Received: 23 September 2024 | Accepted: 7 November 2024 | Published online: 9 November 2024
DOI: 10.59797/ijsc.v52.i2.160

ORIGINAL ARTICLE
Indian Journal of Soil Conservation

Water harvesting structure-farm pond for increasing crop yields and farm income in rainfed semi-arid ecosystem of Karnataka

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***Handling Editor :**
Dr S.M. Vanitha

***Key words:**
Farm pond
Life-saving irrigation
Rainfed farming
Runoff harvesting
Rainwater recycling

ABSTRACT

This study evaluated the impact of farm ponds constructed under the Krishi Bhagya Scheme in the Northern Dry Zone of Karnataka from 2022 to 2024. A total of 320 farmers were selected for data collection, divided into two groups: farmers with or without farm ponds. Each group comprised 160 farmers, who were chosen using a multi-stage stratified random sampling technique. Various statistical methods were used to analyse the data, including descriptive statistics, tabular analysis, and t-tests. The findings indicated that cropping intensity significantly increased among farmers with ponds (157%) compared to those without (142%). This improvement was attributed to effective on-farm rainwater conservation and the harvesting of surplus runoff in ponds, which provided supplemental irrigation during critical periods. Additionally, farmers with ponds experienced greater crop yields and farm income than the control group, resulting in a percentage increase in income from 17% to 48%. Employment generation, measured in man-days, also improved among farmers with ponds, showing a substantial increase in work opportunities, particularly during the rabi season (69%) compared to the *kharif* season (31%). The construction of farm ponds also influenced the number of livestock maintained, particularly cows, sheep, and goats. The ponds provided essential drinking water and fodder, ensuring alternative livelihood opportunities in rainfed regions. Consequently, adopting farm ponds fosters sustainable production and promotes efficient natural resource management in these areas.

HIGHLIGHTS

- Farm pond helps farmers diversify their cropping pattern and integrate different farming systems with agriculture, such as dairy, to increase on-farm and off-farm income in Semi-arid rainfed regions.
- The area under irrigation and cropping intensity was increased for farmers with farm ponds compared to control due to on-farm rainwater conservation and harvesting surplus runoff with farm ponds for supplemental life-saving irrigation.
- The crop yields and farm income for farmers with farm ponds were increased compared to control due to protective life saving irrigation, particularly during critical crop growth stages with farm ponds.
- Farmers with farm ponds were more resilient to drought and sustaining income than control due to harvesting excess runoff and used for farming and other economic activities.

1 | INTRODUCTION

Agriculture is the backbone of the Indian economy, with nearly 55% of the population relying on it as their primary source of income and livelihood. Rainfed agriculture accounts for more than 50% of the net sown area and plays a significant role in producing food grains, particularly coarse cereals, rice, pulses, and oilseeds in India (Rao *et al.,* 2019). However, this sector faces numerous bio-physical and socio-economic challenges. The limited resource base has negatively impacted crop and livestock productivity (Venkateswarlu, 2011). Additionally, the irrigation potential in these areas is not fully utilized, resulting in significantly lower crop productivity compared to regions with irrigated agriculture. Therefore, effective strategies and planning are essential to optimize the natural resource base, enhance crop productivity, and achieve the goal of doubling farmers' income in rainfed areas. Fragile agroecosystems with low productivity characterize rainfed farming and are largely practised in arid, semi-arid, and dry sub-humid regions. Low productivity in this region is mainly due to marginal and erratic rainfall exacerbated by high runoff and evapotranspiration losses. Sufficient availability of soil moisture during crop growth is a limiting factor, and soil degradation is a critical factor that results in low productivity. These regions receive an average annual rainfall of 500 to 700 mm, which is highly erratic and unevenly distributed during cropping seasons. There is an abundant scope and opportunities for harvesting excess runoff in the rainfed region of different states of the country (Wani *et al.,* 2003). Therefore, proper management and utilization of surplus runoff is crucial to increase rainfed farm productivity. In addition, farm-level adoptions of rainwater harvesting structures were highly effective in rainfed farming and had a multiplier effect on farm income (Shalander Kumar *et al.,* 2016).

In Karnataka, Agriculture is predominantly rainfed and the state is experiencing recurring droughts and floods simultaneously in different regions. A glance into the rainfall pattern of the state reveals that for every decade, three to four years experience severe drought, sometimes consecutively. The non-availability of irrigation coupled with prolonged dry spells in the rainfed area may lead to crop failure and low productivity. Supplementary irrigation in rainfed agriculture through farm ponds reduces the risk of total crop failure due to dry spells and substantially improves water and crop productivity (Biazin *et al.,* 2012). Realizing the importance of water in the climate change scenario, the Government of Karnataka has implemented the Krishi Bhagya Scheme during 2014-15 to ensure irrigation for sustainable production through on-farm rainwater conservation practices. Water harvesting farm ponds are essential in improving crop productivity and farm income in rainfed regions in climate change situations (Dupdal *et al.,* 2021). Most of the study area, *i.e.,* the Northern dry zone of Karnataka, is characterized by a semi-arid climate with low rainfall, which is highly unpredictable and unevenly distributed in cropping seasons. Crop yields are very poor and unstable due to low and uncertain rainfall and inefficient crop management (Adhikari *et al.,* 2009). Thus, rainwater harvesting ponds helps to conserve and harvest surplus runoff for protective irrigation during critical crop growth stages to improve rainfed productivity. Further, farmers can integrate different farming systems with agriculture, horticulture, fisheries and dairying to enhance on-farm (farming, crop production) and off-farm (extension services, processing, packaging, storage, distribution and retail sale etc.) income in dryland areas (Dupdal *et al.,* 2020). However, economic viability and long-term sustainability of farm ponds were the major concerns for the farmers. Keeping this in view, the present study attempted to analyze the impacts and profitability of farm ponds constructed under the Krishi Bhagya Scheme in the Northern dry zone of Karnataka.

2 | MATERIALS AND METHODS

The present study was conceptualized to study the impact of farm ponds constructed under the Krishi Bhagya Scheme implemented by the Government of Karnataka to enhance the rainfed region crop productivity through efficient rainwater management. Under the scheme, more than two lakh farm ponds were constructed in the farmers' fields with a combined water storage capacity of 1472.31 lakh cubic meters. The Scheme encompasses a farm pond with polythene lining and installing a sprinkler with a diesel pump set (5HP) to promote micro-irrigation and increase water use efficiency. Therefore, the current study evaluates the change in cropping patterns, crop productivity, and farmers' incomes with and without farm pond interventions.

2.1 | Study Area

Ballari and Vijayapura districts under the northern dry zone of Karnataka were chosen for the present study as they fall under a semi-arid region with low and deficit rainfall. Ballari district is located in the eastern part of Karnataka and lies between 15°30' and 15°50', north latitude and 75°40' and 77°11' East longitude. The district receives a mean annual rainfall of about 633 mm, which is non-uniformly distributed over the district. Predominant soil types are red and deep black soils. The main occupation of the district is agriculture, and more than 75% of the population depends on agriculture and allied activities for their livelihood. The major crops of the district were paddy, chilli, maize, sorghum, sunflower, cotton and chickpea. Vijayapura district, located in the northern part of Karnataka, lies between 150 50' and 170 28' North latitudes and 74°54' and 76°28' East longitudes. The mean annual rainfall of the district is 594 mm, with 52% of annual rainfall received during the *rabi* season. This zone received low annual unimodal rainfall and comprised mostly medium to deep black soils with diversified cropping patterns (Dupdal *et al.,* 2022). The important crops were pearl millet, groundnut, pigeon pea, green gram, maize, sorghum, sunflower, safflower and chickpea.

TABLE 1 Water stored in selected sample farm ponds in the study area

Size of farm pond	No. of sample	Water storage (m^3) @ 2 fillings
15*15*3	40	35280
21*21*3	40	78480
28*28*3	40	15070
30*30*3	40	175680
Total	160	304510

2.2 | Data Source

For analyzing the impact of farm ponds, farmers with and without farm ponds were selected within the same village. Farmers were selected based on a multi-stage random sampling technique across the northern dry zone of Karnataka. A total of 320 farm household data was collected through pre-tested interview schedules during 2022-2024. Of 320 farm household samples, 160 were farmers with farm ponds, and 160 were farmers without farm ponds selected for a comparative study. For data collection, dryland districts were selected purposively in the northern dry zone of Karnataka. Under each district, one taluk and two villages were selected for primary data collection. The selected taluka were Ballari taluk in Ballari district and Vijayapura taluk in Vijayapura district and selected villages were K. Veerapura and Joladarasi in Ballari taluka and Nagatan and Hunsyal in Vijayapura taluk. The primary data on cropping patterns, crop yields, and income were collected from sample farmers with and without farm ponds. Further, data relating to employment status and livestock components were collected from farmers with and without farm ponds.

2.3 | Statistical Tools Used

Descriptive statistics such as frequency, percentage, tabular analysis and t-test were used to study the impact of farm ponds on cropping patterns, crop productivity and returns, and employment accrued among the beneficiary farmers in the study area compared to control farmers.

3 | RESULT AND DISCUSSION

3.1 | Socio-economic Characteristics of Sample Farm Households

The socioeconomic characteristics of farmers with and without farm ponds revealed that nearly 53% of control farmers were in the old age groups, while 45% of farmers with ponds were in middle-aged groups (Table 2). The education of farmers had implications for technology adoption and its usage. A higher level of education among farmers helped them access more advanced technology and information than their counterparts. Less than one-third of the farmers with ponds were illiterate. In comparison, more than one-third of control farmers were illiterate, and only five per cent of farmers attained graduation, while 10% of farmers with ponds attained graduation. Farming experience was higher for farmers with ponds (55%) than control farmers (30%). The majority of sample farmers in both categories were under a small size of land holding with <2 hectares followed by a large size of holding (> 2 ha). Farmers with ponds possessed more livestock (48%) than control farmers (38%) since farm ponds provided sustained water availability for fodder production and drinking for animals. The off-farm employment among control farmers (43%) was higher than that of farmers with ponds (28%) as farm ponds provided supplemental irrigation, increasing employment opportunities and man months in agriculture/crop cultivation among farmers with ponds. Further, with the adoption of farm ponds risk, the ability and accessibility to institutional credit increased among farmers with ponds (50%) compared to control farmers (38%).

3.2 | Farm Pond and its Impact on Cropping Pattern and Cropping Intensity

The impact analysis of farm ponds on cropping patterns revealed that the area under irrigation increased due to on-farm conservation and harvesting of rainwater for protec-

TABLE 2 Socio-economic characteristics of sample farm households

S.No.	Particulars	Farmers with ponds		Farmers without ponds	
		f	%	*F*	%
1.	Age (years)				
	Young (<35)	36	23	28	18
	Middle (35-50)	72	45	48	30
	Old (>50)	52	33	84	53
	Total	160	100	160	100
2.	Education (No.)				
	Illiterate	44	28	64	40
	Primary	64	40	72	45
	High school	32	20	16	10
	Graduation	20	13	08	05
	Total	160	100	160	100
3.	Farming experience (years)				
	Low (<15)	24	15	40	25
	Middle (16-25)	48	30	72	45
	High (>25)	88	55	48	30
	Total	160	100	160	100
4.	Social category (No.)				
	SC/ST	64	40	56	35
	OBC	36	23	40	25
	General	60	38	64	40
	Total	160	100	160	100
5.	Land holding type (No.)				
	Marginal (< 1 ha)	36	23	40	25
	Small (<1-2 ha)	68	43	64	40
	Large (>2 ha)	56	35	56	35
	Total	160	100	160	100
6.	Possession of livestock				
	Yes	76	48	60	38
	No	84	53	100	63
	Total	160	100	160	100
7.	Off-farm employment				
	Yes	44	28	68	43
	No	116	73	92	58
	Total	160	100	160	100
8.	Access to institutional credit				
	Yes	80	50	60	38
	No	80	50	100	63
	Total	160	100	160	100

Source: Field Survey Data, 2022

tive irrigation, particularly utilized during critical crop growth stages. The area under chickpea (28.26 ha) and onion (19.83 ha) were higher among farmers with ponds as compared to control farmers (19.73 ha) and (6.93 ha), which was due to the adoption and harvesting of excess runoff water with farm ponds resulting in increased water availability for life saving irrigation and also in-situ soil moisture conservation (Table 3). The study also revealed a difference in grossed cropped area (15%) for farmers with farm pond compared with control. The difference in the gross cropped area was mainly attributed to the increase in relative cropped area in the *rabi* season as compared to the *kharif* season; thus difference in cropping intensity to the tune of 157% for farmers with farm ponds as compared to control (142%) was observed and difference in cropping intensity between farmers with and without farm pond was found statistically significant at less than 0.01 level of probability. Desai (2007) and Dupdal (2023) in their studies revealed that the construction of farm ponds had brought about a perceptible change in cropping intensity by increasing the area under *rabi* crops in the case of farmers with ponds as compared to farmers without farm ponds.

TABLE 3 **Impact of farm ponds on cropping pattern and Cropping Intensity**

Crop	With farm ponds		Without farm ponds	
	Area (ha)	Percent to the total area	Area (ha)	Percent to the total area
Redgram	17.17	7.45	18.11	9.30
Cotton	14.92	6.48	14.61	7.50
Maize	14.43	6.26	15.34	7.88
Jowar	11.66	5.06	13.81	7.09
Bajra	10.57	4.59	13.44	6.90
Onion	11.77	5.11	13.47	6.92
Fallow land	33.17	14.40	24.16	12.41
Total *kharif* area	113.69	49.34	112.94	58.00
Chickpea	28.26	12.26	19.73	10.13
Safflower	12.06	5.23	10.81	5.55
Coriander	10.69	4.64	4.7	2.41
Jowar	15.73	6.83	10.13	5.20
Sunflower	11.06	4.80	8.87	4.56
Onion	19.83	8.61	6.93	3.56
Wheat	10.88	4.72	5.55	2.85
Fallow land	8.22	3.57	15.07	7.74
Total *rabi* area	116.73	50.66	81.79	42.00
Gross cropped area	230.42	100.00	194.73	100.00
Net cultivated area		146.86		137.1
Cropping intensity (%)				
Mean	157.82		142.13	
Std. Error Mean	8.23		5.47	
t-value	7.196*			

**Significance at P<0.01.*

3.3 | Impact of Farm Ponds on Crop Yields and Farm Income

The findings of the impact of the adoption of farm ponds for rainwater harvesting and supplemental irrigations had differences in the crop yields and net income of farmers with farm ponds (Table 4 and Fig. 1). There was a difference in crop yields particularly coriander (23%), onion (21%) and maize (18%) over cultivation of crops without irrigation from farm pond under rainfed situations. The 't' test showed

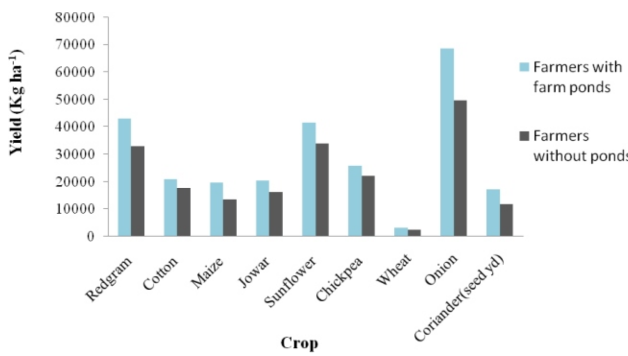

FIGURE 1 **Impact of farm pond on farmer's net income with and without pond**

TABLE 4 **Economics of farmers with and without farm ponds**

Crop	Farmers with farm pond			Farmers without farm pond			Additional income to farmers with farm pond (₹ ha^{-1})	% difference over control	t-value
	Yield (q ha^{-1})	COC (₹ ha^{-1})	Net returns (₹ ha^{-1})	Yield (q ha^{-1})	COC (₹ ha^{-1})	Net returns (₹ ha^{-1})			
Redgram	12.47	39244	43058	10.62	37321	32771	10287	31	4.275*
Cotton	9.43	36450	20884	8.66	34964	17689	3196	18	1.854
Maize	30.09	39328	19709	25.42	39345	13529	6180	46	3.800
Jowar	12.91	20265	20265	11.64	18679	16125	4140	26	3.526**
Sunflower	10.81	27677	41507	9.35	25949	33891	7616	22	1.274*
Chickpea	10.33	28144	25882	9.24	26284	22041	3841	17	3.964**
Wheat	12.7	20150	6838	11.80	19413	5662	1176	21	0.316
Onion	181.75	58752	68473	150.26	45505	49677	18796	38	0.876*
Coriander	5.76	23075	17245	4.69	21166	11664	5581	48	2.508**

***Significant at P<0.01, *Significant at P<0.05.*

a significant difference in farmers' yields with farm ponds compared to control farmers. The difference in farmers' yields with ponds was mainly due to increased protective irrigation, particularly during critical crop growth stages and improved soil moisture. The field bunds constructed in the farmer's fields increased the soil moisture and reduced the cracks in the fields laid out with farm ponds over the control conditions. Results revealed that due to the difference in crop yields of farmers with ponds, additional income was ₹ 18796 ha^{-1} for onion and ₹ 10,286 ha^{-1} for redgram. Similar findings were reported by Kumar *et al.* (2016), Raizada *et al.* (2018), Gireesh *et al.* (1997) and Kumar *et al.* (2024).

The percent difference in farmers' income with farm ponds ranged from 17 to 48% for different crops over control farmers, and net income realized was higher (30%) than farmers without farm ponds. The results align with the findings of Rao *et al.* (2019), who reported that income gains resulted from improvement in crop yield, change in cropping pattern towards high-value crops, increase in cropping intensity and expansion of cultivated area where the ponds were located. This study found in conformity with studies of Dupdal *et al.* (2021) and reported that farm pond intervention enhanced 25-30% of crop productivity as harvested rainwater available for providing one or two protective irrigations to crops at critical growth stages during dry spells and drought. Rao *et al.* (2017) and Reddy *et al.* (2018) reported similar results for increasing crop productivity and net returns with farm pond irrigation. The study was also in line with the findings of Umesh *et al.* (2024), reporting that tank rejuvenation of selected traditional community tanks helped to improve the livelihood of 50 to 70% of small and marginal farmers through increasing crop yields in Yadgir district of Karnataka.

TABLE 5 Impact of farm ponds on employment among beneficiary farmers (Man days/farm)

Particulars	With farm ponds	Without farm ponds	% difference	t-value
Kharif	90	85	6	0.3
Rabi	40	08	400	10.8**
Total	130	93	40	2.7**

*Note: ** indicates 1% level of significance.*

TABLE 6 Share of farm-households owning livestock and small ruminants (Nos.)

Livestock	Farmers with ponds	Farmers without ponds	% Change
Cow	57	31	83.9
Buffalo	17	13	30.77
Sheep	23	14	64.3
Goat	43	25	72.0
Bullock	15	13	15.38
Poultry	48	51	-5.9

3.4 | Farm Pond and its impact on employment among beneficiary farmers

The results of employment generated due to the adoption of farm ponds revealed that there was a difference in man-days for farmers with the adoption of farm ponds (130 man days/farm) as compared to control (93 man days/farm) (Table 5). The difference in man-days for beneficiary farmers was attributed to an increase in man-days, particularly during the *rabi* season compared to the *kharif* season. The excess runoff water harvesting followed by supplemental irrigation with a farm pond increased the area under irrigation, which demanded more labour and employment opportunities in the farm compared to the control condition. The 't' test showed a significant difference in the employment generated for farm pond beneficiaries and control farmers. The study findings align with Kumar *et al.* (2016), who reported that farm ponds led to the diversification of the cropping system and an increase in crop yield, which helped improve employment generation.

3.5 | Share of Farm-households Owning Livestock and Small Ruminants

Livestock rearing is one of the alternative livelihood enterprises in the village, and it plays a vital role in sustaining and strengthening farmers' income. It also helps reduce rural poverty and nutritional security and is resilient to drought and climate variability. In the study area, there exists a per cent difference in the share of cows (83.9%), goats (72%) and sheep (64.3%) for farmers with pond over control, implying that the farmers with pond are more resilient and sustaining compared to the control farmers (Table 6).

The percentage difference in livestock population among beneficiary farmers was mainly due to the availability of green fodder and drinking water for animals with the support of farm ponds. Even during the drought period, it was easy for the farmers to fetch water for the animals after the construction of farm ponds.

5 | CONCLUSIONS

Sustainable agriculture production in the rainfed regions is challenging under climate change, mainly due to unpredictable and erratic rainfall, frequent droughts followed by prolonged dry spells and crop failures. However, these vagaries can be overcome by farm-level adoption of farm ponds for rainwater harvesting and efficient utilization and management of excess runoff water for increasing rainfed productivity. It helps the farmers diversify their cropping system and integrate different farming systems with agriculture, such as dairy, to increase on-farm and off-farm income in rainfed areas. It also helps efficiently utilise and manage natural resources in the rainfed region. It is evident from the study results that there was a difference in cropping pattern cropping intensity and crop yields for the adoption of farm ponds. The area under irrigation was increased due to on-farm rainwater conservation and harvesting utilized for supplemental life saving irrigation. There is a difference in crop yields and farm income for farmers with farm ponds compared to control due to protective life saving irrigation during critical crop growth stages with farm ponds. Further, results also revealed that the percent gain in income of farmers with farm ponds ranged from 17 to 48% over control farmers, and net income realized was higher than farmers without farm ponds. The employment generation in terms of man days was higher for farmers with pond than control farmers. This was mainly attributed to an increase in man-days, particularly during the *rabi* season compared to the *kharif* season. Due to the adoption of farm ponds, there was an increase in livelihood opportunities such as dairy through livestock rearing as farm ponds served as a source of drinking water and green fodder for the livestock even during drought periods.

ACKNOWLEDGEMENTS

Authors express their sincere thanks to Agriculture Department located at Ballari and Vijayapura districts for providing technical information and guidance for selection of study area for primary data collection.

DATA AVAILABILITY STATEMENT

Data are available for reasonable reasons from the first author.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR'S CONTRIBUTION

RD: Conceptualization, Formal analysis, Methodology, Writing - original draft. BSN: Data curation, Writing - review and editing. MNR: Data curation, Writing - review, and editing. RKN: Data curation, Writing - review, and editing. BKR: Supervise, validate, and write - review and editing.

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How to cite this article: Dupdal, R., Naik, B.S., Ramesha, M.N., Ravi, K.N. and Rao, B.K. 2024. Water harvesting structure-farm pond for increasing crop yields and farm income in rainfed semi-arid ecosystem of Karnataka. *Indian J. Soil Cons.,* **52** (Global Soils Conference - 2024 Special Issue): S68-S73.