Rainwater Harvesting Technologies in Arid and Semi-Arid Region of Karnataka to Mitigate Climate Change Impacts

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Abstract

Climate change in the form of temperature increase and rainfall variability has intensified in the last three decades. Rainwater harvesting is one of the mitigation strategies in drought-prone regions. Hence, studies on rainwater harvesting technologies were conducted in four villages of Tumkur, Gadag, Belagavi and Chikkaballapura districts during 2011 to 2018 as a part of National Innovations in Climate Resilient Agriculture (NICRA). During 2017, 77,700 m^3 and 6,410 m^3 of water was harvested in farm ponds and water harvesting structures, respectively. The harvested water was used for supplemental irrigation during drought periods to increase and stabilize crop production and improve the system's productivity. After desilting of community pond the water storage capacity has increased by 2-3 times and also there was an increased cropping intensity of the village. Plastic lining materials had shown efficacy in minimizing seepage and percolation losses. *In-situ* moisture through trench cum bund conserved the harvested rainwater during June-August which has increased the surrounding soil moisture content and kept the moisture for a longer duration. This increased the yield of the groundnut by 20.59 per cent which was not possible without trench cum bunding. The ground water level in open wells and borewells started improving by diverting runoff water into defunct / less yielding borewells.

Keyword : Climate change, Impact, *In-situ* moisture, Mitigations, Rainwater harvesting technologies

Climate change has altered the weather parameters largely in terms of rainfall behavior and temperature anomalies. The varied rainfall behavior due to climate change led to more frequent and intense heavy rainfall events and extended dry spells in the 21st century (Raghavan e*t al.*, 2020), which has a greater impact on the sustainability of fragile rainfed ecosystems than irrigated ecosystem. In India, 60 per cent of the total cultivated area is managed as a rainfed ecosystem, where in crop production is dependent on rainfall, having no facility for protective or lifesaving irrigation.

India ranks first among the rainfed agricultural countries of the world in terms of both extent and value of produce. Rainfed agriculture supports 40 per cent of the national food demands (Cherukumalli Srinivasa Rao *et al.*, 2015). Rainfed areas receive an annual rainfall between 400 mm and 1000 mm, which is unevenly distributed, highly uncertain, erratic and more frequent water scarcity events usually in summer months as well as in years with deficient monsoon rainfall and drought years. As a result, a significant fall in food production is often noticed.

In the arid and semi-arid regions of Karnataka, agriculture is the prime source of income for local inhabitants. Recent environmental externalities are a threat to agricultural sustainability. One of the major constraints for agricultural production is the availability of irrigation water during dry spells (Prasanna Kumar, 2019). Droughts may generate severe water shortages, even for drinking purposes, due to the decline of the groundwater table. Mitigation of climate change by improving agricultural water conservation and management practises is more important for reducing crop production vulnerability to climate variability (Gezie, 2019). This is an important attempt to reduce the vulnerability of smallholder farmers through enhancing and upscaling rainwater harvesting techniques so as to increase crop yields. The concept of rainwater harvesting, as used in this paper, refers to a basket of soil and water conservation techniques designed to enhance rainwater infiltration (Tolossa *et al.,* 2020). Rainwater use efficiency at the farm level can be increased by several management practices which include *in-situ* moisture conservation *viz.,* bunding, contour cultivation, mulching, ridges and furrows, the addition of crop residues to improve infiltration and reduce sediment levels, crop rotations, soil amendments and *ex-situ* conservation through farm ponds, check dams, percolation ponds, borewell recharge and other rainwater harvesting structures for the collection of excess rainfall flowing from the farm area. Hence, the present investigation was carried out to evaluate the rainwater harvesting technologies in the arid and semi-arid regions of Karnataka to mitigate climate change impacts.

Material and Methods

Rainfed agriculture's success hinges on the effective use of rainfall, with the primary goal being 'a better crop for every raindrop'. The participatory trials were undertaken on farmers' fields from 2011 to 2018 under the project 'National Innovations in Climate Resilient Agriculture' (NICRA), which is in operation in four districts of Karnataka state, namely Tumkur, Gadag, Belagavi, and Chikkaballapura. Table 1 shows the villages that were chosen for the study, as well as the soil types, normal rainfall and climatic vulnerabilities.

Climate constraints in the area, natural resource assessments, farming circumstances, crop production limits, climatic sensitivity, yield gaps, and potential for climate change adaptation were the steps followed in selecting villages in different districts. In chosen farmer's fields, action plans to show acceptable rainwater harvesting systems to minimize climatic vulnerability, especially drought, were implemented. Farmers in the demonstration villages were chosen based on their desire to participate in participatory research, the topography of the land unit, the crops grown, and rainwater gathering options. A list of farmers was determined in group meetings before the demonstrations, and the selected farmers were provided specialized skill training. Farmers' fields in the chosen village were used to demonstrate enhanced intervention (Table 2).

Rainwater Harvesting Structures

96 farmponds, 13 percolation ponds and 7 water storage structures were demonstrated in 116 farmer's fields at D. Nagenahalli village in Tumkur district and de-silting of 12 community ponds were demonstrated in Yadagud village, Belagavi district. A rainwater harvesting structure is a dugout with a specific shape and size, as well as an appropriate inlet and outlet structure for collecting surface runoff from the farm. A pond's size should be proportional to the catchment region that contributes surface runoff to the site. The volume of water in rainwater harvesting structure is calculated using the formula after the top width, bottom width, depth and side slope are known

$$V = \frac{(A + 4B + C)}{6} \times D$$

Table 1

Information of selected villages

NICRA village	Taluk and District	Annual rainfall	Soil type	Climate variability
D. Nagenahalli village	Korategere Taluk, Tumakur	584	Red sandy soil	Drought
Mahalingapur	Gadag	641	Red gravel	Drought
Yadagud	Hukkeri taluk, Belagavi	773	Black and red sandy soil	Drought
S. Raguttahalli village	Chintamani taluk, Chikkaballapura district	590	Red loamy soil	Drought

Where,

V = Volume of the farm pond (m^3)

A = Top width = 2 x D + Bottom width

B = Middle width = (Top + Bottom) / 2

C = Bottom width

D = Depth of water in rainwater harvesting structure

The stored water in the rainwater harvesting structure was lifted by a 1.5 HP pump and used for protective irrigation. The protective irrigation area was documented in ha. The income generated from utilization of harvested water was calculated by multiplying the output (produce) with the prevailed market price at the time of harvest.

In-situ Moisture Conservation through Trench Cum Bunds

In-situ moisture conservation in groundnut crop was demonstrated in 99 farmer's fields in S. Raguttahalli village, Chikkaballapura district, using trench cum bunds across the slope at 4.5 m horizontal intervals. Simultaneously, groundnut without trench cum bund was taken up as a control. The yield and economic statistics were documented using a standard procedure.

Borewell Recharging

In 10 farmer's fields in Raguttahalli village, Chintamani taluk, Chikkaballapura district, a borewell recharging demonstration was built up under the NICRA project to record the impact of recharging by delivering runoff water to a failing poor yielding borewell with filter bed. A sensor-based submersible pressure transmitter was used to measure the groundwater table level (ft). These hydrostatic level transmitters have a tiny diameter and are suspended from the well, borehole, deep bore well or monitoring well by their cable.

Results and Discussion

Rainwater Harvesting Structures

The study included the construction of 96 farm ponds and seven water harvesting structures (cement/ stone slab/ plastic/ gunny bags lined) with varied capacities. In 2017, farm ponds and water harvesting structure collected 77,700 m^3 and 6,410 m^3 of water, respectively, benefiting 128 farmers. A total of 46.4 ha were given protective irrigation using harvested water from these structures, resulting in an improvement in agricultural productivity. Rainwater harvesting technologies mitigated climate change vulnerability by allowing for the use of stored harvested rain water for protective irrigation at critical stages during drought period, which enhanced and stabilised crop yield and improved system productivity (Rajendra Dayananda Gowda and Dollis, 2021).

TABLE 2

Area and number of farmers under different intervention

NICRA village	Intervention	Area/Unit	No. of farmers
D. Nagenahalli	Farm pond	96	121
	Percolation pond	13	20
	Water harvesting structure	7	7
	Protective irrigation	46.4 ha	63
	Farm pond lining	6	6
Mahalingapur	Protective irrigation	25.2 ha	36
Yadagud	Desilting of community pond	12	133
	Protective irrigation	82.5 ha	133
S. Raguttahalli village	Borewell recharge	10	10
	Tench cum bund	69 ha	99

TABLE 3

Details of rainwater harvesting structures and potential capacity created at D. Nagenahalli village

Name of the Intervention	Units (No.)	Farmers (No.)	Volume of water harvested (m^3)	Protective irrigation potential created (ha)
Farm pond	96	121	77,700	36.8
Percolation pond	13	20	1,750	-
Water storage structure	07	07	6,410	9.6

Thirteen percolation ponds were dug in scientifically planned locations across the village to ensure filling. The rainwater storage capacity of these ponds was estimated to be 1750 m^3, which helped 20 farmers through borewell recharge (Table 3). High intensity rainfalls are common in the semi-arid and arid regions of India (Garg 1987; Athawale 2003).

We may not be able to find alternative source of water, thus the water lost through seepage from ponds is priceless. Due to excessive seepage in dugout farm ponds on red soils, rainwater held in the ponds will be lost after a few months of rain. Unlined ponds are ineffective in storing water for long periods of time. As a result, pond liner is required to keep collected water in the pond for longer periods of time. Farm ponds with plastic lining materials under red sandy soil and red clay had reduced seepage loss per day (10.2 mm / day and 9.4 mm / day, respectively), whereas those without lining had higher seepage loss (35.0 mm / day and 15.2 mm / day, respectively). Water loss was reduced by 70.85 per cent in red sandy soil and 38.85 per cent in red clay soil, respectively (Table 4). Water storage with lining enhanced water use efficiency, resulting in a 4.0 ha increase in irrigated area. Plastic films as a lining material have opened up a lot of possibilities since they provide an impermeable lining that prevents water loss due to seepage. (Singh *et al.,* 2006; Samuel and Satapathy, 2008 and Samuel *et al.,* 2013). Polyethylene lining is the cheapest among all the lining materials, which are conventionally being used (Kumar *et al,* 2007).

De-Silting of Community Pond

Siltation over the years lead to a reduction in storage capacity, drying of the water in these ponds before monsoons, aggravating the water crisis in the village. Table 4, indicated that in Yadagud village, Belagavi district, 12 community ponds were de-silted as a result, the water storage capacity has increased from 443.12 to 3112.87 m^3. This facilitated supplemental irrigation to crops in both *kharif* and *rabi* season. After de-silting of community pond the water storage capacity has increased by 2-3 times and protective irrigation potential has gone up to 125.7 ha. Totally 133 farmers benefitted by de-silting of community pond. Before desilting, there was only one crop per year and after this intervention there was an increased cropping intensity of the village. Water recycled from harvested rain water help in applying

TABLE 4

Performance of plastic film lined water storage structures

Intervention	Area irrigated (ha)	Red sandy soil		Red clay soil	
		Average water loss per day (mm)	Per cent reduction in water loss	Average water loss per day (mm)	Per cent reduction in water loss
Lining with plastic film	4.0	10.2	70.85	9.4	38.2
Without lining	1.8	35.0	-	15.2	-

TABLE 5
Impact of de-silted community pond at NICRA village

Village and District	Name of structures constructed / repaired	No. of farmer benefited	Water storage capacity (m^3)		Protective irrigation potential created (ha)	Increase in cropping intensity (%)	
			Before	After		*Kharif*	*Rabi*
Yadagud, Belagavi	Dongari Nala	7	379.62	1419.37	11.4	173.80	235.48
	Thaladappa Nala	5	73.85	443.12	7.6	187.50	214.29
	Janamatti	13	419.34	2096.70	16.2	179.16	226.32
	Walake Tota	9	486.00	1615.0	7.4	180.00	225.00
	Janamatti School Tota	5	171.72	629.72	4.4	175.00	233.33
	Aralimatti Nala	6	69.35	403.0	9.5	188.05	213.56
	Yamagarni Nala	8	315	994.14	12.5	167.03	249.18
	Badigertota Nala	10	402.20	1239.39	14.	168.03	246.99
	Magennitota Nala	8	276.07	1131	13.2	156	278.85
	Old Janamatti Nala	48	782.55	3112.87	17.4	159.7	267.42
	Patil Tota-I	5	232	728 .0	5.4	178.06	213.06
	Patil Tota-II	9	278	852 .0	6.7	169.03	236.9

supplementary irrigation during dry spells as well as pre-sowing irrigations in *rabi* season that helps in augmenting productivity (Samuel, 2010). Due to irrigation facilities, the farmer's harvests two to three crops in a year leading to increased opportunities (Murthy and Nagabhushanam, 2017).

Protective Irrigation

During dry spells, the water collected in the rainwater harvesting structure was utilised for protective irrigation. The performance of groundnut, maize, greengram and pigeonpea influenced by protective irrigation is indicated in Table 6. Groundnut grown with protective irrigation using harvested rain water recorded higher pod yield, gross return, net return and B:C ratio (15.1q/ ha, Rs.60400/ ha, Rs.36240/ha, 2.5, respectively) compared to farmer practice without protective irrigation. Maize, greengram and pigeonpea all showed similar effects. The findings are comparable to Venu *et al*. (2015). There is a chance of rain failure in *kharif*, according to Rajendra Dayananda Gowda and Dolli (2021); at this situation, farmers harvested rain water for

TABLE 6
Yield and economics of different crops as influenced by protective irrigation

Crop	Pod/ grain yield (q/ha)		% increase in yield	Gross return (Rs./ha)		Net return (Rs./ha)		B:C ratio	
	Improved practice	Farmer's practice		Improved practice	Farmer's practice	Improved practice	Farmer's practice	Improved practice	Farmer's practice
Groundnut	15.1	9.95	51.7	60400	39800	36240	17258	2.5	1.8
Maize	24.19	17.60	37.44	29025	22969	8529	4597	1.41	1.25
Greengram	8.30	4.6	80.43	53950	29900	34470	11540	2.76	1.62
Pigeonpea	14.50	10.40	39.42	65250	46800	54000	35750	5.80	4.20

Improved practice: Protective irrigation, farmer's practice: without protective irrigation

TABLE 7

Yields of groundnut due to construction of trench cum bunds

Treatment	Pod/ grain yield (q/ha)	% increase in yield	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
Groundnut with trench cum bund	12.3	20.59	55,350	34,100	2.60
Groundnut without trench cum bund	10.2		45,900	24,650	2.16

protective irrigation, reducing drought vulnerability and achieving long-term productivity and economic gains. Santosh Nagappa Ningoji *et al.* (2021) reported that higher grain / pod yield was recorded with providing protective irrigation during dry spell in French bean.

In-Situ Moisture Conservation

The trench cum bunding technology adopted in the project performed a dual purpose; it prevented soil erosion while also acting as water conservation pits, conserving soil moisture for longer duration. Groundnut with trench cum bund showed greater pod yield, gross return, net return and B:C ratio (12.3q/ ha, Rs.55350/ ha, Rs.34100/ ha and 2.60, respectively) than groundnut without trench cum bund (10.2 q/ ha, Rs. 45,900/ ha, Rs.24,650/ ha and 2.16, respectively) (Table 7). Trench cum bund structure has conserved the soil and water *in-situ* and enhanced the ground water table which in-turn helped the crops during long dry spells, thus enabled farmers to increase their income and also arrested soil erosion and served as water reservoir pits that keeps soil moisture intact for longer duration and facilitates availability of soil moisture to the crop (Steiner and Rockstrom, 2003; Itabari, 1999).

Borewell Recharge

Recharge of borewells were undertaken by farmers by diverting runoff water into less yielding bore wells. The water flowing in the channel was made to pass through a filter media before entering into recharge structure to avoid accumulation of silt. Study of borewells at the beginning of the project indicated water table at 700-800 ft in S. Raguttahalli village, Chintamani taluk, Chikkaballapur district. Re-charging interventions combined with water conservation activities in the village rejuvenated the borewells. The Table 8 indicated that during 2014-15 and 2015-16, depth of the ground water

TABLE 8

Raise of water level in bore wells due to various NRM activities at S. Raguttahalli

Village and District	Farmers Name	Bore well Depth (ft)	Water level (ft)		
			2014-15	2015-16	2016-17
S. Raguttahalli village, Chintamani taluk, Chikkaballapur district	Munireddy R.V.	300	180	268	39
	Venkatareddy R.E.	180	160	170	42
	Lakshmi Narayanappa	650	350	420	68
	Sriramareddy R.V.	780	600	712	65
	G. R. Nagaraju	700	556	610	312
	Keshavareddy R.K.	300	110	150	27
	Srinath	900	620	750	118
	Munivenkatareddy R.V.	500	280	400	56
	Sharadamma	900	680	754	153
	Venkataravanappa	930	567	700	418

table level improved from 110 ft to 680 ft. and 150 ft. to 754 ft., respectively but due to deficit rainfall during 2016-17, depth of the water table improved only from 27 ft. to 418 ft. There is an abundant scope and opportunity for harvesting excess runoff in the rainfed region in different states of the country and to rejuvenate the defunct/ low yielding borewells (Wani *et al.,* 2003), when treated with runoff filtration beds to enhance the groundwater level and improve the water yield. Similar results of improved borewell yield with artificial recharge pit were reported by Shivakumar (2006). Reddy and Khybri (2008) conducted similar type of study and observed that the groundwater level in the open wells and borewells started rising from June till the end of September and later declined during first week of October. The increased discharge rate with artificial recharge was ascribed to improved ground water resources as the diverted water is least subjected for evaporation losses. Good amount of water encouraged sustainable intensification of cropping to improve income and livelihood of farmers.

Rainwater harvesting structure has the potential to mitigate the climate change vulnerability of rainfed agriculture to achieve sustainability in terms of production and economic gains. Plastic lining of farmpond can minimize the seepage, percolation and increased water use efficiency thereby extending protective irrigation area with the stored water. Harvested water will help in providing supplementary irrigations during dry spells as well as pre-sowing irrigations in *rabi* season that helps in augmenting productivity. The runoff water diverted from the catchment area to recharge pits of the defunct / low yielding borewells resulted in improved water table level in the vicinity and trench cum bunding helped in soil and moisture conservation leading to higher productivity of crops cultivated.

REFERENCES

ATHAWALE, R. N., 2003, Water harvesting and sustainable supply in India, *Environment and Development Series,* Centre for Environment Education, Rawat Publications, Jaipur and New Delhi.

CHERUKUMALLI SRINIVASA RAO, RATTAN LALX, JASTI V. N. S. PRASAD, KODIGAL A. GOPINATH, RAJBIR SINGH, VIJAY S. JAKKULA, KANWAR L. SAHRAWATJJ, BANDI VENKATESWARLU, ALOK K. SIKKA AND SURINDER M. VIRMANI, 2015, Potential and challenges of rainfed farming in India. *Available, Advances in Agronomy,* **133** : 115 - 181

GEZIE, M., 2019, Farmer's response to climate change and variability in Ethiopia : A review. *Cogent Food & Agriculture,* **5** (1).

GARG, S. K., 1987, Hydrology and water resources engineering, *Khanna publishers*, Delhi, pp.: 110 - 181.

ITABARI, J. K., 1999, Optimizing soil water use in the semi-arid areas of Kenya, efficient soil water use: the key to sustainable crop production in dry areas. *Proceedings of the workshops organized by the Optimizing Soil Water Use Consortium,* 26-30 April, Niamey, Niger, pp. : 85 - 104.

KUMAR, M., KUMAR, A., SINGH, S. R. K., KUMAR, N., SRIVASTAVA, A. K., 2007, Application of plastics in agriculture of NW Himalaya : Water harvesting and utilization, *Technical Bulletin,* **28** (3/2007), VPKAS, Almora, Uttarakhand.

MURTHY, M. A. AND NAGABHUSHANAM, K., 2017, A scale to measure climate resilience management level among farmers and its application. *Mysore J. Agric. Sci.,* **51** (2) : 331 - 338.

OWEIS, T. AND TAIMEH, A., 1996, Evaluation of a small basin waterharvesting system in the arid region of Jordan. *Water Resources Management,* **10** : 21 - 34.

PRASANNA KUMAR, K. R., 2019, A study on the impact of climate change on agriculture and agro based industries in Karnataka, *International Journal of Innovative Research in Technology,* **3** (6) : 2349 - 6002

RAGHAVAN, K., JAYANARAYANAN, S., GNANASEELAN, C., MUJUMDAR, M., KULKARNI, A. AND CHAKRABORTY, S. (Eds.), 2020, Assessment of climate change over the Indian region. *A Report of the Ministry of Earth Sciences* (MoES) (1st ed), Government of India, Springer Singapore, Springer Nature.

RAJENDRA DAYANANDA GOWDA AND DOLLIS, S., 2021, Utilization of farm pond and its impact on productivity under Krishi BhagyaYojane. *Int. J. Curr. Microbiol. App. Sci.*, **10** (1) : 426 - 433.

REDDY AND KHYBRI, M. L., 2008, Estimation of ground water recharge in semi-arid watershed. *Indian Journal of Dryland Agricultural Research and Development*, **6** (2) : 37 - 45.

SAMUEL, M. P. AND SATAPATHY, K. K., 2008, Concerted rainwater harvesting technologies suitable for hilly agro-ecosystems of Northeast India. *Current Science,* **95** (9) : 1130 - 1132.

SANTOSH NAGAPPA NINGOJI, THIMMEGOWDA, M. N., MUDALAGIRIYAPPA, SHIVARAMU, H. S., VASANTHI, B. G. AND MAHABALESHWAR HEGDE, 2021, Comparative performance of dryland cropping systems under reduced runoff farming in alfisols of Karnataka. *Mysore J. Agric. Sci.,* **55** (3) : 199 - 208 .

SINGH, R. K., NGACHAN, S. V. AND CHOWDHURY, P., 2013, Enhancing productivity of micro watershed based farming systems through lined water harvesting tanks in north eastern hills. *Indian Journal of Soil Conservation*, **41** (1) : 36 - 40.

SHIVAKUMAR, B. L., 2006, Conservation of ground water through artificial recharge using roof top rainwater in RV College of engineering campus, Bangalore (a case study). *National Seminar on Rainwater Harvesting and Water Management,* 11-12 Nov., 2006, Nagpur.

SINGH, R. K., LAMA, T. D., SAIKIA, U. S. AND SATAPATHY, K. K., 2006, Economics of rainwater harvesting and recycling for winter vegetable production in mid hills of Meghalaya. *Journal of Agricultural Engineers,* **43** (2) : 33 - 36.

STEINER, K. G. AND ROCKSTROM, J., 2003, Increasing rain-water productivity with conservation tillage', *African Conservation Tillage Network Information*, Series No. 5.

TOLOSSA, T. T., ABEBE, F. B. AND GIRMA, A. A., 2020, Review : Rainwater harvesting technology practices and implication of climate change characteristics in Eastern Ethiopia. *Cogent Food & Agriculture*, **6** (1) : 1724354.

VENU, B. N., RAVI SIMHA, L. AND VENKATARAMANA, R. V., 2015, Economic analysis of farm ponds in Tungabhadra project command area of Karnataka, India. *International Journal of Agricultural Science and Research*, **5** (3) : 193 - 198.

WANI, S. P, PATHAK, P, SREEDEVI, T. K., SINGH, H. P. AND SINGH, P., 2003, Efficient management of rainwater for increased productivity and groundwater recharge in Asia. Book chapter in Water Productivity in Agriculture : Limits and Opportunities for Improvement edited by Kijne, *et al.,* 2003. CABI publishing, Cambridge, USA.

(*Received :* December 2021 *Accepted :* February 2022)