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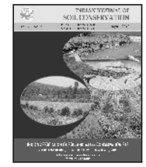

Bio-engineering measures for resource conservation and enhanced productivity in sloping uplands of Eastern ghat region in Odisha

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ABSTRACT

Eastern ghats region of Odisha is highly vulnerable to varying degree of land degradation due to undulating topography, steep slopes, high runoff and soil loss. To combat these problem, an on farm experiment was conducted during 2009-2015 in the research farm of ICAR-Indian Institute of Soil and Water Conservation (IISWC), Koraput for evaluating different bio-engineering measures. Five different bio-engineering measures along with control (farmers' practice) were taken on 4% and 8% slope with cultivation of predominant crop *ragi* of the region. Earthen bunding combined with broom grass produced minimum runoff (11.6%) followed by earthen bunding alone (12.3%) with maximum in farmers' practice (18.7%) of cultivation under 4% slope. Similar trend in runoff was found from 8% slope with minimum in earthen bunding with broom grass (13.7%) and maximum in farmers' practice (24.5%). Unlike runoff, minimum annual soil loss of 8.8 t ha^{-1} resulted from stone bunding combined with broom grass followed by stone bunding alone (8.9 t ha^{-1}) on 4% slope. *Ragi* yield was 14.5 q ha^{-1} followed by 14.0 q ha^{-1} and 13.5 q ha^{-1} from stone bunding with broom grass, stone bunding and earthen bund + broom grass, respectively at 4% slope. Similar trend with lesser yield among the treatments was observed at 8% slope. Maximum water use efficiency (WUE) of 2.1 kg $ha^{-1}mm^{-1}$ was obtained from earthen bund + broom grass followed by stone bund (1.9 kg $ha^{-1}mm^{-1}$) and stone bund + broom grass (1.8 kg $ha^{-1}mm^{-1}$) from both the slopes. Therefore, either type of bunding supported with broom grass may be adopted for managing the sloping upland of Eastern ghat region.

1. INTRODUCTION

Production with conservation is vital of all resource conservation measures and management practices. The stress on resource conservation had been necessitated due to uncontrolled and unlimited exploitation of natural resources like soil, water and vegetation with the sole aim of continuing the production. As far as the sloping land is concerned soil and water conservation (SWC) measures assumes paramount importance. Conservation not only means the physical protection but the quality of these resources, the latter being the crucial concern today.

There is a tremendous pressure on hilly sloping upland in Eastern ghat of Odisha for food production due to high population growth and limited scope in expansion of agriculture in low lands. Rainfed uplands in Eastern ghat of Odisha consist of red soils with medium to high erodibility (Chaudhary *et al.*, 1999) and the slope varies in the range of 2 to 15%. Topographically, the uplands are located just downside the denuded and shifting cultivation ravaged hillocks. Due to high and intense rainfall (about 1,500 mm yr^{-1}) and no or very sparse vegetation, a large amount of runoff generated, which severely erode the downside cultivated lands (silt production rate 5.5-23.7 t $ha^{-1}yr^{-1}$), and thus, jeopardizing the sustainability of crop productivity and ecological balance (Sudhishri *et al.*, 2003). It results lowering in crop production/yield periodically due to high runoff and continuous loss of top fertile soil leading to worst consequences. Among the cereals grown in the uplands, except finger millet, all the other cereals performed poorly than national average (Adhikary *et al.*, 2015). The productivity of these crops is less than 103 kg ha^{-1} (Dass *et al*., 2009) due to land degradation and low soil fertility resulting from the heavy water erosion and meager input use.

The importance of rainwater conservation, erosion control and maintaining soil productivity is increasing for sustaining agricultural production (Sahoo *et al*., 2015). Hence there is an immediate need of implementing of SWC measures, to bring sustainability in agriculture on sloping uplands. The practice of stone bunding is considered to be immediate answer to the increasing erosion induced degradation problems in hill tops slopes of Eastern ghats region of Odisha (Sudhishri *et al*., 2006). The effects of various vegetative barriers and filters on *in-situ* soil moisture conservation and in increasing crop yield were reported by several authors (Chunale and Patil, 2002; Prasad *et al.*, 2005; Tiwari and Kurothe, 2006; Krishna Rao *et al*., 2015, Sahoo *et al*., 2016). In India, a local grass, sambuta (*Saccharum spp*.) growing voluntarily in uplands as well as in waterlogged soils, was found to be as competent as vetiver in reducing the runoff and soil loss when planted on the miniature earthen bunds at a horizontal distance of 10 m on an 11% slope (Sudhishri *et al*., 2008). Contour bund with live bund of *Leucaena lucocephala* achieved the highest grain yield of pearl millet crop (Bhanavase and Bangar, 2002). During initial stage of tea plantation, maximum tea canopy of 34.5% in post monsoon period was found due to the effect of bio-engineering conservation of contour staggered trench with cover crop of beans (Sahoo *et al*., 2014). Higher green tea yield with bio-engineering conservation measures under new tea plantation were recorded over control (Sahoo *et al.*, 2016). Under similar sloping and degraded land condition of Eastern ghat region, where cultivation is practiced without following any conservation practice, instead of only vegetative or mechanical measures, the combination of both called bio-engineering resource conservation measures were experimented and the efficacy was evaluated to maintain sustainable production with resource conservation.

2. MATERIALS AND METHODS

Study Area

On farm experiment was conducted during 2009-2015 in the research farm of ICAR-IISWC, Koraput for appraising different bio-engineering resource conservation measures. The site represents the most common 4-8% sloppy area in the Eastern ghat region of Odisha used for growing rainfed crops like *ragi*, Niger and Upland paddy by the tribal people without any protection measures for runoff and erosion control. The effective rainfall in the experimental area is about 900 mm during the cropping period. The soil represents to red lateritic *Udic Paleustalfs* with sandy loam texture (sand 64.5%, silt 19.3% and clay 16.2%). The surface soil had organic carbon content of 0.38% with available N, P, K of 186.5 kg ha^{-1}, 6.0 kg ha^{-1} and 294.6 kg ha^{-1}, respectively. The soil depth in the area under cultivation is about 0.9-1.0 m with initial soil organic C (%) content at soil depths of 0-15 cm and 15-30 cm are in the range of 0.52-0.536% and 0.324-0.335%, respectively. Higher Organic C was found in surface soil from all the cultivated plots. The pH and EC values found in the range of 5.4 to 6.02 and 5.32-6.95 μS cm^{-1} respectively from both the soil depths.

Experimental Details

The experiment was laid out in randomized block design on two slopes (4% and 8%) in plots size of 800 m^2 with two stone/earthen bunds and/or vegetative barrier of broom grass across the slope, thereby dividing the plot into three replications (Photo 1). Five bio-engineering conservation measures and one farmers' practice of cultivation (Table 1) were taken with a test crop of *ragi* sown at spacing of 15 x 10 cm and recommended seed rate of 10 kg ha^{-1}. The broom grass planted in double row, staggered at row to row and plant to plant spacing of 50 cm and 20 cm, respectively. Pre-emergence herbicide was applied in all the treatments two days after sowing to control weeds. The basal dose of nitrogen, phosphorus and potassium were applied in the form of DAP and MOP @ 220 and 110 kg ha^{-1}, respectively. Manual hand weeding was done and split dose of nitrogen was applied at one month after sowing.

Runoff and Soil Loss Monitoring

The gauging devices (stage level recorders) with

Photo 1. Stone and earthen bunding with broom grass

Table: 1
Treatment details of conservation measures

Treatments	Specification
T_1: Stone bund + broom Grass	Graded bund (cross section - 0.56 m^2 and slope - 0.6%)
T_2: Stone bund	Graded bund (cross section - 0.56 m^2 and slope - 0.6%)
T_3: Earthen bund + broom grass	Graded bund (cross section-0.4 m^2 and slope - 0.6%)
T_4: Earthen bund	Graded bund (cross section-0.4 m^2 and slope - 0.6%)
T_5: Broom grass	Double row, staggered (row to row - 50 cm and plant to plant 20 cm)
Control	No conservation measure

Coshocton wheel silt sampler are installed at the down end of the plots for runoff monitoring. The plots were separated to isolate the runoff from the adjacent plots with earthen bunds along the slope and as per the bioengineering measures across the slope. Runoff analysis was made on daily basis and expressed in mm. The soil loss was estimated from runoff sample of 500 ml collected from runoff tank after stirring to determine the silt content. The collected sample is allowed to settle down the sediments and then filtered and oven dried at 105^0C for 24 hrs. The weight of the sample is measured and estimated following the standard procedure and total soil loss is estimated by adding the soil loss from all the events and expressed in t $ha^{-1}yr^{-1}$.

Water Use Efficiency (WUE)

The amount of soil moisture within the root zone depth (30 cm) was considered for the estimation of WUE. The actual crop water use was calculated using the following water balance equation:

$$Rn = R + \Delta S - D + \int Fx\, dt \quad ...(1)$$

Where, Rn = Net rain water used during the year (mm), R = Rainfall of the year (mm), ΔS = Change in soil moisture storage (mm), Initial soil moisture (mm) – Final Soil moisture (mm), D = Runoff (mm), Fx = Soil moisture contribution due to capillary action over time t (Negligible due to slope, shallow root zone and deep water table).

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

$$\Delta S = \frac{(M_2 - M_1) \times \varrho_b \times d_1}{100} \quad ...(2)$$

Where, M_1 and M_2 are the percentage of soil moisture on weight basis in the beginning and end of the cropping period. ϱ_b = Bulk density, d_1 = Root zone depth (cm).

Water use efficiency (RWUE) was determined by dividing the *ragi* yield (kg) with the net rain water (mm) used.

3. RESULTS AND DISCUSSION

Runoff

The annual runoff for the cropping period (July to November) during the experiment period was monitored from all the treatments under both the slopes (Fig. 1). Minimum runoff of 11.6% was obtained from earthen bunding supported with broom grass followed by earthen bunding alone (12.3%) under 4% slope. However, stone bunding supported with broom grass (12.5%) and stone bunding alone (13.2%) also successfully reduced the runoff in comparison to control plot (18.76%). The runoff from all treatments found significantly different from control at 5% level

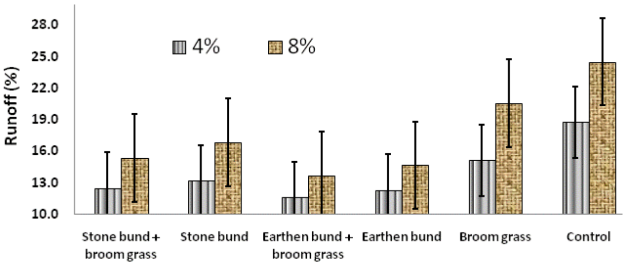

Fig. 1. Annual runoff (%) from different bio-engineering measures

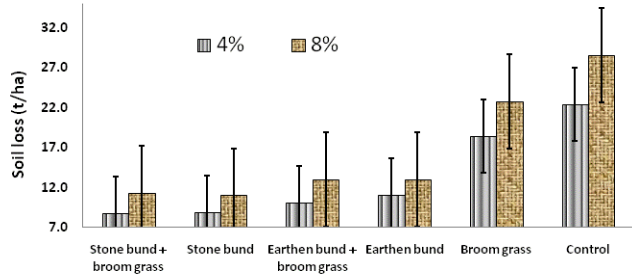

Fig. 2. Annual soil loss (t ha^{-1}) under different bio-engineering measures

of significance (CD (0.05) = 3.4). The difference in runoff from either type of bunding (earthen/stone) or either type of bunding supported with broom grass are found statistically insignificant among them. Maximum runoff was observed from all the conservation measures under both the slopes during first year of experiment due to poor settlement of bunds as well as establishment vegetative measures. The decreasing trend in runoff over the years in the treatments under both the slopes are due to settlement of bunds and establishment of the broom grass where it is combined with bunding. Higher runoff from respective treatment with similar trend was observed from all the plots under 8% slope than the plots under 4% slope due to the direct effect of higher slope. The minimum runoff observed in earthen bunding combined with broom grass (13.7%) followed by earthen bund (14.7%) and stone bund + broom grass (15.3%) and maximum in control (24.5%) at 8% slope. Similar to 4% slope, the difference in runoff from either type of bunding (earthen/stone) or either type of bunding supported with broom grass are found statistically insignificant among them and significantly different from control at 5% level of significance (CD (0.05) = 4.17). The runoff from the treatment of broom grass alone was also found statistically insignificant from control in 8% slope thereby not effective when treated alone.

Soil Loss

Minimum annual soil erosion of 8.8 t ha^{-1} was observed from stone bunding combined with broom grass followed by stone bunding alone (8.9 t ha^{-1}) at 4% slope (Fig. 2). Unlike runoff, the annual soil erosion was not minimum either in earthen bunding supported with broom grass nor in earthen bunding alone due to the fact that earthen bund itself contribute soil loss during initial years of bunding resulting from the repair and maintenance of earthen bund in comparison to stone bund. Therefore, as far as reduction in soil loss is concerned, stone bund performed better due to better solidity and no further maintenance or disturbance in comparison to earthen bund. Therefore, despite more runoff in stone bunding, the sediment concentration is less in the runoff sample from the plot with stone bunding than earthen bunding. However, all the treatments other than vegetative measure of broom grass alone were effectively reduced the soil erosion and found statistically significantly different from control plot (22.4 t ha^{-1}) at 5% level of significance (CD (0.05) = 4.6). Vegetative barrier of broom grass alone is not much effective either in controlling either runoff or soil loss in both the slopes. Similar trend in soil loss was observed from all the plots under 8% slope. Maximum soil loss was observed from all the conservation measures under both the slopes during first year and decreased over years due to establishment of treatments. Higher soil loss was also observed in treatments under 8% slope in comparison to the corresponding treatments in 4% slope, due to direct effect of higher slope and runoff. Minimum annual soil erosion of 11.0 t ha^{-1} was observed from stone bunding followed by stone bunding combined with broom grass alone (11.3 t ha^{-1}) at 8% slope with maximum of 28.6 t ha^{-1} in control. Over the time, the space in stone bund fully sealed with soil and resembled like any permanent RR masonry bund, thereby causing minimum soil erosion. Similar to 4% slope, all the treatments other than vegetative measure of broom grass alone in 8% slope were effectively reduced the soil erosion and found statistically significantly different from control plot at 5% level of significance (CD (0.05) = 5.9).

Crop Yield and Water Use efficiency

Variation in the *ragi* yield was observed under different bio-engineering measures during the experiment period. Maximum yield of 14.5 q ha^{-1}

followed by 14.0 q ha^{-1} and 13.5 q ha^{-1} were recorded from stone bunding with broom grass, stone bunding and earthen bund + broom grass, respectively at 4% slope with minimum in control (9.6 q ha^{-1}). Similar trend in yield was also obtained from the treatments under 8% slope with insignificant variation in either type of bunding alone or in combination of broom grass. But the yield in control plots is minimum in both the slopes and the difference is quite significant from all the treatments. Higher yield was obtained from all the treatments in 4% slope in comparison to the corresponding treatment in 8% slope during entire period of experiment. The *ragi* yield was found in decreasing trend over the years despite decreasing runoff (%) as well as soil erosion in both the slopes. This may be due to the fact that, in the later part of the experiment, insufficient rain received for initial few days after sowing followed by heavy rain resulted in poor growth and weed infestation. The WUE (Fig. 3) was estimated using crop yield from different treatment measures from both the slopes with the net rainwater absorbed. The maximum rain water-use efficiency of 2.1 kg $ha^{-1}mm^{-1}$ was obtained from earthen bund + broom grass followed by stone bund (1.9 kg $ha^{-1}mm^{-1}$) and stone bund with broom grass plantation (1.8 kg $ha^{-1}mm^{-1}$). Lowest WUE of 1.2 kg $ha^{-1}mm^{-1}$ was obtained from the control plot showing the effect of conservation measures either alone or in combination for higher WUE.

4. CONCLUSIONS

Bio-engineering conservation measures for managing the sloping upland of Eastern ghat region of Odisha are highly effective in controlling runoff and soil erosion. Among different bio-engineering measures, considering the control in runoff and soil erosion, crop yield and WUE and other effectiveness of earthen bunding supported with broom grass is found as very good bio-engineering SWC measures. However, due to in significant difference in SWC values, yield and overall performance, any bunding combined with vegetative barrier of broom grass can be adopted for resource conservation and enhanced productivity.

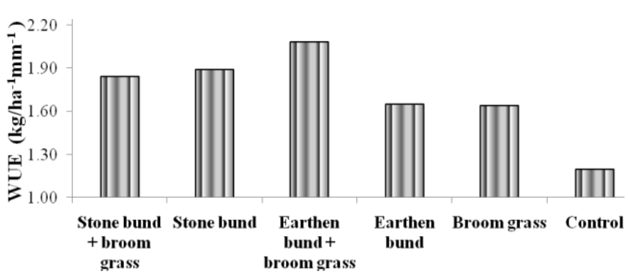

Fig. 3. Water use efficiency under different bio-engineering measures

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