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Original Research Article

Farming methods impact on soil and water conservation efficiency under tea [*Camellia sinensis* (L.)] plantation in Nilgiris of South India

Dhruba Charan Sahoo [a,*], Made Gowda Madhu [a], Sivagnanam Santhana Bosu [b], Om Pal Singh Khola [c]

[a] *Indian Institute of Soil and Water Conservation, Research Center, Sunabeda 763002, Odisha, India*
[b] *Tamil Nadu Agricultural University, Agricultural Engineering College and Research Institute, Coimbatore 641003, Tamil Nadu, India*
[c] *Indian Institute of Soil and Water Conservation, Research Center, Nilgiris 643004, Tamil Nadu, India*

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ABSTRACT

Growing of tea on sloping land without any soil and water conservation measures causes enormous soil loss especially in the initial years. For sound soil and water conservation planning, there is a need to evaluate the various conservation measures as related to the amount of expected runoff and soil erosion. In this context, a field study was conducted in the farmer's field in Nilgiris of South India, for evaluating the impact of farming methods on soil and water conservation efficiency under new tea plantation. One year old B-6 tea clones were planted at double hedge spacing (135 cm × 75 cm × 75 cm) in two slopes (8–12% and 30–35%) with treatments *viz.*, contour staggered trenches (CST), vegetative barrier (VB), CST alternate with VB, CST with cover crop of beans and farmers' practice of plantation. Minimum runoff (14.6%) was observed from CST with cover crop of beans followed by CST (15.4%) under 8–12% slope range with exactly similar trend in runoff from the plots under 30–35% slope. Contrary to runoff, minimum soil loss was observed from CST (4.9 and 6.9 t ha^{-1} yr^{-1}) followed by CST with cover crop of beans (5.3 and 7.3 t ha^{-1} yr^{-1}) under 8–12% and 30–35% respectively. Implementation CST and CST with cover crop of beans are resulted in better soil moisture under both the slope ranges in comparison to remaining measures as well as farmers' practice of plantation. Therefore, either CST alone or in combination with cover crop of beans are recommended for soil and water conservation under new tea plantation in the hill slopes.

1. Introduction

Soil and water have always been vital for sustaining life and becoming more limited as population increases. These resources are already under intensive use and misuse. Every year millions of tons of soil are washed away to the rivers and sea by erosion. The swelling population, poor land management, vulnerable soils and hostile climates add up to lethal combination that promote soil erosion bringing with it environmental degradation. Soil erosion is a serious problem and major contributor to the soil loss in the new tea plantation areas, as it is cultivated in the altitude ranging from 500 to 2500 m above mean sea level with slope range of 10–50%. In India, tea is grown over an area of 5780 km^2 mainly under rainfed sloping conditions (Madhu, Sahoo, Sharda, & Sikka, 2010) with annual rainfall varying from 1150 to 6000 mm. In Nilgiris of south India, tea is cultivated in areas having well distributed annual rainfall of about 1200 mm. Growing of tea on sloping land without any soil and water conservation measures causes enormous soil loss especially in the initial years (Madhu, Sikka, Tripathi, Raghupathy, & Singh, 2001). The problem of erosion in new tea plantations in Nilgiris is getting as high as 28–40 t ha^{-1} yr^{-1} over the years in the absence of any vegetative canopy and soil conservation measure (Chinnamani, 1977; Madhu & Tripathi, 1997). Therefore soil loss assessment is a major concern in long run as it affects the yield of green leaves and its sustainability.

Various factors such as rainfall intensity, duration, slope and cultural practices influence the runoff and soil loss behavior in new tea plantation. The farmers' practice of tea plantation, involves uprooting of bushes and shrubs for land preparation and planting the tea clones at desired spacing without following any conservation measures to control runoff and soil erosion. The

* Corresponding author.
E-mail address: dcsahoo@gmail.com (D.C. Sahoo).
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disturbance of top soil in process of land preparation and plantation leads to considerable soil erosion through accumulated runoff along the slope length. Many tea estates in Darjeeling hills in the North-East India, the Nilgiris and the high range in south India have recurrently suffered from soil erosion problem. In Sri Lanka, Krishnarajah (1985) reported a loss of 20 t of soil per hectare within six months in absence of any earthwork. Soil erosion on sloping field in tea plantation area also leads to a lot of environmental problem. The on-site impacts caused to thin soil layer, deterioration in soil structure and decrease in soil nutrient (Zhang, Zhang, Bu-zhuo, & Yang, 2003). Evidence of soil degradation can be seen in the low soil organic matter content, cation exchange and water-holding capacity, highly acidic pH, high soil compaction, erosion, nutrient leaching, accumulation of xenobiotics and toxic aluminum present under intensive teal plantations (Senapati, Panigrahi, & Lavelle, 1994; Senapati et al., 1999). Therefore, proper planning and implementation of soil and water conservation measures is very much needed in the initial period of plantation. Keeping these in mind, the study was conducted to estimate the conservation efficiency of different farming methods in the initial stages of tea plantation under different slope ranges in Nilgiris of South India.

2. Materials and methods

2.1. Study area

A field study was conducted during 2007–2009 in the farmer's field representing the most common area for tea in Nilgiris district (11° 26′ 40″ N and 76° 45′ 58″ E, 2150 m above mean sea level) of South India. The climate is temperate to sub-tropical with long term mean annual rainfall of 1276 mm with 79.4% occurring during South-West and North-East monsoons. The mean monthly maximum and minimum temperatures are 22.1 °C and 8.5 °C occurring in April and January, respectively with mean annual temperature of 15.0 °C. Mean relative humidity is about 76% most of the time, favoring tea cultivation in the region.

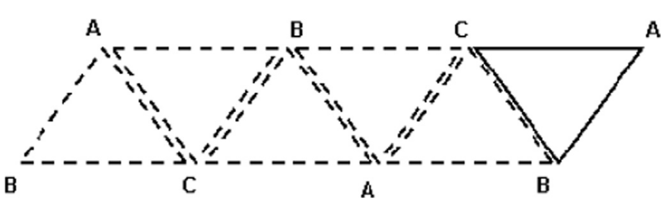

Fig. 1. Triangular frame for double hedge layout.

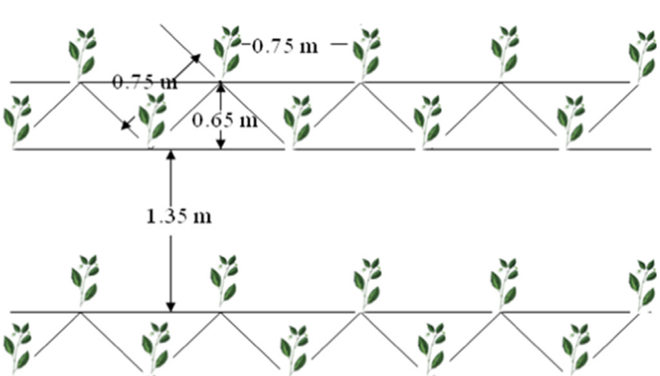

Fig. 2. Layout of tea plantation.

2.2. Layout and plantation

The experiment was laid out in a Randomized Block Design with four replications in 20 plots each on two slopes (8–12% and 30–35%) to accommodate four farming methods and one farmers' practice of cultivation. Double hedge planting (135 cm × 75 cm × 75 cm) along the contour line accommodating 13,200 plants ha^{-1}was followed by using a triangular frame (0.75 m each side) for laying out the double hedge rows and plant spacing (Figs. 1 and 2). One year old B-6 tea clones were planted before the onset of North-East monsoon during the month of September, 2007 in humid climate and moist soil for better establishment of young tea plants.

2.3. Treatment details

Treatments*	Specification
T_1: Contour staggered trenching(CST)	180 × 30 × 45 cm (Length × Width × Depth).
T_2: Vegetative barrier (VB)	Two rows of geranium at P-P and R-R spacing of 30 cm.
T_3: CST alternate with VB	180 × 30 × 45 cm alternate with VB at same spacing.
T_4: CST with cover crop	180 × 30 × 45 cm with beans as a cover crop during monsoon period.
T_5: Control	Farmers practice of cultivation without any conservation measures.

*All the conservation measures are taken in the space between the double hedge rows.

2.4. Runoff, soil loss and soil moisture monitoring

The multi-slot divisors are installed at the down end of the plots for runoff monitoring by measuring the runoff depth collected in each compartment in the stilling tank as well as in the collecting tank (Figs. 3 and 4). The plots were separated to isolate the runoff from the adjacent plots using 60 cm height strips of metal sheet. The soil loss was estimated from runoff sample of 500 ml collected from stilling tank after stirring to determine the soil loss. Events wise runoff and soil loss analysis was made and expressed in mm and t ha^{-1} yr^{-1}, respectively. Soil moisture content was monitored by collecting soil samples using auger at

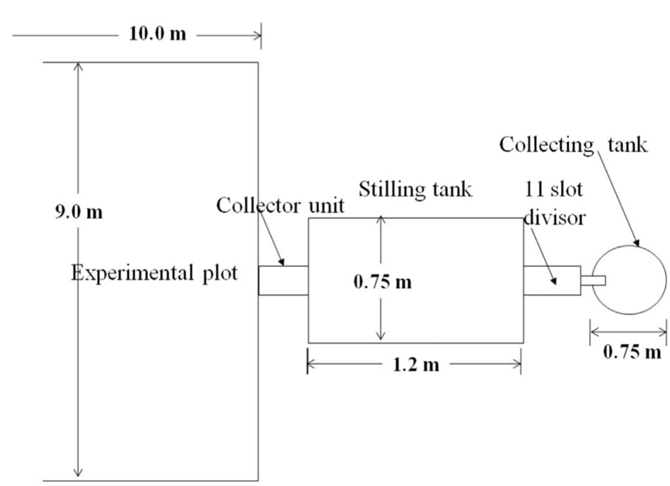

Fig. 3. Plan of experimental plot and runoff collection unit.

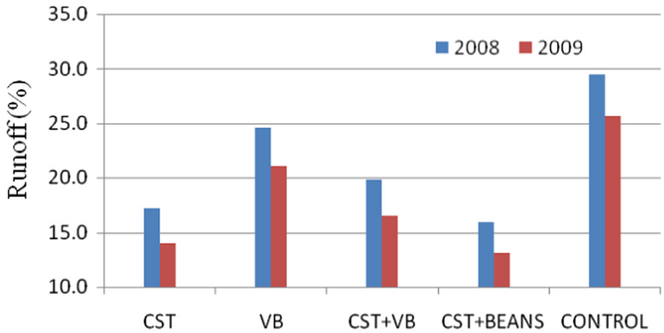

Fig. 4. Runoff (%) under different farming methods in 8–12% slope.

20 cm, 40 cm and 60 cm soil depths during post monsoon period at monthly intervals and estimated gravimetrically to quantify the moisture content.

2.5. Estimation of conservation efficiency

Water conservation efficiency (WCE) and soil conservation efficiency (SCE) of different conservation measures in comparison to farmers' practice (control) was calculated in percent using the formula below.

$$\text{WCE or SCE} = \frac{(A-B)}{A} \times 100$$

where A=Runoff or soil loss from the plot under farmers' practice.

B=Runoff or soil loss from the plot with conservation measures.

3. Results and discussion

3.1. Runoff and soil loss

The rainfall received during first year (2008) and second year (2009) are 986 mm and 1212 mm respectively, causing less total runoff in the first year than second year from all the treatments under both the slope ranges. However, the percentage of runoff to rainfall is higher in the first year in comparison to the following year from all the treatments in both the slopes showing the enhanced effect of conservation measures over time (Figs. 4 and 5). Minimum runoff of 107.1 mm and 117.2 mm were obtained during first and second year respectively from CST with cover crop of beans under 8–12% slope range. This was followed by the treatment of CST with 115.7 mm and 120.4 mm of runoff against the maximum values of 197.6 mm and 228.6 mm from the plot under farmers' practice during same period respectively.

Exactly similar trend in annual runoff values were obtained from the plots under slope range of 30–35% with minimum runoff from CST with cover crop of beans (130.2 mm and 142.5 mm) followed by CST (140.5 mm and 163.8 mm) in contrast to maximum runoff of 225.5 mm and 279.3 mm from plots under farmers' practice in first and second year respectively. Therefore, it may concluded that, CST is very much effective either alone or in combination in controlling runoff in the initial stages of tea plantation. Similar kinds of lower percent of runoff to rainfall were reported under different conservation practices by Mane, Mahadkar, Ayare, and Thorat (2009). Higher runoff volume and percent were found from all the treatments in comparison to the respective treatments in 8–12% slope during both years. There is about 17% increase in mean annual runoff from all treatments due to increase in slope. Low percent of runoff to rainfall were also reported under different land use systems by Vinod, Anwarulla, and Vishwanath (2003).

Minimum soil loss was observed from CST during both years with mean value of 4.9 t ha^{-1} yr^{-1} followed by CST with cover crop of beans (5.3 t ha^{-1} yr^{-1}) under 8–12% slope. This is in reverse trend to the annual runoff received from these treatments, where minimum runoff obtained from CST with cover crop of beans. This could be due to the disturbance of the top soil surface while taking the cover crop of beans, thereby accelerating the process soil detachment and transportation than one time making of CST. However, by taking the cover crop of beans followed by the intercultural operations and uprooting at the end, the soil became more porous following more rainfall get absorbed and produced less runoff. Though maximum runoff was obtained from the plot under farmers' practice, the soil loss is maximum (10.0 t ha^{-1} yr^{-1}) from plot under vegetative barrier. Vegetative barrier alone could reduce the runoff to some extent, but not the erosion because of vulnerability of the top surface while taking the vegetative barrier followed by normal intercultural operations. Therefore, the treatment of vegetative barrier is relatively less successful from the remaining treatments as far as the erosion is concerned.

Similar trend in soil loss were observed from all treatments under 30–35% slope range. Minimum soil loss during the study was observed in the plot under CST (6.9 t ha^{-1} yr^{-1}) followed by CST with cover crop of beans (7.3 t ha^{-1} yr^{-1}) and CST alternate with vegetative barrier (9.9 t ha^{-1} yr^{-1}) which shows that the CST either alone or in combination with the vegetative measures like cover crop of beans is the best in reducing erosion when compared to other treatments. In this case, maximum soil loss was obtained from the plot under vegetative barrier due to similar reason as explained. Badhe and Magar (2004) noted similar findings of staggered trenches when compared to the other treatments for soil loss reduction. Similar nature of observations were reported by various authors (Subudhi, Pradhan, & Senapati, 1998; Mishra & Sahu, 2001; Mane et al., 2009) under different land use and conservation measures.

3.2. Soil and water conservation efficiency

The highest water conservation efficiency (WCE) of 45.8% and 48.7% were obtained in CST with cover crop of beans during first and second year respectively with mean value of 47.3% in the slope range of 8–12% followed by CST with mean value of 44.4% (Table 1). Similarly maximum water conservation efficiency of 42.6% and 49.0% with mean value of 45.6% were obtained in the CST with cover crop of beans in first and second year respectively in slope range of 30–35% followed by CST with mean value of 39.5%. The establishment tea canopy in the second year caused in increasing the WCE than first year was observed in all the treatments in both the slopes. Lowest value of WCE was found in vegetative barrier of geranium alone in all the slopes, therefore not suitable in rainwater conservation. In general higher WCE were obtained in all treatments in the lower slope range than the respective

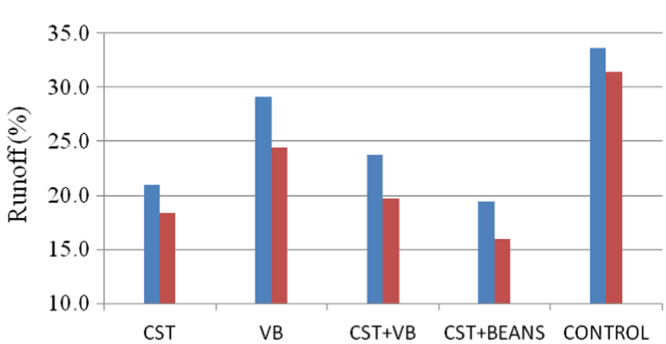

Fig. 5. Runoff (%) under different farming methods in 30–35% slope.

Table 1
Soil and Water conservation efficiency of different farming methods.

Treatment/Year	CST		VB (Geranium)		CST alternate with VB		CST+Beans	
	8–12%	30–35%	8–12%	30–35%	8–12%	30–35%	8–12%	30–35%
WCE (%)								
2008	41.4	37.7	16.6	13.5	32.6	29.3	45.8	42.3
2009	47.3	41.4	20.4	22.1	35.6	37.0	48.7	49.0
Mean	44.4	39.5	18.5	17.8	34.1	33.2	47.3	45.6
SCE (%)								
2008	43.4	42.5	−14.7	−9.1	7.8	16.9	41.8	38.7
2009	46.7	45.3	−10.3	−2.0	13.4	22.2	40.1	43.0
Mean	45.0	43.9	−12.5	−5.5	10.6	19.5	41.0	40.8

treatments in the higher slope range due to higher difference in runoff between treated plots and the plot under farmers' practice (control).

Contrary to WCE, soil conservation efficiency (SCE) did not follow exactly similar trend among the treatments in both the slopes. The mean SCE in CST, CST with cover crop of beans, CST alternate with vegetative barrier and vegetative barrier were obtained 45.0%,41.0%,10.6% and −12.5% respectively in slope range of 8–12%. The maximum SCE in CST due to the minimum soil loss as a result of relatively less disturbance on the top soil in comparison to the remaining treatments. This is due the fact that, in the process of growing vegetative barrier and cover crop of beans, the top soil get disturbed repeatedly as compared to the one time making of trenching. The negative soil conservation efficiency is obtained in vegetative barrier alone due to top soil disturbance because of plantation and intercultural operation for establishment leading to excess erosion than farmers' practice of plantation. Similar trend in SCE was also noted in the plots under higher slope range with maximum in CST (43.9%) and minimum in vegetative barrier (T_2) (−5.5%). However, the treatment of CST alternate with vegetative barrier shows modest efficiency in all cases.

There is close difference in water conservation efficiency as well as soil conservation efficiency between CST with cover crop of beans and CST under both the slope ranges in both the years. Therefore, it may be concluded that either CST alone or in combination with cover crop can be suitably adopted for effective soil and water conservation under new tea plantation. Soil conservation efficiency was negative for vegetative barrier of geranium showing insignificant effect in reducing erosion under such condition.

3.3. Soil moisture

Maximum mean soil moisture content of 25.1% was observed in CST followed by CST with cover crop of beans (23.3%) and minimum of 19.4% at 20 cm depth in VB under 8–12% slope during post-monsoon season. Similar result of soil moisture was observed with maximum (24.1%) in CST followed by CST with cover crop to minimum of 18.6% in the plot of farmers' practice under 30–35% slope range. However, the close values of soil moisture contents between CST and CST with cover crop followed by CST alternated with VB shows the effect of CST either alone or in combination in soil moisture conservation. Similar trend in soil moisture among all the treatments at other depths also. Higher soil moisture content can be attributed to runoff retention in the trenches followed by absorption in the soil profile within the root zone. Moisture conservation and higher moisture availability in the soil profile have been reported by Singh et al. (2005) and Regar, Rao, and Joshi (2009) due to conservation measures.

4. Conclusion

Conservation measures in new tea plantation on hill slope are highly effective in controlling runoff and soil erosion due to their conservation effect on top soil and runoff retention. Implementation of CST with cover crop of beans and CST helps in maximum reduction in runoff due to temporary water storage in the trenches followed by absorption, resulted in minimum erosion and better soil moisture in the root zone of the plants. Therefore, either CST alone or in combination with cover crop of beans are recommended for soil and water conservation under new tea plantation in the hill slopes.

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