access to farm pond. This land was otherwise remained fallow before they had these ponds dug. In relative terms, area under tomatoduring *kharif* increased by more than 10 per cent and that under groundnut decreased by about 15 per cent.

TABLE 1. IMPACT OF FARM LEVEL RAINWATER HARVESTING THROUGH FARM PONDS ON CROPPING PATTERN IN THREE DISTRICTS, 2012-13

Chittoor			Adilabad			Anantapur		
Crop	Absolute change (ha) (2)	Relative change (per cent) (3)	Crop	Absolute change (ha) (5)	Relative change (per cent) (7)	Crop	Absolute change (ha) (9)	Relative change (per cent) (10)
(1)			(4)			(8)		
Groundnut	-9.68	-15.3	Cotton+ Pigeonpea	16.2	2.4	Groundnut +Pigeonpea	-3.3	-4.0
Tomato	12.76	10.7	Soybean	-4.2	-3.2	Sunflower	3.2	2.6
Rice	2.2	1.6	Tomato	2.6	0.8	Rice	0.6	0.4
Mango	0.8	0.6	Sorghum +pigeonpea	-2.6	-1.9	Pearl millet	0	-0.1
Cotton	0.4	0.4	Green gram	-0.4	-0.3	Orange	0	0.0
Chilli	0.2	0.2	Dry rice	1.6	0.9	Pigeonpea	0	0.0
Tomato (rabi)	0.2	-0.1	Mango	2.4	1.4	Crossandra	0	0.0
Groundnut (rabi)	1.2	1.0	Sorghum (rabi)	-0.8	-0.6	Pearl millet (Rabi)	1.6	1.2
Pearl millet	0.8	0.7	Wheat	-0.4	-0.3	Rice (*rabi*)	0	0
Maize	0.4	0.4	Tomato (rabi)	0.4	0.2			
			Groundnut (rabi)	0.4	0.2			
			Sesame	0.4	0.2			
			Chickpea	0.4	0.2			

Notes There was increase in total cropped area in all the districts. In Adilabad as much as an additional 16 ha was brought into cultivation because of the 100 ponds selected. The corresponding figures for Chittoor and Anantapur are 9.2 and 2.1, respectively.

Adilabad District

The area sown under cotton + pigeon pea, the major cropping system in the district, increased by about 16.2 ha for the 100 farmers as a whole. More area was also sown under tomato as compared to when there was no rainwater harvesting through farm pond. Farmers started growing crops like green gram, rice, mango and sesame after digging farm pond, while sorghum, soybean and wheat showed a decline in the area under cultivation. Through increase in irrigation through ponds, the farmers could extend cultivation to an additional 16 ha of land.

Impact of Farm Ponds on the Yield of Crops and Income

Harvesting and use of rainwater led to considerable increase in the yield of crops grown (Table 2). This together with changes in cropping pattern, area cultivated and cropping intensity resulted in increase in returns attributable to farm pond. The distribution of farm ponds based on the additional returns so generated is presented in Table 3.

TABLE 2. IMPACT OF FARM LEVEL RAINWATER HARVESTING THROUGH FARM PONDS ON CROP PRODUCTIVITY IN THREE DISTRICTS, 2012-13

Anantapur		Chitttoor		Adilabad	
ps (1)	Yield increase (per cent) (2)	Crops (3)	Yield ncrease (per cent) (4)	Crops (5)	Yield increase (per cent) (6)
Sweet Orange	23	Tomato (k)	28	Tomato	45
Rice	36	Mango	55		
Pearl millet	32	Rice	33	Soybean	39
Sunflower	14	Groundnut (K)	48	Cotton+Pigeonpea	21
Crossandra	45	Chilli[$]	--	Sorghum+pigeonpea	28
Groundnut+Pigeonpea	2	Cotton[$]	--	Green gram	80
Pigeonpea	27	Tomato(R)	38	Groundnut	30
Bean[$]	--	Groundnut(R)	25	Sorghum	44
Pearl millet	24	Pearl millet[$]	--	Tomato	14
Rice	9	Maize[$]	--	Wheat	18

$These crops were not grown by farmers before farm ponds; K: k*harif* R: r*abi*

TABLE 3. DISTRIBUTION OF FARM PONDS ACCORDING TO ADDITIONAL RETURNS GENERATED IN THREE DISTRICTS, 2012-13

Additional returns(Rs./pond/year) (1)	Anantapur (2)	Chittoor (3)	Adilabad (4)
<5000	34	12	3
5000-10000	34	35	5
10001-15000	22	21	12
15001-20000	2	12	11
20001-25000	3	7	12
25001-30000	4	2	17
30001-35000	0	1	10
>35000	1	10	30
Total	100	100	100

Anantapur District

The yield increases attributable to access to irrigation through rainwater harvested through farm pond was highest for crossandra, rice and pearl millet. Groundnut, the major crop in the district, showed only a marginal yield gain. More than eighty per cent of the farm ponds generated additional returns up to Rs.15000 per year.Sixty-eight ponds could generate less than Rs.10000 and only ten ponds could generate an additional return of more than Rs 15000 per year. Of all the three districtsAnantapur received least annual rainfall presenting limited scope for harvesting water. However, it is also most crucial to protect the yields and incomes of farmers in such a situation.

Chittoor District

The yield of all crops increased by more than 25 per cent compared to a situation before farm ponds were dug. The yield gains were particularly visible in the case of groundnut and tomato. Even the yield of mango, a perennial fruit tree, was also found to yield considerably higher probably because of groundwater recharge as it is not directly irrigated with harvested water. The highest yield increase was for mango followed by groundnut and tomato. The additional returns attributable to farm ponds varied widely. However, returns generated by 80 out of 100 ponds fell in the range of Rs.5000 -20000 per year. As mentioned, these additional returns arose due to changes in crop yields, cropping pattern, cropping intensity and additional area brought into cultivation.

Adilabad District

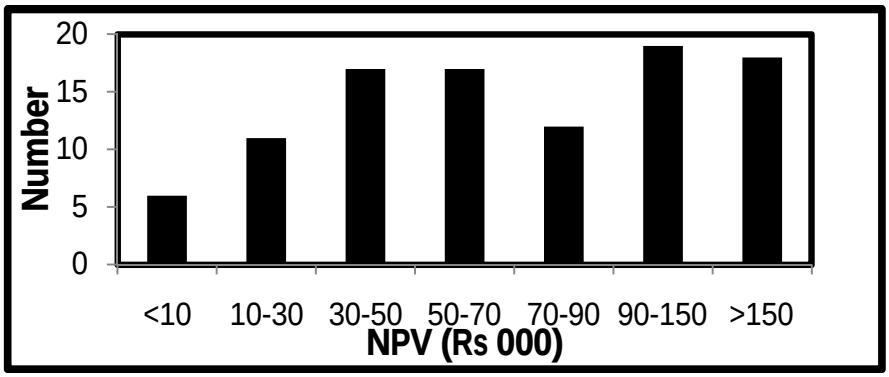
The district with relatively higher annual rainfall offers considerable scope for bigger farm ponds as more run-off is possible. Though all the crops grown witnessed noticeable yield increases, higher yield gain was observed with green gram (80 per cent) and tomato (45 per cent). Crops like sorghum, groundnut and soybean also showed significant increases in the yield with irrigation provided using harvested rainwater through farm pond. Majority of the farm ponds in this district generated returns more than Rs. 20000 per year.

Financial Feasibility of the Farm Ponds Across the Three Districts

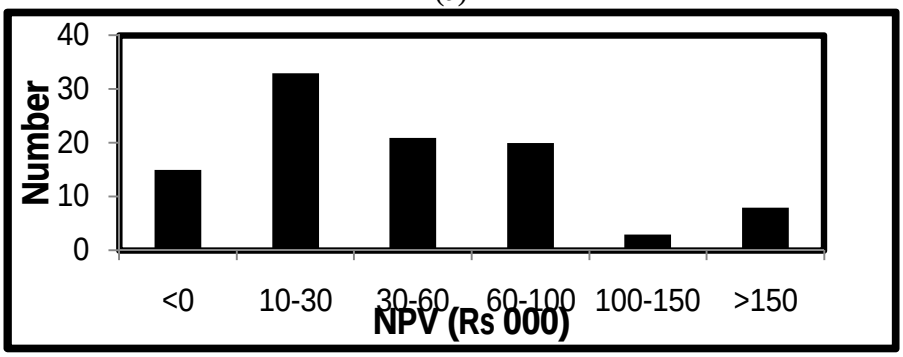
In order to examine the financial feasibility of the farm ponds, the benefit-cost ratio and net present value were analysed for 100 ponds in each district. Assuming a life of 15 years for the farm ponds, the economic viability in terms of NPV (Table 4) and BC ratio (Figure 1) was calculated for all the 100 ponds each across the three districts. The BC ratio and NPV was found to vary significantly across the districts. The results of the same are discussed below.

TABLE 4. DISTRIBUTION OF FARM PONDS ACCORDING TO BENEFIT COST RATIO IN THREE DISTRICTS

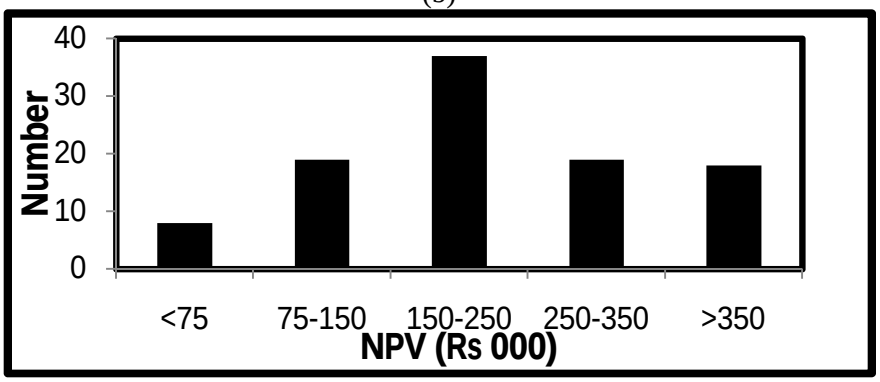
BC Ratio	Anantapur	Chittoor	Adilabad
(1)	(2)	(3)	(4)
<2.5	62	14	0
2.6-5	28	31	5
5.1-10	9	33	20
10.1-15	1	11	32
15.1-20	0	3	20
20.1-25	0	3	16
>25	0	5	7
Total	100	100	100



(a)



(b)



(c)

Figure 1. Distribution of farm ponds based on net present value in (a) Anantapur (b) Chittoor and (c) Adilabad Districts

Anantapur District

It was observed that 33 out of 100 ponds gave an NPV of less than Rs.30000 (Fig 1). It is interesting to note that four ponds recorded an NPV in excess of Rs. two lakhs and investment in 15 ponds was found to be unviable with a negative NPV. About 60 per cent of the ponds had BC ratio less than 2.5 and with 15 ponds among them unviable. There were no ponds with BC ratio more than 15.

Chittoor District

It is observed that 12 ponds out of 100 gave an NPV less than Rs.5000 out of which three ponds were found to be unviable with negative NPV. It is also interesting to note that three ponds recorded an NPV in excess of Rs. 5 lakhs (Figure 1). Majority of the farm ponds (75 per cent) had BC ratio between 2.5 to 10 and eight ponds were more profitable with BC ratio more than 20.

Adilabad District

The ponds in this district were found to be more profitable when compared to others. On an average the NPV of ponds was 2.5 lakhs while it was also found that investment in 3 ponds recorded NPV in excess of 6 lakhs (Figure 1). All 100 ponds were found to be viable. More than 60 percent of the ponds had BC ratio more than 10.

These results are in line with other studies which looked at the impact of farm ponds at farm level. Kumar *et al*. (2016) reported average annual net returns of Rs. 40,000 (US$60) due to on farm rainwater harvesting in Anantapur. The net returns varied between US$60 to US$140 across different locations in India. Malik *et al*. (2013) also reported that rainwater harvesting through farm ponds was a viable option to enhance crop yields and income in Madhya Pradesh. Investments in decentralized rainwater harvesting through digging farm ponds was found to have positive net present value (Rs. 1.2 to 1.3 lakhs) and benefit-cost ratios ranging between 1.9 and 2.3 in Rajasthan (Kumar *et al.*, 2017).

Determinants of Profitability of Farm Ponds

To examine the determinants of profitability of ponds, the additional returns generated per year was regressed on independent variables, viz., size of the plot where the pond is located (ac), size of the pond (M^3), change in cropping intensity (%), whether water is lifted to irrigate the crop, whether there is a bore well in the plot and number of fillings in the season. The results for the three districts are presented in Table 5.

TABLE 5. DETERMINANTS OF PROFITABILITY OF FARM PONDS, ANANTAPUR, CHITTOOR, AND ADILABAD DISTRICTS

Variable	Anantapur		Chittoor		Adilabad	
	Regression coefficient	Standard error	Regression coefficient	Standard error	Regression coefficient	Standard error
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	-3572.7	4798.6	-22305.30*	6611.48	12453.6	7236.35
Plot size	1661.5*	322.98	5064.72*	970.89	3310.71*	959.17
Pond size	39.49*	23.20	16.20	14.62	18.547*	5.98
Whether water is lifted	3874.34*	1544.06	4741.50	3451.32	15820.17*	5646.70
Change in cropping pattern	10456.89*	2147.91	8453.6*	2929.22	-276.341	2843.77
Change in cropping intensity	-1432.24	2516.31	4833.89	3517.26	-1776.94	5940.97
Whether bore well present in the same plot	-1783.83	1323.81	5781.95*	2922.77	-3416.69	4055.41
No. of fillings	-1162.58	837.163	5013.37*	1786.72	-409.87	1357.46
R^2	0.55		0.44		0.34	

* Significant at 5 per cent at least.

Anantapur District

The results indicated that four variables, size of plot, size of pond, change in cropping pattern and use of water for irrigation were found to have significant positive effect in increasing returns. Variables such as slope of the plot, presence of a bore well and number of fillings were not found to have significant effect. It was observed (Table 5) that the average size of the plot and pond were much larger in the case of most profitable ponds. Similarly, the yield effects were more prominent as well as the changes in cropping pattern. The additional returns from farm pond was found to be associated with changes in cropping pattern in favour of horticultural crops such as sweet orange and tomato. The negative relationship between number of fillings and additional returns, though statistically not significant, in Anantapur and Adilabad districts was possibly due to moderation of benefits from farm pond in the years of better rainfall which lead to more frequent filling of ponds. The positive relationship in Chittoor can be attributed to the fact that the district receives rainfall with north-east monsoon as well and thus helps extend the cropping season and thus helps to increase the cropping intensity.

Chittoor District

It is observed from the Table 5 that the profitability was significantly influenced by the size of the plot where the pond was located. The number of fillings and cropping pattern change in favour of high value crops were also found to increase the profitability of farm ponds significantly. Crops like cotton, pearl millet, chilli and maize added to the existing cropping pattern and thus increased profitability. Farm ponds also helped in recharge of bore wells and thereby increasing the yields of crops.

Adilabad District

In this district, the size of the plot where the pond was located, size of pond and use of lifting device to pump water for irrigation were found to be positively influencing profitability of farm pond. Adilabad has comparatively bigger farm ponds making it possible to harvest more rainwater. These have also led farmers to increase the cropped area with shifts in cropping pattern, thereby increasing the profitability of ponds (Table 5).

Performance Differentiators of Most and Least Profitable Farm Ponds

In order to further understand the determinants of profitability, the characteristics of five most profitable and five least profitable ponds were examined (Table 6). It was observed that the average size of the plot and pond were much bigger in case of the most profitable ponds. Across the three districts, Adilabad had larger size ponds and plot size. The profitability of ponds also increased with increase in cropping intensity and changes in cropping pattern which is evident from the table. The top performing ponds also showed that they help in recharge of bore wells in the plot and also enough water is available for irrigation through pumping, while there were no bore wells and pumping in Adilabad and Chittoor with exception of two in Anantapur district.

TABLE 6. CHARACTERISTICS OF MOST AND LEAST PROFITABLE FARM PONDS IN THREE DISTRICTS

Variables	Chittoor		Adilabad		Anantapur	
(1)	Top (2)	Bottom (3)	Top (4)	Bottom (5)	Top (6)	Bottom (7)
Cropping intensity (per cent)	131.43	100	114.4	112.9	179	100
Cropping pattern change (no.)	4	2	4	2	4	0
Bore wells (no.)	4	0	4	0	5	2
Pumping (no.)	1	0	4	0	3	1
Pond size (cu.m)	203	195	791.0	147.6	240	208
Plot size (acres)	3.2	1.1	5.5	3.2	5	2.3

Thus, it can be concluded that rainwater harvesting through farm ponds is an effective strategy for enhancing farm incomes through higher crop yields, cropping intensity and diversification towards high value crops. The harvestable amount of rainwater, which is a function of rainfall and catchment area, access to water lifting device and usage of harvested water were found to be associated with viability of rainwater harvesting through farm ponds.

IV

SUMMARY AND POLICY IMPLICATIONS

Improving the productivity of and income from rainfed agriculture should form an important element of any strategy for a more inclusive growth and enhancing incomes of farmer households. In the context of rainfed agriculture, harvesting and use of rainwater for protective and/or productive irrigation assumes importance. This paper, using primary data from 300 farm ponds from three districts with varying rainfall, soil types and cropping pattern showed that rainwater harvesting through farm ponds was effective in enhancing farm incomes considerably across locations. The income gains were a result of improvement in crop yields, change in cropping pattern towards high value crops, increase in cropping intensity and expansion of cultivated area where the ponds were located. Further, the profitability returns due to farm pond were influenced by size of the plot where the pond was located, size of farm pond and when farmers were able to pump the water harvested to irrigate the crop through a pumping device. These findings imply that the design of farm ponds should be location-specific taking into consideration the rainfall and run-off possibilities. Further, the plot where the pond is located should be reasonably large in size so that the harvested water can be gainfully utilised. If the pond and plot are too small, economic returns that can be generated may be too small to elicit the interest of the farmers. In Anantapur, most farm ponds located in plots less than 1 ha in size did not generate enough returns to meet the costs involved. That the incomes from plots where the ponds were located considerably increased, even doubled in some cases, underscores the potential role of farm ponds towards achieving the goal.

Interactions with farmers also brought out that during the years of normal/ above normal rainfall, the benefits from pond seem to be moderated. The farm ponds are also found to impact ground water recharge and access to irrigation. Though there is clear evidence of benefits from ponds still its adoption is less than what is possible. Unawareness and small farm size were major reasons for non-adoption. Therefore, the policy focus must be for the construction of water harvesting structures particularly farm ponds wherever feasible and public and private investment may be focussed to expand its adoption especially in rainfed regions of our country. Designing and making available low cost and more efficient pumping devices suitable to lift water from shallow depth may also help popularise farm ponds.

Received July 2019. *Revision accepted November 2019.*

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