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Influence of land management practices on rainwater productivity of major crops in the Nilgiris

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ABSTRACT

A field experiment was conducted during 2003–06 at the Research Centre, Udhagamandalam, Tamil Nadu to compare the influence of different land management practices, like inward sloping bench terraces, outward sloping bench terraces and sloping lands with vegetative barriers on rainwater productivity (RWP) of major crops (potato, cabbages, carrot and beans) in the Nilgiris. The treatments included 2% inward sloping bench terraces, 5 and 10% outward sloping bench terraces with planting of medicinal plants on the terrace riser, farmers' practice and 25% sloping land with strips of geranium as vegetative barrier across the slope. The crop rotation of potato (*Solanum tuberosum* L.) cabbage (*Brassica oleracea* L. var. *capitata* L.) in the first year and carrot–beans in the second year was followed for 2 rotations. Runoff from the treatments did not vary significantly. The soil moisture in the root zone of 30 cm was found to be consistently higher in the sloping land with vegetative barrier resulting in significantly higher yield of crops. The average rainwater-use efficiency of potato, cabbage, carrot (*Daucas carota* L.) and beans was found to be 48.9, 60.4, 21.5 and 9.5 kg/ha-mm, respectively, with maximum in the sloping land (25%) with vegetative barrier. The maximum rainwater productivity (6.3 kg/cu.m) of potato obtained from the sloping land (25%) with vegetative barrier, followed by 10% outward slope with geranium on the riser (4.8 kg/m^3) and 10% outward slope with cineraria on riser (4.7 kg/m^3) under normal rainfall condition.

Key words: Inward sloping bench terraces, Land management, Medicinal plants, Outward sloping bench terraces, Rainwater productivity, Vegetative barrier

Rainwater is the most important natural source of water for agricultural production. India is the monsoon-dependant country for its agriculture and rainfed crops is under high risk due to rainfall variability in quantity and distribution. Therefore, utilization of rainwater for maximizing water-use efficiency through suitable land management practices is very much essential. The challenge to produce more food under increasing water scarcity has lead to the notion that crop water productivity needs to increase (Kijne *et al.* 2002, 2003). Many attempts have been made for increasing the water-use efficiency from the available water. Number of innovations have been made for small-scale farmers to manage water effectively during the dry season, and increase on-farm water efficiency using simple, affordable microirrigation systems (Polak and Yoder 2006).

These efficiency measures need to be studied in both rainfed as well as irrigated agriculture. Increasing water-use efficiency of field crops was possible through proper irrigation and water management practices (Norwood and Dumler 2002, Kar *et al*. 2006). Various studies have been made on water-use and yield relationship of specific crops on specific locations, with specific cultural and water management practices and showed crop water productivity for staple crops, such as wheat, barley and rice (Kijne *et al.* 2002, Ahmad *et al.* 2004) whereas very few information is available for vegetables. Increased water-use efficiency by maximum utilization of rainwater through different land management practices is necessary for growing vegetable crops under rainfed conditions.

In the Nilgiris, majority of the area is cultivated under bench terrace and inward sloping (1–2%) terraces are normally recommended for better soil and moisture retention. However, most of the farmers maintain outward sloping terraces to provide better drainage conditions for the major vegetable crops cultivated in the region. Even, many of the

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farmers converted the terraces to sloping land when the crop diversification scheme was introduced by the Horticulture Department during eighties. The main reasons for the lack of willingness to construct or maintain the bench terraces by the farmers are small land holdings, high cost of terrace construction mechanically and reduction in area available for cultivation by terracing, thereby reducing the returns unless the area lost due to riser not utilized. Cost-effective technologies for the efficient utilization of the risers have been attempted earlier. Cultivation of tea on the risers not only increases the total area under cultivation under terraced conditions, but also provides good income and risk minimization by crop diversification (Sundarambal and Singh 2009). Alternate crops are very much essential to meet the needs of different farming community. Keeping this in mind the experiment was conducted to find out the suitability of selected medicinal and aromatic plants on riser and to increase the rainwater-use efficiency and productivity of major crops through different land management practices by increasing the crop productivity apart from minimizing the risk of crop failure under rainfed condition.

MATERIALS AND METHODS

The field experiment was conducted for 4 years from 2003–06 in the research farm and adjacent farmer's field of the Research Centre, Central Soil and Water Conservation Research and Training Institute, Udhagamandalam located at an elevation of 2 217 m above mean sea level and at a latitude of 11° 24′ N and longitude of 76° 41′ E. The average annual rainfall is about 1 200 mm received from both south-west and north- east monsoons.

The experimental soil was very deep, well drained and silty clay loam. The soil belongs to the order Ultisols and described as Ootacamund series. The mean soil *p*H was of 4.7, EC 0.1 dS/m, organic C 19 g/kg, with available N, P, K of 430.9, 99.2 and 82.6 kg/ha, respectively.

Ten treatments were laid out in a randomized block design with 3 replications in plots of 120 m^2 (each plot consisting of 3 benches of size 40 m^2 each) with promising medicinal and aromatic plants found by Singh *et al*. (2001) as follows. T_1, Outward bench terraces (10% slope) + grass on the risers with farmers practice nutrient management; T_2, outward bench terraces (10%) + grass on riser with recommended nutrient management practices; T_3, inward bench terrace (2%) + grass on the riser; T_4, outward bench terraces (5%) + rosemary (*Rosemarinus officinalis*) on riser; T_5, outward bench terraces (5%) + geranium (*Pelargonium graveolens*) on the riser; T_6, outward bench terraces (5%) + cineraria (*Cineraria martima*) on riser; T_7, outward bench terraces (10%) + rosemary on the riser; T_8, outward bench terraces (10%) + geranium on the riser; T_9, outward bench terraces (10%) + cineraria on riser; T_{10}, vegetative barrier of geranium across the slope in 25% sloping field.

The crop rotation of potato–cabbage in the first year and carrot–beans in the second year was followed. In the first season (May to September) potato and carrot, whereas in the second season (September to December) cabbage and beans were grown in alternate years. Recommended crop management practices were followed in all the treatments (T_2–T_{10}) except in the farmers' practice (T_1) where fertilizer mixtures (2000 kg/ha) of No.4 mixture available in the ratio of 6 : 12 : 6 (N, P, K) for potato and 1500 kg/ha of No. 5 mixture available in the ratio of 9 : 9 : 9 (N, P, K) for cabbage, carrot and beans were used instead of the straight fertilizers for supplying nutrient. The yield was recorded after the harvest of each crop.

Three to six-month old seedlings of the respective medicinal plants were planted on the risers and maintained. In the sloping field (T_{10}), 1 m strips of geranium was established as vegetative barrier across the slope at every 10 m length of the field. The first harvesting of geranium was done 6 months after planting (6 MAP) and that of cineraria and rosemary 10 MAP. The subsequent harvests of geranium and cineraria was done at an interval of 4 months, whereas rosemary was harvested at longer intervals as its performance was poor on the riser. The mean yield of each crop and returns were worked out by taking into account the selling price of the fresh plant material. In order to work out the yield from the system as a whole, the yield of 2 crops on the bench in a year and that obtained from the respective medicinal/aromatic plant on the riser was converted to potato-equivalent yield by considering the wholesale selling prices of these crops.

Soil moisture availability under different treatments in the root zone depth was measured at monthly intervals using soil moisture meter (Delta-T profile probe) with access tubes permanently fixed in the centre of each plot. Surface soil samples (0–15 cm) were collected initially and after every year, and were analyzed for *p*H, EC, organic carbon, available N, P and K following the standard procedures (Jackson 1973). Rainfall at the experiment site was monitored using the automatic rain gauge installed at the site. Runoff was monitored from plots by using multislot divisor installed in all the treatments.

The net rainwater used during the cropping period was considered for the estimation of rainwater-use efficiency. The actual crop water-use was calculated using the following water balance equation.

$$Rn = R + \Delta S - D + \int Fxdt$$

where Rn, Net rainwater used during the cropping period (mm); R, rainfall during the cropping period (mm); ΔS, change in soil moisture (initial-final) storage (mm).

Change in soil moisture, ΔS, in the root zone was determined using the following equation

$$\Delta S = \frac{(M_2 - M_1) \times \rho_b \times d_1}{100}$$

where M_1 and M_2, Per cent soil moisture on weight basis in the beginning and end of the cropping period; ρ_b, bulk density of the soil and d_1 is the root zone depth (30 cm); D, runoff (mm); Fx, soil moisture contribution due to capillary action over time t (due to high slope and deep water table, this is taken as negligible).

Rainwater-use efficiency was determined by dividing the yield (kg) of vegetable crops by the net rainwater used. The net water used (cu.m) was calculated from the water balance equation as given above with multiplying the area and appropriate conversion of the unit. Then rainwater productivity (kg/m^3) was determined by dividing the potato equivalent yield by the net rainwater used (m^3).

RESULTS AND DISCUSSION

Rainfall and runoff

The annual rainfall received at the experimental site during 2003, 2004, 2005 and 2006 was 848, 1619, 1397, and 1103 mm, respectively. Maximum runoff (17.9 mm) was observed from 10% outward bench terrace with rosemary on the riser (T_7), followed by 5% outward bench terrace with cineraria (*Cineraria martima*) on riser (T_6). However, runoff did not vary considerably among the treatments under study.

The results revealed that even in the outward slopping terraces, with the additional protection of risers by planting of medicinal plants, the runoff was reduced to a greater extent. Even in the treatment of sloping land (25%) with vegetative barrier (T_{10}), the runoff resulted (8.3 mm) quite less than the other treatments having lesser outward slope. Therefore, with vegetative barriers across the field, cultivation on the sloping land also taken up for conserving the valuable soil and water. Moreover, yield of all the crops in this treatment (T_{10}) was significantly higher in the second crop rotation.

Soil moisture

The average initial and final soil moisture in root zone of the crops revealed that the soil moisture storage was considerably higher throughout the growing periods in both the seasons in the sloping land with vegetative barrier (T_{10})

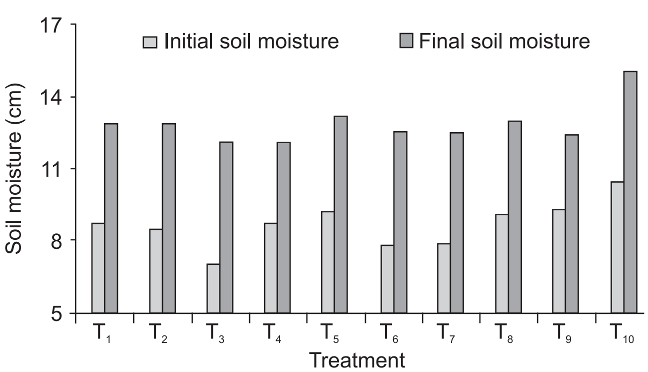

Fig 1 Average soil moisture for the first season crops under different treatments

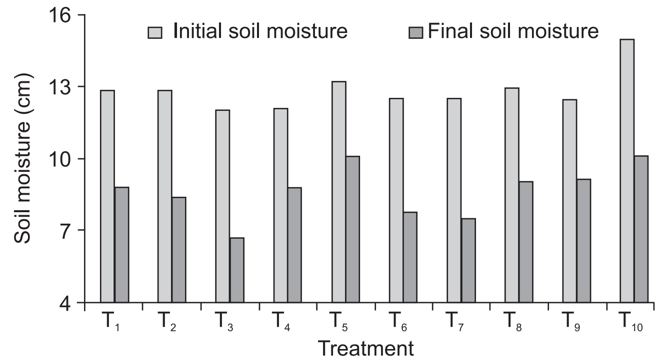

Fig 2 Average soil moisture for the second season crops under different treatments

(Figs 1, 2). The higher moisture content in the root zone during the growing period definitely resulted in the higher yield in T_{10}. For vegetable crops, viz potato, cabbage, carrot and beans, the soil moisture up to 30 cm depth was crucial for germination of seeds in April–May in the first crop season and for good yield in the later part of the second season (November–December). The treatments with vegetative barriers arrest the surface movement of water and facilitate the downward movement which further moves laterally at the sub-surface layers of the soil. The undisturbed layers of soil with better drainage conditions along with the higher moisture availability in the root zone of the soil resulted in the higher yield in these sloping plots as already reported by Muralidharan *et al.* (2008).

Yield

The experiment site was covered with bushes and shrubs for a long time before the start of the experiment. Therefore, the initial organic C was high and resulted in a high yield of potato in all the treatments in the first year (Table 1). The cabbage crop followed by potato in 2003, produced below normal yield due to the poor rainfall, particularly during the cropping season. From statistical analysis, no significant difference in the yield of potato and cabbage was found among the treatments. In the case of carrot (2004), yield was significantly higher as compared to all other treatments due to better drainage conditions and the higher moisture availability at the root zone of the soil in strips of geranium (1 m) as vegetative barrier across the slope in 25% sloping field (T_{10}) and the yield in the remaining treatments were at par. But the yield of beans in 2004 was maximum in 10% outward slope + grass on the risers with recommended nutrient management practices, followed by the farmers practice nutrient management (T_1). This might be due to higher quantity of fertilizer mixtures applied as per the farmer's practice.

The trend was very clear in the second crop rotation. In all the crops, significantly higher yield was obtained in the sloping plot with barriers of geranium (T_{10}). In the case of cabbage (2005) and carrot (2006), the farmers' practice (T_1)

Table 1 Yield of vegetable crops (tonnes/ha) under different land management practices

Treatment	Potato			Cabbage			Carrot			Beans		
	2003	2005	Mean	2003	2005	Mean	2004	2006	Mean	2004	2006	Mean
OBT (10%) + grass on the risers with farmers' practice nutrient management	32.9	11.0	22.0	13.3	51.1	32.2	20.6	21.9	21.3	3.9	3.5	3.7
OBT(10%) + grass on riser with recommended nutrient management practices	26.0	11.6	18.8	9.6	32.2	20.9	12.8	15.2	14.0	2.7	2.8	2.8
IBT(2%) + grass on the riser	29.0	9.8	19.4	14.3	35.3	24.8	17.5	14.0	15.8	2.8	3.3	3.1
OBT (5%) + rosemary on riser	26.0	11.4	18.7	11.3	32.5	21.9	12.2	10.6	11.4	1.3	2.4	1.9
OBT (5%) + geranium on the riser	28.1	12.2	20.2	12.3	32.9	22.6	16.8	13.5	15.2	2.4	3.2	2.8
OBT (5%) + cineraria on riser	33.8	12.2	23.0	16.4	41.2	28.8	20.9	16.1	18.5	2.9	3.6	3.3
OBT (10%) + rosemary on the riser	32.2	9.6	20.9	13.3	33.6	23.5	19.2	18.7	19.0	2.8	3.2	3.0
OBT (10%) + geranium on the riser	32.1	12.4	22.3	12.9	37.8	25.4	20.6	16.0	18.3	1.8	3.0	2.4
OBT (10%) + cineraria on riser	27.7	12.4	20.1	11.1	41.3	26.2	15.2	12.2	13.7	2.5	2.6	2.6
Strips of geranium as vegetative barrier in 25% sloping field	32.0	21.3	26.7	14.3	59.7	37.0	38.9	28.3	33.6	2.6	4.0	3.3
SEm±	3.36	2.19		1.97	3.10		3.45	3.12		0.67	0.36	
CD (P=0.05)	NS	5.7		NS	9.2		10.2	9.3		NS	NS	

OBT, Outward bench terrace; IBT, inward bench terrace

Table 2 Potato equivalent yield (tonnes/ha) from different treatments

Treatment	2003	2004	2005	2006	Mean
OBT (10%) + grass on the risers with farmers' practice nutrient management	37.4	12.9	28.0	12.6	22.7
OBT(10%) + grass on riser with recommended nutrient management practices	29.2	8.2	22.3	9.1	17.2
IBT (2%) + grass on the riser	33.8	10.4	21.6	9.1	18.7
OBT (5%) + rosemary on riser	29.8	7.6	23.2	7.7	17.1
OBT (5%) + geranium on the riser	32.2	14.6	28.1	13.7	22.1
OBT (5%) + cineraria on riser.	39.2	18.5	32.5	16.9	26.8
OBT (10%) + rosemary on the riser	36.6	12.1	21.8	12.0	20.6
OBT (10%) + geranium on the riser	36.4	15.6	29.9	14.5	24.1
OBT (10%) + cineraria on riser	31.4	15.7	32.7	14.2	23.5
Strips of geranium as vegetative barrier in 25% sloping field	36.8	24.4	46.1	20.7	32.0
Mean	34.3	14.0	28.6	13.1	
SEm ±	3.74	2.02	2.59	1.55	
CD (P=0.05)	NS	6.0	7.7	4.6	

OBT, Outward bench terrace; IBT, inward bench terrace

also recorded significantly higher yield, obviously due to the higher quantity of fertilizer mixtures applied, which may not be sustainable over a period of time due to high input cost and lack of organic manures. The higher yield in T_{10} is clear indication why farmers cultivate on sloping land or outward sloping terraces under normal annual rainfall. The puertorican type of terraces developed in this manner and after a period of 4–5 years these sloping lands are automatically converted to terraces with the vegetative barrier occupying the riser portion.

The mean PEY showed that the sloping field with strips of geranium as vegetative barrier (T_{10}) gave the highest yield (32.0 tonnes/ha), followed by T_6, T_8 and T_9. This could be concluded that the net income can be increased from the system as a whole by growing medicinal/aromatic plants on the riser in addition to providing enough protection in conserving runoff and soil loss (Table 2). The yearly average PEY showed that maximum yield was obtained during 2003, followed by 2005. Minimum potato equivalent yield obtained during 2006, followed by 2004 with very minimum difference between them. These variations may be attributed due to the variation in the rainfall during growing period. However, there was no significant difference in potato equivalent yield among the treatments during 2003 may be due to very high yield attributed to the high organic content in the beginning. In the remaining years, difference in potato equivalent yield was significant with maximum in T_{10} followed by T_6 and considerably reduction in the remaining treatments. But there was no consistency in the minimum potato equivalent yield with any particular treatment over the years.

Rainwater-use efficiency

The maximum rainwater-use efficiency (RWUE) of potato, cabbage, carrot and beans was 56.5, 83.1, 38.7, 11.6 kg/ha-mm, respectively. The RWUE of potato, cabbages and carrot differed significantly among the treatments except beans. The maximum RWUE was obtained from the sloping land (25%) with vegetative barrier of geranium across the slope (T_{10}), followed by 10% outward bench terraces + grass on the risers with farmers' practice nutrient management (T_1) for potato, cabbage and carrot crops (Fig 3). But in case of beans, though maximum RWUE obtained in T_1, there is not much difference in RWUE between T_1 (11.6 kg/ha-mm) and T_{10} (11.5 kg/ha-mm). However, low RWUE was obtained in 5% outward bench terrace with rosemary (T_4) on riser for potato (42.7 kg/ha-mm), carrot (13.3 kg/ha-mm) and beans (6.4 kg/ha-mm), whereas the same for cabbage (47.2 kg/ha-mm) in 10% outward bench terrace with grass on riser and recommended nutrient management practices (T_2). The increase in RWUE about 15.6, 37.6, 79.4, 21.2% for potato, cabbage, carrot and beans, respectively in the sloping land (25%) with vegetative barrier of geranium across the slope (T_{10}) over the average RWUE from all the treatments. As the rainfall in the experimental area remains same over all the treatments and there is not much variation in the runoff, therefore the higher moisture storage and maximum yield

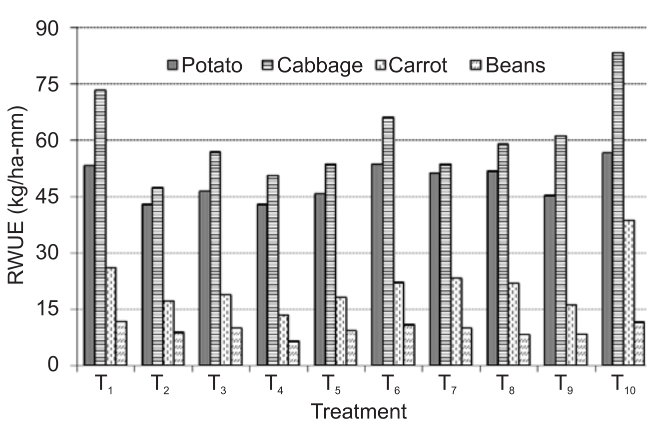

Fig 3 Average rainwater-use efficiency under different treatments

obtained in the sloping land (25%) with vegetative barrier of geranium (1 m) across the slope (T_{10}) resulted for the higher RWUE as compared to other treatments. There was no particular trend in RWUE among the treatments either inward or outward bench terraces with 5 to 10% slope having different riser plantation.

Rainwater productivity

The highest rainwater productivity of the system was obtained from the sloping land (25%) with vegetative barrier of geranium (1 m) (T_{10}), followed by 10% outward bench terrace + geranium on the riser (T_8) and 10% outward bench terrace with cineraria on riser (T_9) under normal rainfall condition (Fig 4). This is due to the increase in equivalent yield by growing the medicinal and aromatic plants on the

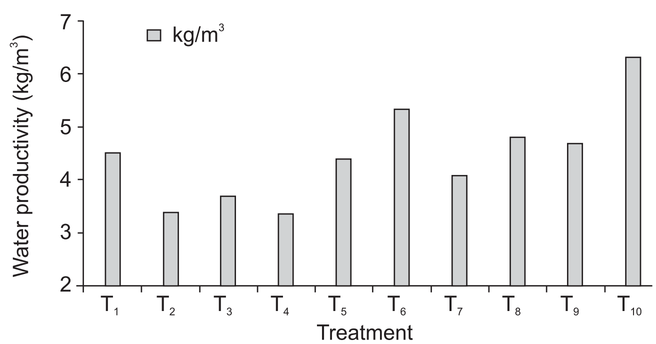

Fig 4 Rainwater productivity of the system under different treatments

riser. Due to growing of medicinal plants as vegetative barrier as well as on the riser, there is optimum use of net available water which increases the total potato equivalent yield of the system and rainwater productivity. Thus, it could be concluded that suitable land management practices enhanced the rainwater productivity.

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