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Land management practices for resource conservation under vegetable cultivation in Nilgiris hills ecosystem

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Abstract

Different land management practices were studied for determining soil and water conservation efficiencies, soil and nutrient retention and crop water use efficiencies under vegetable cultivation in sloping and terraced land of the Nilgiris, South India. Inward slope bench terraces (2%) and outward sloped bench terraces (5 and 10%) with riser protection through medicinal/aromatic plants, sloping lands (25%) with 1 m strips of vegetative barriers of medicinal plant were taken with cultivation of potato-cabbage in the first year and carrot-beans in the second year for two rotations. Highest water conservation efficiency (WCE) of 96% was obtained in 5% outward bench terraces with rosemary (*Rosemarinus officinalis*) on riser. But maximum soil conservation efficiency (SCE) of 98%, soil retention of 22447 t yr^{-1} and N, P, K retention of 5.37, 1.24, 1.03 t yr^{-1} respectively was found in 10% outward bench terraces with grass on riser + recommended nutrient management practices. However, due to highest crop yield and water use efficiency under land management practice of 25% continuous slope with vegetative barrier across the slope with relatively high WCE, SCE and soil and nutrient retention capacity, this practice is highly acceptable by farmers'. Therefore, vegetable cultivation on sloping land with intervention of suitable vegetative barrier at regular intervals is recommended for effective resource conservation in the fragile hill ecosystem of Nilgiris.

Key words

Crop water use efficiency, Land improvement index, Soil conservation efficiency, Water conservation efficiency

Introduction

Agriculture is the engine of overall economic growth (World Bank, 2005) and therefore, broad-based poverty reduction (IFAD, 2001; Irz and Roe, 2000; DFID, 2002; Koning, 2002). The resource conditions in rainfed areas shows a grim picture of water scarcity, fragile environments, drought and land degradation due to soil erosion by wind and water, low rainwater use efficiency (35–45%), high population pressure, poverty, low investments in water use efficiency (WUE) measures, poor infrastructure and inappropriate policies (Wani *et al*., 2003b; Rockström *et al*., 2007). Though the problem of runoff, soil loss and land degradation has been existing for long, the pace has greatly increased in recent times due to burgeoning population and increased exploitation of natural resources.

In India, as per harmonized database on degraded/ wastelands, about 68.4% (82.57 million ha) of the total degraded lands (120.72 million ha) are due to water erosion (Maji, 2007) and losing 5.37 to 8.4 million tons of plant nutrients every year (Anonymous, 2000) leads to low crop productivity (Bhattacharya *et al.,* 2007). Reduction in crop yield up to 60% (Sharda *et al*., 2010) is due to removal of top soil through erosion processes under various soil types in India. Land management practices are required to control soil erosion, prevent further land degradation and sustain agricultural production (De Graaff *et al*., 2008). Every 1% increase in agricultural yield translates to 0.6–1.2% decrease in the percentage of absolute poor (Thirtle *et al*., 2002). Therefore the greater challenge to enhance productivity of crops under increasing water scarcity condition is by enhancing crop water productivity (Kijne *et al*., 2002) through appropriate land management practices which will affect water and nutrient status in soil, thus increasing plant growth and yield (Ali and Talukder, 2008; Falkenmark and Rockström, 2004). Measures to enhance effective precipitation include *in-situ* soil and water management techniques such as conservation agriculture, bunds, terracing, land leveling, use of biomass mulch, crop rotation, no till, ridge till, trenching, vegetative barrier, contour row planting, ridges and furrows and various combination of these techniques greatly increases green water in the crop roots zone (Rockstrom *et al*., 2010). Addressing resource conservation and management holds the promise in future agriculture compounded by growing population. Soil and water conservation have always been vital for sustaining agricultural production to meet the needs of growing population and livestock. The importance of rainwater conservation, erosion control and maintaining soil productivity is increasing for sustaining agricultural production.

In the Nilgiris hills of South India, vegetable crops are cultivated in outwardly sloped bench terraces to avoid water logging through better drainage. Even many farmers are converting the terraces into outward sloping land due to difficulty in terrace maintenance and reduction in net area available for cultivation. Cost-effective technologies for terrace maintenance and utilization of terrace risers have been attempted by cultivating tea on risers, which increases the net area under cultivation in terraced conditions. However, alternate options are essential to meet the growing needs of farming community and crop diversification. Therefore, outward (5-10%) and inward (2%) slope bench terrace land management practices with rosemary, geranium and cineraria on the terrace risers and vegetative barriers in sloping lands was studied for resource conservation and enhancing crop water use efficiency.

Materials and Methods

Study area : The study was carried out at the Central Soil and Water Conservation Research and Training Institute, Research Centre, Nilgiris, South India located at an elevation of 2217 m above msl. The climate is sub-tropical temperate with long term average annual rainfall of 1242 mm, out of which 42 % is received from South-West (June to September) and 40 % from North-East monsoon (October to December) with erratic summer rains (pre-monsoon showers). High rainfall erosivity was observed during the month of September and October and then from April to July. The mean annual temperature is 15.0 ºC with a maximum temperature of 22 ºC (April) and minimum 7.7 ºC (January). Mean evaporation is 3.17 mm per day with a maximum of 4.67 mm per day in March and minimum of 2.29 mm per day in August. Mean annual potential evaporation is 988 mm and reference crop evopotranspiration (ET0) is 3.16 mm day^{-1} (Allen *et al*., 1998).

The soil is very deep, well drained, silty clay loam belonging to the order *ultisols, Ootacamund* series. It is acidic in nature (pH 4.7) with EC 0.1 dS m^{-1}, organic carbon content of 1.9% available N, P, K of 431, 99.2 and 82.6 kg ha^{-1}, respectively. The general land slope of the site was 25%.

Experiment details : Ten land management practices (T1 to T10) were laid in randomized block design with three replications in plot size of 120 m^2 in three outward bench terraces (OBT) or inward bench terraces (IBT).

T_1: OBT(10%) + grass on the risers with farmers practice of nutrient management; T2 : OBT (10%) + grass on riser with recommended management practices; T_3: IBT(2%) + grass on the riser; T_4: OBT(5%) + Rosemary (*Rosemarinus officinalis*) on the riser; T_5: OBT(5%) + Geranium (*Pelargonium graveolens*) on the riser; T_6: OBT(5%) + Cineraria (*Cineraria martima*) on riser; T_7: OBT(10%) + Rosemary (*Rosemarinus officinalis*) on the riser; T_8: OBT(10%) + Geranium (*Pelargonium graveolens*) on the riser; T_9: OBT(10%) + Cineraria (*Cineraria martima*) on riser; T_{10}: Vegetative barrier (*Pelargonium graveolens*) across 25% continuous slope

Crop and agronomic practices : Potato-cabbage and carrot-beans were followed in first and second year respectively for two crop rotations. Recommended crop management was practiced in all the treatments except in the farmers' practice of nutrient management (T1), where fertilizer mixtures of 2000 kg ha^{-1} available in the ratio of 6: 12: 6 (N, P, K) for potato and 1500 kg ha^{-1} available in the ratio of 9: 9: 9 (N, P, K) for cabbage, carrot and beans were applied. Three to six months old seedlings of medicinal plants were planted on the risers and maintained. In the sloping field (T10), 1 m strips of geranium were established as vegetative barrier across the slope at every 10 m interval. The first harvest of geranium was done at 6 months after planting (6 MAP) and that of cineraria and rosemary at 10 MAP. The subsequent harvest of geranium and cineraria was done at regular interval of 4 months, whereas rosemary was harvested at an interval of 6 months due to late establishment on the riser. The yield from the whole system was calculated by converting the yield of all crops on the bench terrace and that obtained from the respective medicinal/aromatic plants from the riser to potato equivalent yield (PEY) by taking into account the selling price of each crop.

Runoff and soil loss measurement : A standard siphon type recording rain gauge was used to measure the amount and intensity of rainfall. Runoff was monitored from all the treatments using multi-slot divisor (Wasi Ullah *et al.*, 1972) connected with tank and barrel installed at the end of experimental plot. The GI sheet (60 cm height) were installed around each plot of 120 m^{2}to divert the runoff water from each plot to tanks through multi-slot divisor. Total volume of runoff was calculated using the depth of collected water and dimensions of the tank and barrel. Runoff volume was measured at 8.30 A.M. (IST) daily after all rainfall events during the last 24 hrs and soil loss was calculated from sample volume of 500 ml runoff water collected from each runoff tank after stirring to determine the silt content. Event wise rainfall analysis was made and expressed in mm and t $ha^{-1}yr^{-1}$ for runoff and soil loss, respectively.

Conservation efficiencies : Water conservation efficiency (WCE) and soil conservation efficiency (SCE) of different bio-engineering land management measures were calculated using the equations from Madhu *et al*. (2001).

Results and Discussion

The loosened subsoil due to land preparation by uprooting of bushes and trees caused higher water retention combined with low annual rainfall (848 mm) which resulted in highest conservation of rain water (runoff less than 1% of rainfall) in all the land management practices during first year. However, in spite of good annual rainfall (1619 mm) during second year, the runoff was in the range of 3.6-33.8 mm from the plots showing the impact of land management practices in conserving rainwater (Fig.1). Similar trend in rainwater conservation was also observed in the subsequent years, conforming the positive impact of land management practices.

High rate of soil loss during 2006 in respective treatments in comparison to previous years was observed due to relatively high surface runoff resulted from number of high intensity rainfall events. From the mean annual data, it was observed that the soil loss did not vary considerably among the treatments and followed a similar trend to that of surface runoff, varying from 0.27 to 1.47 t ha^{-1} (Fig. 2) in comparison to 10.82 t ha^{-1} in the farmer's practice under similar land slope conditions. Soil loss from all the plots were within the permissible soil loss limits of 10.0 of t $ha^{-1}yr^{-1}$ (Mandal and Sharda, 2011) which showed the effect of land management practices in controlling soil loss.

Minimum surface runoff of 3.8 mm and maximum WCE of 96 % was obtained in outward bench terraces (5%) with Rosemary (*Rosemarinus officinalis*) on riser (T4) followed by 94 % WCE (5.4 mm of surface runoff) in outward bench terraces (10%) with grass on riser (T2). Maximum runoff of 17.9 mm was produced from 10% outward sloped bench terrace with rosemary (*Rosemarinus officinalis*) on the riser (T7) resulting in minimum WCE of 80.5 % followed by 16.7 mm runoff (81.8 % WCE) in 5% outward sloped bench terrace with cineraria (*Cineraria martima*) on the riser (T6) (Fig.3). Land management of 25% continuous slope with vegetative barrier of geranium across the slope (T10) produced runoff of 8.3 mm (91% WCE) which was relatively better than the remaining practices. The effectiveness of different vegetative barriers in rain water conservation and soil loss reduction reported similar results by several workers (Bhardwaj and Sindhwal, 2007; Bhanavase *et al*., 2007; Mane *et al*., 2009). The mean runoff varied from 0.3 to 1.4% among all the treatments during the experimental period in comparison to 7.4% in the farmer's practice of cultivation in outward sloped terraces without any conservation measures. WCE was more than 80% in all the plots showing effectiveness of bio-engineering management practices in enhancing rainwater conservation.

Soil loss (t ha^{-1}) during initial three years was very low due to high WCE of all the management practices. Maximum SCE of 97.5 % was in outward bench terraces (10%) + grass on riser with recommended nutrient management practices (T2) followed by

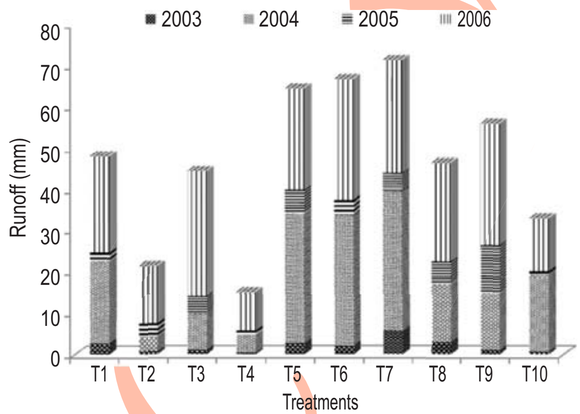

Fig. 1 : Runoff under different land management practices in Nilgiris

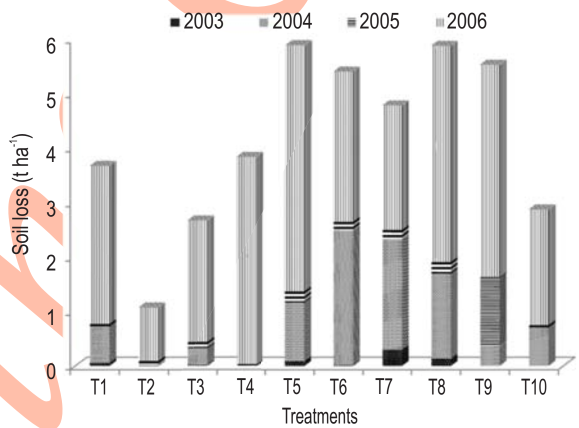

Fig. 2 : Soil loss under different land management practices in Nilgiris

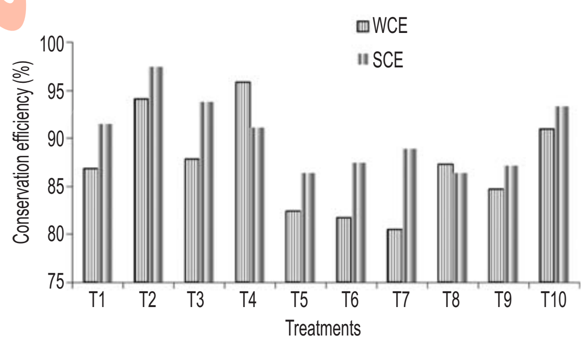

Fig. 3 : Conservation efficiency under different land management practices in Nilgiris

93.8% in inward bench terrace (2%) + grass on the riser (T3) and minimum of 86.4 %in outward bench terraces (5%) + Geranium (*Pelargonium graveolens*) on the riser (T3) (Fig.3). SCE was more than 85 % in all the practices showing the impact in soil loss reduction on sloping lands.

It was found that in the outward slope bench terraces with riser protection of vegetative measures, the soil and water conservation efficiency was more than 80% in all practices and provided additional returns from medicinal plants grown on the terrace risers. Further, it was found that, in sloping land with strips of geranium produced only runoff of 8.3 mm and soil loss of 0.72 t ha^{-1}(91% WCE and 93.3% SCE), was better due to higher water use efficiency than the remaining measures under bench terraces with riser protection.

Reduction in land slope within the inter space of vegetative barrier was observed due to detachment of soil from upper side of slope and deposited behind the barriers (Fig.4). The original land slope reduced from 25 % to 20% at the end of four years of experimentation resulted in increase in land improvement index (LII) to18 %. Further, continuing this practice for few more years, an outward slope bench terrace suitable for vegetable cultivation will be formed with vegetative barrier providing both protection and additional return. Earlier studies have also reported a LII of 29 % in vegetative barrier with one row of *Tripsacum laxum* and two rows of pine apple at 1.5 m vertical interval (Madhu *et al*., 2007).

Soil and nutrient retention in the entire Nilgiris due to cultivation of potato, carrot, cabbage and beans was estimated taking the total area under these crops. Soil and nutrient loss from different land uses were compared with the farmers' practice of cultivation in outward sloped land without any conservation measure. Reduction in soil and nutrient losses are taken as retention due to land management practices. Maximum soil retention was found in 10% outward sloped bench terraces + grass on riser with recommended nutrient management practices (T2) in all crops (Table 1) in comparison to remaining management practices. However, carrots gave maximum

Table 1 : Soil retention by land management practices under different crops in the Nilgiris

Treatment	Soil retained (tonnes)			
	Potato	Carrot	Cabbage	Beans
T_1	15811	22728	5929	4941
T_2	16850	24221	6319	5266
T_3	16209	23300	6078	5065
T_4	15746	22634	5905	4921
T_5	14924	21454	5597	4664
T_6	15118	21732	5669	4724
T_7	15368	22091	5763	4802
T_8	14929	21460	5598	4665
T_9	15068	21661	5651	4709
T_{10}	16129	23185	6048	5040
Average	15615	22447	5856	4880

OBT= Outward bench terraces, IBT= Inward bench terraces

Table 2 : Nutrients retention by land management practices under different crops in the Nilgiris

Treatments	N (tonnes)				P (tonnes)				K (tonnes)			
	Potato	Carrot	Cabbage	Beans	Potato	Carrot	Cabbage	Beans	Potato	Carrot	Cabbage	Beans
T_1	3.79	5.44	1.42	1.18	0.87	1.25	0.33	0.27	0.73	1.04	0.27	0.23
T_2	4.03	5.80	1.51	1.26	0.93	1.33	0.35	0.29	0.77	1.11	0.29	0.24
T_3	3.88	5.58	1.46	1.21	0.89	1.28	0.33	0.28	0.74	1.07	0.28	0.23
T_4	3.77	5.42	1.41	1.18	0.87	1.25	0.33	0.27	0.72	1.04	0.27	0.23
T_5	3.57	5.14	1.34	1.12	0.82	1.18	0.31	0.26	0.68	0.98	0.26	0.21
T_6	3.62	5.20	1.36	1.13	0.83	1.20	0.31	0.26	0.69	1.00	0.26	0.22
T_7	3.68	5.29	1.38	1.15	0.85	1.22	0.32	0.26	0.71	1.01	0.26	0.22
T_8	3.57	5.14	1.34	1.12	0.82	1.18	0.31	0.26	0.69	0.98	0.26	0.21
T_9	3.61	5.19	1.35	1.13	0.83	1.19	0.31	0.26	0.69	0.99	0.26	0.22
T_{10}	3.86	5.55	1.45	1.21	0.89	1.28	0.33	0.28	0.74	1.06	0.28	0.23
Average	3.74	5.37	1.4	1.17	0.86	1.24	0.32	0.27	0.72	1.03	0.27	0.22

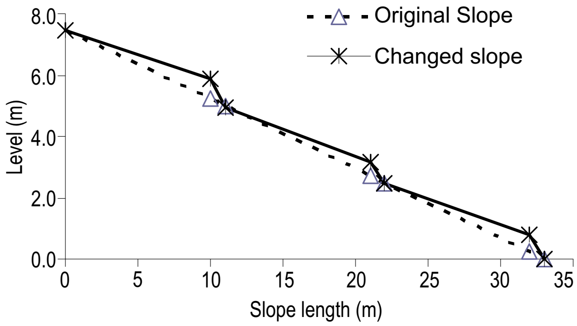

Fig. 4 : Change in slope through strips of vegetative barrier in Nilgiris

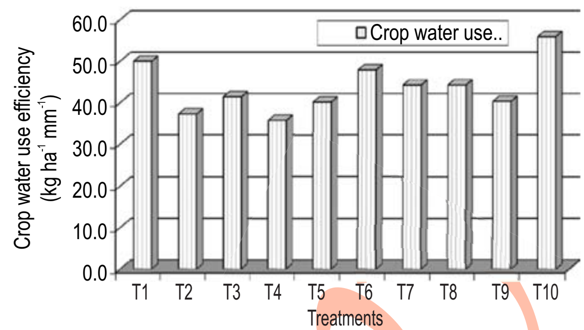

Fig. 5 : Crop water use efficiency under different land management practices in Nilgiris

average soil retention (22447 t yr^{-1}) among different crops. Nutrients (N, P, K) retention through different land management practices under different crops is given in Table 2. Similar trend in nutrient retention (N, P, K) with maximum values was found in 10% outward sloped bench terraces + grass on riser with recommended nutrient management practices (T2) followed by inward bench terrace (2%) + grass on the riser (T_2) and land management of 25% continuous slope with vegetative barrier of geranium across the slope (T10)in all crops. Maximum quantities of N, P, K retention was observed in carrot and was found to be 5.37, 1.24, 1.03 t yr^{-1} respectively. Similar results of nutrient conservation were observed (Joshi, 2004) in different land use system through reduced runoff and soil loss in comparison to bare land.

The crop water use efficiency (CWUE) was estimated as described in methodology by taking potato equivalent yield (PEY) of all crops. Highest CWUE (55.9 kg $ha^{-1}mm^{-1}$)was obtained in 25 % sloping land with vegetative barrier across the slope followed by 10 % outward bench terraces + grass on the risers with farmers practice nutrient management(50.0 kg $ha^{-1}mm^{-1}$) (T1) (Fig.5) as compared to other land management practices. Lowest CWUE was observed in 5 % outward bench terrace with rosemary (T4) on riser (35.7 kg $ha^{-1}mm^{-1}$) followed by 10 % outward bench terrace with grass on riser and recommended nutrient management practices (37.3 kg $ha^{-1}mm^{-1}$) (T2). There was 35% and 21% increase in CWUE in 25 % sloping land with vegetative barrier across the slope (T10) and 10% outward bench terraces+grass on the risers with farmers practice nutrient management(T1) respectively over the average CWUE of remaining conservation measures. Similar results were reported in rain water-use efficiency (RWUE) and enhanced rainwater productivity of tea through conserving rainwater by different conservation measures in the Nilgiris (Madhu *et al.,* 2010).

All the land management practices that were experimented resulted in more than 80 % WCE and 85 %SCE, therefore encouraging soil and water conservation measures. Therefore, in fragile hill ecosystem with small land holdings, vegetable farming on sloping land with intervention of suitable vegetative barrier of medicinal plants at regular intervals is recommended for effective resource conservation.

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