Research Article

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Efficacy of water conservation measures in coconut plantations to enhance ground water resource and coconut yield in West Coast region

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Abstract

Efficacy of water conservation measures in coconut plantations to augment ground water resource and coconut yield in the West Coast region was studied by implementing two conservation measures, half moon bund and trench, in coconut gardens. Impact of these conservation measures was studied by monitoring the amount of water conserved by these structures and the improvement in the coconut yield due to these interventions. An attempt was also made to study the contribution of the conserved water in increasing the local ground water resource by monitoring the yield of '*Surangams*', an indigenous water harnessing structure, that draws water from unconfined aquifer in the hillock where the water conservation measures were undertaken. The conservation measures were taken up in a total area of 17,200 m^2 in the coconut gardens of nine farmers and two control plots also was selected having a total area of 4900 m^2 each having one S*urangam* in their respective catchment area. The study revealed that a positive correlation exists between the rainfall and water conserved. However, the amount varied from plot to plot. This variation is mainly due to the non uniformity of the catchment areas, mainly the size of catchment and nature of water conservation structure. Average amount of rain/runoff water collected in plots where a combination of half-moon bund and trench were taken up in the coconut gardens was 51 m^3 per year. This was only 30 m^3 and 27 m^3 when half-moon bund and trench alone was taken up. There was only a meagre improvement in the annual *Surangam* yield due to the conserved water. However, the improvement was more noticeable (13%) during the non-rainy season, December to May. The plots where two conservation structures, half-moon bund and trench together, were taken up showed 58 per cent increase in the yield of coconut. Coconut yield increased by 37 and 29 per cent where only one conservation structure was taken up, *i.e.,* half-moon bund and trench, respectively. During the same period, average coconut yield in the control plots was decreased marginally from 61 to 56 nuts per palm per year. This shows the possibility of conserving water and enhancing the productivity of coconut in rain fed area by adopting water conservation measures in the hilly region of West Coast. The fact that majority of the coconut cultivation in this region is still under rain fed condition adds to the significance of the result.

Keywords: Coconut, groundwater, nut yield, *'Surangam'*, water conservation

Introduction

Majority of the Western Ghat range steep and rugged mass of hills with elevation varying from 100 to 2700 m and receives an average annual rainfall of 3700 mm. However, even after receiving high precipitation, more than three times of the national average, many parts experience severe scarcity of water during summer months. This happens mainly because a major portion of the rainfall is received during a short period of four months, June to September. Most of the rainwater is lost as surface runoff due to undulating topography. These factors coupled with low water holding capacity of the lateritic soil prevailing in this region results in moisture stress after the withdrawal of monsoon.

'*Surangam*' is a unique indigenous method of harnessing groundwater adopted by farmers of

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Kasaragod district in Kerala state and Dakshina Kannada district in Karnataka state. It is constructed by digging a nearly horizontal tunnel in to a hillock to intercept the sloping unconfined aquifer (Basak *et al.,* 2005). Rural people of this region have been using such a unique water harnessing technique for more than two centuries.

In recent years, problems caused by water shortage have occurred in the region. This is a result of the rate of population growth and rapid economic development. Water resources have become the constraints and bottlenecks of the socio-economic and ecological environment. The diminishing groundwater resource has reduced the yield of S*urangams*. In many cases, these water tunnels turned from perennial flow into intermittent, and some even got dried up permanently. A large number of farmers in the region cultivate plantation crops like coconut, rubber, cashew *etc.* Conservation agriculture can offer immediate advantages to these farmers by increasing rainwater harvesting and serving as a mitigation strategy against climate change and late or variable rainfall (Pittelkow *et al.,* 2014; Rockstrom *et al.*, 2009; Theirfelder and Wall, 2010). This study was taken up to augment the groundwater resource and to enhance the yield of *Surangams* by adopting suitable site specific water conservation measures. Since *Surangams* extract water from the unconfined aquifer, yield of it would be a direct measure of the impact of water conservation measures in the catchment area.

The coconut palm flowers throughout the year, irrespective of seasons. Hence soil moisture availability, as well as other growth conditions, should be congenial throughout the year for high productivity in coconut. Most of the coconut growing soils in the west coast, being low in water holding capacity, aggravate the deleterious effects of dry spell. The drought affects the initiation and growth of fronds and inflorescences, affects female flower development and results in abortion of spadices, button shedding, drooping of leaves and bunches, poor endosperm developmentand reduction in size of nuts (Coomans, 1975). Initiation and differentiation of vegetative and reproductive primordial are very sensitive to moisture stress. Drooping of leaves, breaking of petioles, shedding of buttons and immature nut fall are the common symptoms of drought injury (Rethinam, 1991). In this context, this study was contemplated to find out the efficacy of water conservation measures in coconut plantations to enhance groundwater resource in India's West Coast region. The study also intended to understand the impact of the water conservation measures on crop productivity and coconut yield.

Materials and methods

The study area was the hilly tracts of West Coast in Kasaragod district of Kerala state. In order to study the efficacy of water conservation measures to augment the groundwater resources and to enhance the coconut yield, the proposed water conservation measures were taken up in the catchment, coconut farm, of nine *Surangams* (Fig.1). Two other coconut plots having a *Surangam* each in their catchment were taken as control where no water conservation measure was taken up.

Water conservation measures

1. Half-moon bund around coconut basin reinforced with pineapple

A flat basin with a slight inward slope towards upstream was made around the coconut palm by excavating soil from the upstream side and filling the excavated soil at the downstream side. After making the basin, a bund of 30 cm height and about 50 cm width was made at the downstream side of the coconut using the excavated soil. Two layers of pineapple plants (*Ananas comosus*) were planted with a spacing of 20 cm row to row and 20 cm plant to plant on the bund. The bund prevented runoff and water collected within the basin get percolated down. Pineapple roots would reinforce the bund and stabilize it in addition to giving an additional income from fruit yield. The coconut basin was mulched with coconut leaves and other agricultural waste.

2. Trench filled with coconut husk

Trenches of 50 cm width x 50 cm depth and suitable length (equal to the distance between two coconut basins) were made in between two rows of coconut palms. These trenches were then filled with coconut husk. Coconut husks were filled in layers

with the bottom layers facing up and top two layers facing down. A bund of 30 cm height and suitable width (>50 cm) was made at the downstream using the excavated soil and reinforced with pineapple as in the previous case. The runoff water from the upper side would be collected in the trenches. Soil particles would also get collected in the trench along with the runoff water. Coconut husk retains the moisture and makes it available for plants during summer months.

The two water conservation structures were taken up in the selected plots individually and in combination. Following are the treatments taken up for the present study.

T_1 - Half-moon bund around coconut basin reinforced with pineapple + trench filled with coconut husk

T_2 - Half-moon bund around coconut basin reinforced with pineapple

T_3 - Trench filled with coconut husk

Details of the selected coconut gardens, treated and control, is given in Table 1.

Contour surveying has been conducted in all the plots prior to the study. Slope of the selected gardens varied from 25 to 57 per cent. The conservation measures were taken up in a total area of 17,200 m^2 in the coconut gardens of nine farmers and two control plots also was selected having a total area of 4900 m^2 each having one *Surangam* in their respective catchment area. Water conservation measures were implemented in the catchment area of the nine *Surangams* during January to May 2012. The two water conservation measures, half moon bund and trench, were taken up manually using contractual labour with the active participation of the individual farmers. The required amount of pineapple, 'Mauritius' variety was procured and supplied to the farmer. Coconut husk was supplied by the farmers themselves.

Two water conservation structures from each category *i.e.*, two each from each treatment, T_1, $T_2$and T_3, were lined with polythene sheet to collect the rain and runoff waterto study the amount of water that could be stored in each conservation structure (Fig. 2 & 3). The farmers were trained to monitor and measure the water collected in the water conservation structures and also to drain the structure as and when it gets filled up by siphon method. They were given field notebooks to note down the water collected in the two lined water conservation structures daily and the *Surangam* discharge weekly. This study was replicated in the farm of ICAR-CPCRI, Kasaragod also as a check. Rainfall measurements were also taken in each site by keeping an open vessel at the courtyard. However, this was not used for the study. Instead the meteorological data obtained from the ICAR-CPCRI meteorological observatory was used.

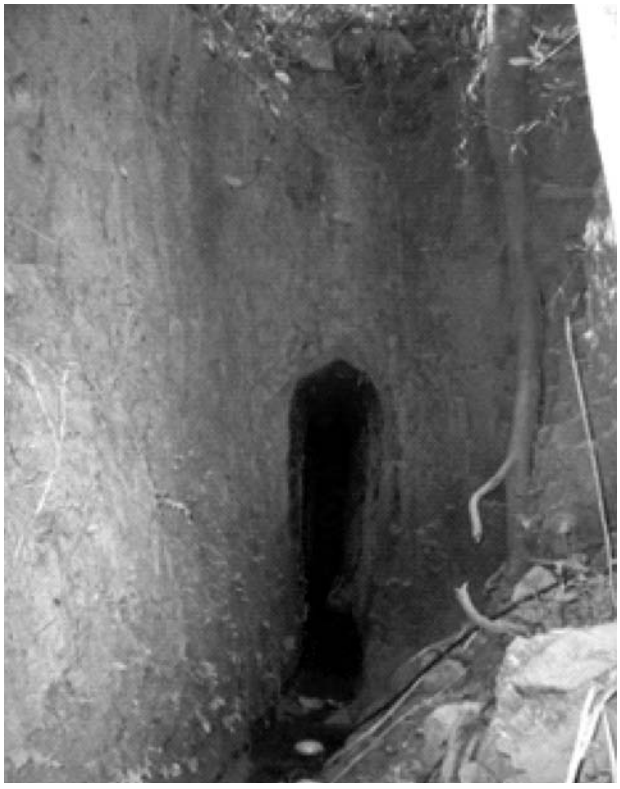

Fig. 1. ***Surangam***

Effect of water conservation measures to augmenting the ground water resource was studied by monitoring the discharge of *Surangam*. The discharge was measured by collecting the water in a container for a given period of time and measuring the same. Measurement of *Surangams* having very high discharge, especially during rainy season, was done by float method. A straight channel of given

Fig. 2. Water conserved in farmers' field

Fig. 3. Water conserved at ICAR-CPCRI campus

uniform cross section was made and the *Surangam* water was directed to flow through it. Velocity of water flow was measured by noting the time required for a float to travel a unit length from the upstream to downstream of the channel. The officers of the institute visited each site once in 15 days and monitored the measurements.

Effect of water conservation measures on the yield of coconut and *Surangam* was studied for four consecutive years after implementing the water conservation measures. This was then compared with the pre-treatment yield of coconut and *Surangam* of the same plot, two year average yield prior to the implementation of the water conservation measures. Effect of these conservation measures was studied again by comparing with the change in yield of coconut and *Surangams* in the two control plots where no conservation measure was taken up.

Results and discussion

Soil characteristics

Bulk density

Bulk density of the soil in the study area was calculated using standard procedure and found that itvariedfrom 1.6 g cm^{-3} to 1.72 g cm^{-3}.

Hydraulic conductivity

Saturated hydraulic conductivity has been measured with constant water head method using undisturbed soil sample. The hydraulic conductivity of the soil varied from 0.00915 to 0.0115 cm s^{-1} at different locations.

Table 1. Details of coconut gardens selected for the study

Plot no.	Treatment	Area of garden (m^2)	Slope (%)	No. of coconuts	Coconut yield before intervention, no. $tree^{-1}$ $year^{-1}$ (Two year average)	Number of water conservation structures	
						Half-moon bund	trench
Plot 1	T_1	1600	34	38	64	38	24
Plot 2	T_1	1400	36	32	52	32	18
Plot 3	T_1	1200	34	28	59	28	16
Plot 4	T_2	1600	47	38	57	38	
Plot 5	T_2	2400	45	56	62	56	
Plot 6	T_2	2800	29	58	59	58	
Plot 7	T_3	1800	25	42	57		28
Plot 8	T_3	1400	34	34	52		26
Plot 11	T_3	3000	57	64	55		48
Plot 9	Control	1700	39	42	63		
Plot 10	Control	3200	36	72	58		

Infiltration studies

Infiltration studies were conducted at the experimental plots using standard double ring infiltrometer. The average basic infiltration rate varied from 14.65 cm hr^{-1} to 15.85 cm hr^{-1}.

Percolation studies

Percolation studies were conducted to determine the seepage/percolation characteristics of the soil at the experiment site. Percolation pits of 50 cm depth was made and filled with water and the rate of water depletion was noted till it get stabilized. The average basic percolation rate obtained at the experiment sites varied from 11.8 cm hr^{-1} to 14.2 cm hr^{-1}. Infiltration and percolation studies showed that the soil in all the ten sites was highly porous and were very much suitable for in-situ water conservation.

Water conserved by water conservation structures

Average amount of rain/runoff water collected in each of the water conservation structures in one year (four year average) is given in Fig. 4. In treatment T_1, where a combination of half-moon bund and trench were taken up in the coconut gardens average water collected was 51 m^3 per year. For T_2, where only half-moon bund was taken up around coconut basin the water collected was 30 m^3 per year. This was only 27 m^3 per year in the case of T_3, where the trench filled was with coconut husk. This was then extrapolated to the entire project area to get the impact of these interventions.

It was observed that the amount of water conserved by each structure varied very much in different plots and treated coconut gardens (Table 2).

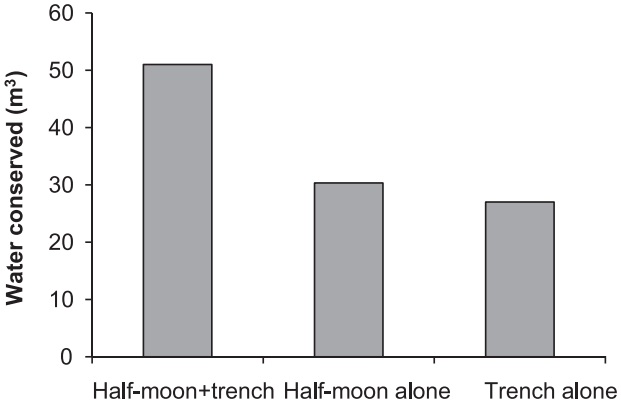

Fig. 4. Water conserved in each treatment

Table 2. Water directly collected in the water conservation structures

Structure	Water conserved (m^3)		
	Low	High	Average
Half moon	23	36	29
Trench	22	32	25

The large variation observed in the amount of conserved water was mainly because of the variation in the size of the coconut basin and the catchment area of each structureand the slope of the land. Though recommended spacing of coconut was 7.5 m x 7.5 m, farmers seldom practiced it. In majority of the cases, the spacing was much less than the recommended spacing and in few cases this was higher. Due to this variation in coconut spacing, catchment area contributing water to the conservation structure and the size of these water conservation structures, especially trench, got changed. This was the major reason for the large variation in the volume of water collected in the structures.

Effect of rainfall on water conserved

Effect of rainfall on water conserved was studied by plotting total monthly rainfall (average monthly rainfall received in four years) against the amount of water conserved in the water conservation structures in the corresponding months in the nine treated plots (Fig. 5).

Results of the study revealed that a positive correlation exists between the rainfall and water conserved. However, the amount varied from plot

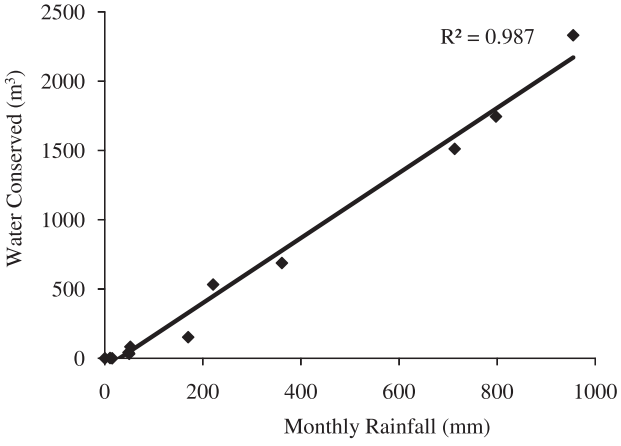

Fig. 5. Effect of rainfall on water conserved

to plot. This variation is mainly due to the non-uniformity of the catchment areas (treated coconut gardens), mainly the size of catchment and water conservation structures.

Effect of catchment area on water conserved

Only a portion of the total *Surangam* catchment, which comes under coconut cultivation, was treated with water conservation measures and subsequently taken up for the study. The study revealed that the amount of water conserved increased with the increase in the treated catchment area (Fig. 6). It may be noticed that the number of water conservation measures was directly proportional to the area of the catchment under treatment and hence the amount of water conserved (Fig. 7).

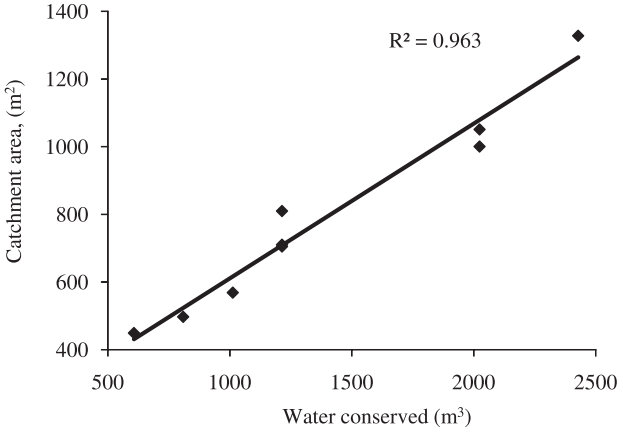

Fig. 6. Effect of treated catchment area on water conserved

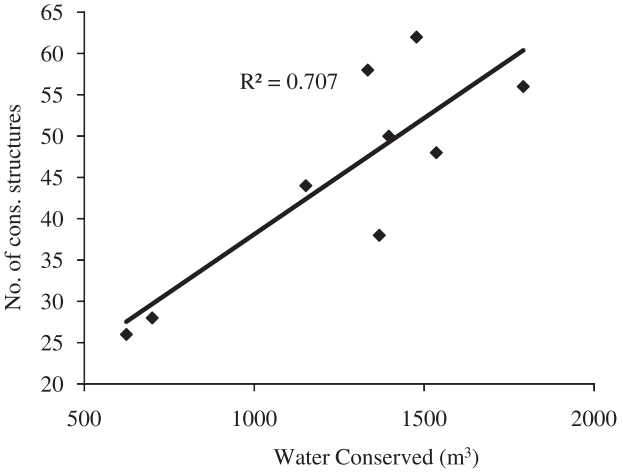

Fig. 7. Effect of number of conservation structures on water conserved

Effect of land slope on water conserved

Though there are several factors affecting the runoff from a catchment, it was expected that the topographical factors, that include the degree and length of land slope, would be having a major effect on the runoff. Effect of land slope on water conserved in half-moon bund is shown in Fig. 8 and that of trench is given in Fig. 9. In both the cases the land slope affected the runoff and enhanced the water conserved in each structure.

Impact of water conservation measures in enhancing *Surangam* yield

Effect of water conservation measures on the yield of *Surangam* was studied for four consecutive years after implementing the water conservation

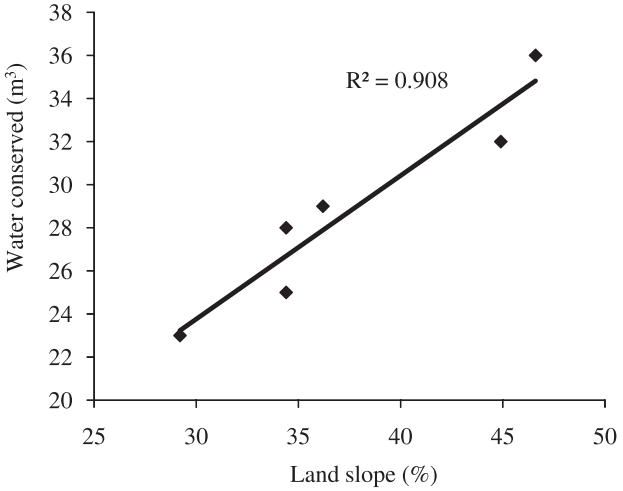

Fig. 8. Effect of land slope on water conserved in half-moon terrace

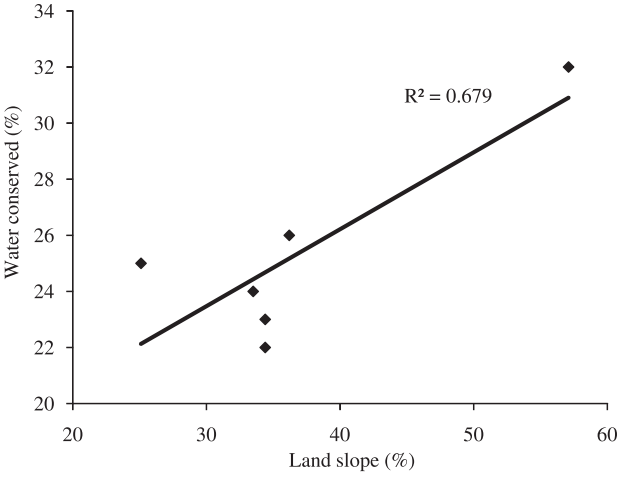

Fig. 9. Effect of land slope on water conserved in trench

measures. This was then compared with the corresponding pre treatment yield, two year average prior to the implementation of the water conservation measures and the yield of control *Surangams* during the same period.

Water conservation measures were taken up in the catchments of the selected *Surangams* during April-May 2012. Impact of water conservation measures in enhancing *Surangam* yield, monthly average yield of treated *Surangams* before and after treatment and the condition of the two control *Surangams* during the same period, is given in Fig. 10. Monthly rainfall during the same period also is given in each graph for better understanding.

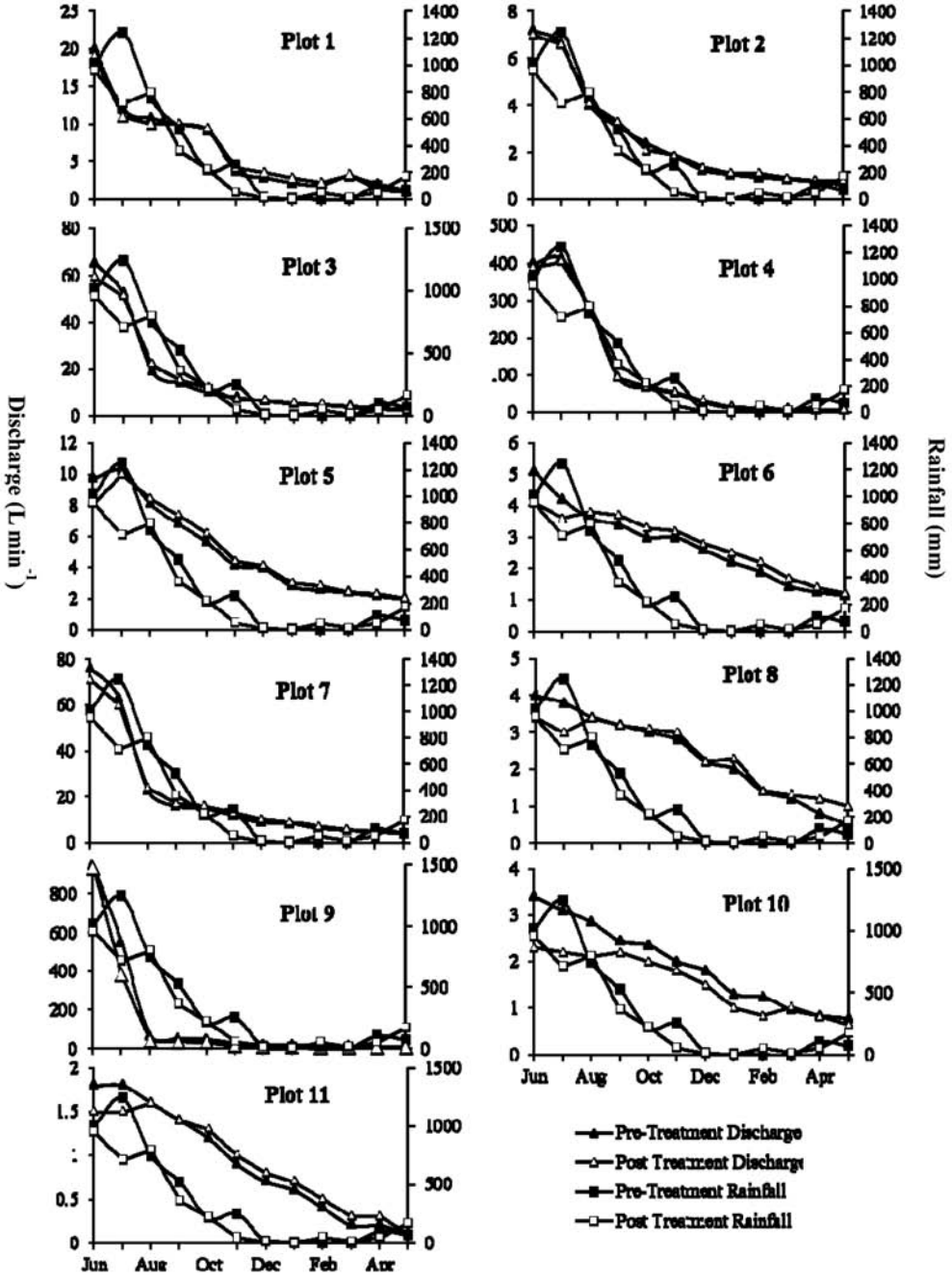

Fig. 10. Impact of water conservation measures in enhancing *Surangam* yield

Table 3. Effect of conserved water on *Surangam* yield

Treatment	Plot	Water conserved (m^3)	% increase *Surangam*		Additional water made available (m^3) discharge		% contribution of conserved water	
			Year	Six months	Year	Six months	Year	Six months
T_1	Plot 01	1478	0.65	20.7	268	11	18	0.74
	Plot 02	1396	1.44	10.6	231	10	17	0.72
	Plot 03	1152	0.04	6.9	42	2	4	0.17
T_2	Plot 04	1368	0.01	12.3	105	4	8	0.29
	Plot 05	1792	1.03	5.2	326	13	18	0.73
	Plot 06	1334	2.07	12.2	357	15	27	1.12
T_3	Plot 07	700	0.25	10.8	53	2	8	0.29
	Plot 08	624	0.04	10.8	105	4	17	0.64
	Plot 11	1536	0.90	22.7	53	2	3	0.13

Amount of water conserved in each plot and its contribution towards *Surangam* yield is given in Table 3. The study revealed that there was only a meagre improvement in the *Surangam* yield because of the water conservation measures. Major reason of this was only a small portion of the catchment area of each *Surangam* was treated with water conservation measures. *Surangam* harness water from the unconfined aquifer that gets replenished by rainwater from a much larger area than the treated area. The water table cannot come up beyond certain limit in the near vicinity of the treated plots due the gravitational force. Moreover, though all the water conserved in the water conservation structures did percolates down, a sizable portion of the percolated water could have been lost as sub surface flow. Another reason is that there was a reduction of 18.5 per cent in the annual rainfall during the post-treatment period compare to the pre-treatment period. There was a reduction of 19 per cent in the annual yield of control *Surangams* due to this reduction in rainfall.

Percentage increase in yield after treatment varied between *Surangams*. This variation in increase in yield between *Surangams* is mainly because of difference in catchment area contributing water to the respective *Surangam* and the characteristics of these catchments.

Water obtained during the non rainy season, December to May, would be of utmost importance to farmers. There was an increase of 13 per cent in the *Surangam* yield due to the conservation measures compared to the pre-treatment yield. Average yield in control got reduced by 37 per cent during the same period mainly due to the 18 per cent reduction in the annual rainfall.

This shows there exists a scope of augmenting the groundwater resource and thereby enhancing the *Surangam* yield by taking up water conservation measures in their catchment areas. The study also shows that the water conservation measures should be carried out in watershed basis to get a sizable improvement in the ground water resources. The fact that in general the groundwater resources in many parts of the west coast is diminishing fast adds to the significance of the study.

Effect of water conservation measures on coconut yield

Effect of water conservation measures on coconut yield was studied by comparing the average coconut yield for two years prior to the intervention and the post-treatment yield (four year average) of the nine treated plots and the two control plots (Fig. 11). Average yield inplots where two

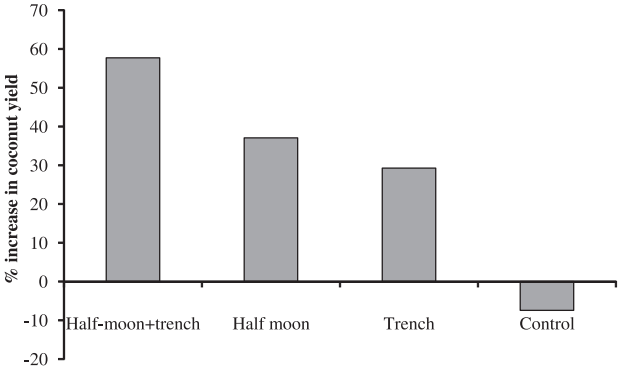

Fig. 11. Effect of water conservation measures on coconut production

conservation structures, half-moon bund and trench together, were taken up yield for two consecutive years prior to the intervention was 58 nuts palm^{-1} year^{-1}. Coconut yield after implementing the water conservation measures (post-treatment) was observed to be 92 nuts palm^{-1} year^{-1} with an increase in the yield by 58 per cent. Coconut yield increased by 37 and 29 per cent where only one conservation structure was taken up, *i.e.,* half moon bund and trench, respectively.

During the same period average coconut yield in the control plots was decreased marginally from 61 to 56 nuts palm^{-1} year^{-1}, *i.e.,* a marginal decrease of seven per cent mainly due to the reduction in rainfall. This shows the possibility of enhancing the productivity of coconut in rain fed area by adopting water conservation measures and confirms the findings of Thamban *et al.* (2014). The fact that majority of the coconut cultivation are still under rainfed condition adds to the significance of the result.

Conclusion

The study revealed that there exists a scope to augment the groundwater resources by taking up water conservation measures in the coconut gardens in the upstream catchments. The study on the effect of water conservation measures on coconut yield suggested the possibility of enhancing the productivity of coconut in rainfed coconut gardens in the hilly region of west coast area by adopting water conservation measures.

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