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Comparison of Indigenous and Mechanical Conservation Technologies for Shifting Cultivation Agro-Ecology of North-eastern Himalaya

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Traditional shifting cultivation with reduced cycle aggravates soil erosion more rapidly in north-eastern India. To address this issue, an erosion plot experiment was conducted from January 2013 to December 2014 at Wokha district of Nagaland, India with five treatments *viz.*, control (T_1), bench terraces (T_2), contour bunds (T_3), bamboo fence (T_4) and wooded log (T_5). Soybean (cv. JS-335) was grown with the standard package and practices. The main objective was to find out the best suitable soil conservation measure to arrest the soil and nutrient loss. The annual soil erosion was measured the highest in treatment T_1 (70.1 t ha^{-1}) followed by T_5 (25.2 t ha^{-1}), T_4 (13.5 t ha^{-1}), T_3 (6.20 t ha^{-1}) and T_2 (0.94 t ha^{-1}) in the first year. In the second year, the extent of soil erosion was reduced, and it followed the order of T_1 (50.7 t ha^{-1}) < T_5 (20.3 t ha^{-1}) < T_4 (8.92 t ha^{-1}) < T_3 (4.62 t ha^{-1}) < T_2 (0.54 t ha^{-1}). Subsistent amount of clay, silt, sand, soil organic matter, major nutrients and micronutrients were lost in both the years. It was also found that the monetary loss in terms of only nitrogenous and potassium fertilizers was contributed 74.9 to 83.2% in the year 2013 and 50.7 to 70.8% in the year 2014, respectively. Considering all treatments across the years, bench terracing across the slope (T_2) is found as the most suitable, but economic point of view, contour bund (T_3) may be recommended for this region.

Key words: Indigenous technical knowledge (ITK), shifting cultivation, soil conservation, soil erosion

Worldwide it was anticipated that more or less 75 billion tonnes (Bt) of fertile soils are lost from the agricultural land each year (Lal 1998; Eswaran *et al.* 2002). In India, about 6.6 Bt of soils are lost per year from the agriculture system (Lal and Stewart 1990; Wen 1993). It has been also estimated that a total of 5,334 million tonnes (Mt) of soil is lost every year at the rate of 16.4 t ha^{-1} annually only by water erosion (Narayan and Ram 1983). Principally, in north-eastern India, the average annual loss of topsoil due to shifting cultivation is 0.9 t ha^{-1} (ICAR 1983). The annual loss of soil from a small experimental plot of shifting cultivation area varied from 30 to 170 t ha^{-1} yr^{-1} (Singh *et al.* 1992).

The North-Eastern Hill (NEH) region of India receives quite a sufficient amount of rain (more than 2000 mm) and the agricultural activities are mostly confined to steep hill slopes. Soil erosion by water, therefore, is the major factor causing land degradation and environmental deterioration. The degradation process is often activated and accelerated by inappropriate land use and/or poor management practices. In this erosion process, water is usually acting as a medium being involved in the soil erosion and nutrient leaching process by enhancing the water runoff in that way decreasing water infiltration and water holding capacity of the soil (Troeh *et al.* 1991). In addition, soil organic matter (SOM) and essential plant nutrients are also transferred from the soil due to which soil depth is getting reduced. Traditional shifting cultivation practices on undulating topography, with a higher magnitude of rainfall, and negligible or without conservation measures in the field compounds the problem manifold.

The shifting cultivation in this region is known to be the first step in the transition from food gathering or hunting to food production and believed to have originated in the Neolithic period around 700 BC (Mandal and Ete 2010). In this system, the land is

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primarily cleared by cutting of the forests, bushes, *etc*. up to stump level during December-January, leaving the slashed materials for drying and final burning to make the land ready for dibbling of seeds of different crops before the onset of monsoon. After 2-3 years, the cultivated area is kept abandoned for natural built-up of soil fertility and a new site is selected to repeat the same process. Initially, when the shifting cultivation originated, it followed the cycle of 15-20 years, enabling the soils to mine adequate nutrients from the sub-soil and enrich the surface soil through decomposition of the litterfall. But, over the past few decades, the NEH region has experienced rapid population growth, which has resulted in expanding cultivation on to marginal land and the cycle reduced to 3-5 years, which hardly provide time for naturally regenerated of soil fertility. Excessive deforestation coupled with shifting cultivation practices have resulted in tremendous soil loss (Saha *et al.* 2012), poor soil physical health, and an uncountable loss of biodiversity. In a study, Saha *et al.* (2011) studied soil erodibility characteristics of six land-use systems and observed that shifting cultivation had the highest erosion ratio (12.5), followed by agriculture (10.4) and other land use systems, indicating the need to adopt tree-based land-use systems for resource conservation. They also reported that soil loss was significantly higher in shifting cultivation (30.2–170.2 t ha^{-1} yr^{-1}), agriculture (5.10–68.2 t ha^{-1} yr^{-1}), and the livestock-based land-use systems (0.88–14.3 t ha^{-1} yr^{-1}) as compared to other modified land-use systems.

Adoption of mechanical conservation measures may assist in minimizing erosion by controlling the localized runoff through reducing the length and/or degree of slope and dissipating the energy of flowing water (Sharda *et al.* 2002). Live-bunds or vegetative barriers are the alternative biological conservation measures and effectively conserve soil and water by moderating the surface runoff (Dass *et al*. 2011) and can facilitate in minimizing the runoff by 18-24% (Ranade *et al.*1995). At the same time, the deficiency in availability of the effective planting materials of the vegetative barriers in the locality is very hard and also needs high level management to grow in hilly tracks, which also becomes difficult for the small and marginal farmers besides the scarcity of adequate rainfall during post-wet season as well having the damage problems of roots by termites and rodents in that season. For this understanding, accepting of the mechanical and technically modified indigenous technical knowledge (ITK) conservation technologies by utilizing locally available materials may possibly become a very significant conservation technique for this region to reduce soil erosion losses.

There is a very scanty of work on the efficacy of conservation measures on soil and nutrient losses under shifting cultivation system. So far, under the complexity of such system, a few attempts might be made. Keeping all the above facts under consideration, a field experiment was conducted with five different conservation measures to study (a) the loss of soil along with its particle distribution *i.e.* loss of sand, silt, clay fractions among the treatments, (b) the effect of conservation practices in reducing loss of major and micronutrients, and (c) sustainability in crop performance and to evaluate soil fertility loss under five conservation systems.

Materials and Methods

Study area

A field experiment was conducted for two years from January 2013 to December 2014 at ICAR Research Complex for NEH Region, Nagaland Centre, Krishi Vigyan Kendra, Wokha, Nagaland, India (26°01.449' N latitude; 94°15.722' E longitude) at 1215 m above sea level with 21% slope. The agro-climatic zone is temperate, sub-alpine to sub-tropical hill. The mean annual rainfall for the last five years was 1996 mm with more than 88% occurring during the period from April to October. The average monthly temperature during the year varied widely between 7.4 to 30.1 °C. The total annual rainfall received in 2013 was 1925 mm (Fig. 1), out of which 24.4% received as pre-monsoon rainfall, 72.7% received as monsoon (June-September) rainfall and 2.9% received as post-monsoon rainfall. The total annual rainfall recorded in 2014 was 1897 mm (Fig. 1) and 10.9% of it was received as pre-monsoon rainfall, 87% as monsoon rainfall and 2.2% as post-monsoon rainfall.

The surface soil (0-20 cm) of the experimental site may be characterized as loamy in texture (clay 21.5%, silt 36.0%, sand 42.5%) with a pH of 5.23, electrical conductivity (EC) 0.255 dS m^{-1}. The experimental soil had organic carbon (OC) 2.88%, available nitrogen (N) 216.4 kg ha^{-1}, available phosphorus (P) 18.8 kg P_2O_5 ha^{-1}, available potassium (K) 539 kg K_2O ha^{-1}, DTPA extractable iron (Fe) 4.76 mg kg^{-1}, manganese (Mn) 1.96 mg kg^{-1}, copper (Cu) 1.02 mg kg^{-1}, zinc (Zn) 0.92 mg kg^{-1} and hot water soluble boron (B) 0.62 mg kg^{-1} were recorded in the soil. According to rating limits of soil test values

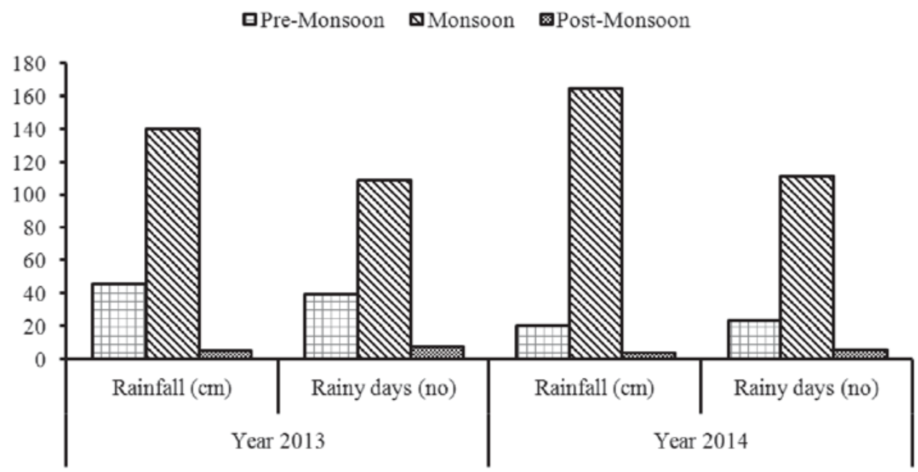

Fig. 1. Rainfall pattern and number of rainy day at pre-monsoon, monsoon (June-September) and post monsoon during the study period

(Muhr *et al.*1965; Soltanpour and Schwab 1977), the soil was salt free and strongly acidic in nature, with high OC, low in available N and P, high in available K, moderate in DTPA extractable Fe, Mn and hot water soluble B, high in DTPA-Cu and low in Zn content.

Experimental details

A field experiment was conducted with five different conservation measures mainly control/non-conservation (T_1), bench terraces across the slope (T_2), contour bunds across the slope (T_3), bamboo fence across the slope (T_4) and wooded log across the slope (T_5). The study site was established in mid-slope pen location on the side of a mound with a mean slope of 21%, which allowed the overland flow to the drain uniformly from the experimental/runoff plots. The plot size was of 22.1 m × 3 m (66.3 m^2) in all treatments. The plots were equipped with CGI sheet border (0.2 cm thick) at the upslope end and on the two long sides and these runoff plots were also separated from each other runoff plot by using 40 cm high over-ground and 30 cm deep underground to prevent between the plot flow of surface and groundwater, respectively. At the lower end of the plot, a concrete wall (300 cm × 30 cm × 70 cm) was constructed with the bricks and mortar, to obstruct the runoff. A 'L' size heavy plastic drainage pipe (15 cm diameter) was also placed at the centre of the concrete bund during construction and connected to the 1000 L runoff collection plastic tank. Soybean (cv. JS-335) was grown with the standard package and practices which is including minimum tillage, proper seed rate (30 kg ha^{-1}), spacing (20 cm × 40 cm), hand weeding (20 and 40 days after sowing) and the application of N-P-K considering the recommended doses 20, 60 and 30 kg ha^{-1}, respectively, applied at the basal stage of soybean. Each year soybean was sown during the last week of April and harvesting was done in the first week of July.

To study the variation in soil, water runoff losses, four soil conservation techniques, including two each mechanical and scientifically modified ITK were adopted along with a control plot replicated thrice (Table 1).

Analytical methods

Daily basis rainfall was recorded by from an automatic weather station (Antrix Corporation Limited, ISRO, Bangalore, Model no. DCPAWSO2) 150 m near by the experimental runoff plots. Monitoring and recorded the runoff data after each rainfall event from 1st January to 31st December in all the year (2013-2014). To estimate the runoff volume that is generated from each runoff plot was measured by reading scale attached to the runoff collection plastic container and then collected runoff water was mixed and two bottles of 1 L of the mixed were transferred to a high-density polythene bottle. These water sample bottles (one bottle from each runoff plot) were kept in the plastic pan to dry under shade at room temperature and dried samples were further analyzed to estimate soil nutrient (available N, P, K, OC, Fe, Mn, Cu, Zn and B) loss. Another bottle of collected runoff water was used to determine accumulated sediment in the runoff tank of each plot. The resultant suspensions were filtered using Whatman No. 42 and then the sediment in the filter

Table 1. Treatment details including type of soil conservation, technology and specification

Treatments	Conservation practice	Conservation type	Technology details	Specification
T_1	Control	No	No	Nil
T_2	Bench terraces	Mechanical	Prepared bench terraces across the slope	Prepared bench terraces at 3 m width, with 0.5% longitudinal gradient and 1.5% inward gradient
T_3	Contour bunds	Mechanical	Mechanical (earth made) contour bund developed across the slope	Contour bunds developed at 3 m vertical intervals with 30 cm top × 20 cm deep parabolic channels on contour by using “A” fame
T_4	Bamboo fence	ITKs	Bamboo fence was placed across the slope	Used locally available bamboo (one fourth of bamboo with 9-10 cm diameter) as fence with 30 cm height at 3 m vertical intervals
T_5	Wooded log	ITKs	Wooded log was used across the slope	Used field available wood log (1 No) with 13 cm diameter as fence at 2 m interval across the slope

paper was oven dried for 24 h at 105 °C. Soil loss was calculated by multiplying sediment concentrations by corresponding flow volumes.

Initial soil samples (n=5) were collected before the start of the experiment in January 2013. Both the initial and final soil samples (0-20 cm) were air-dried and passed through a 2-mm sieve for determination of soil pH, EC in a 1:2.5 soil: water suspension (Page *et al.* 1982), oxidizable OC by the method of Walkley and Black (1934), available N by the alkaline $KMnO_4$ method (Subbiah and Asija 1956), available P by Bray and Kurtz (1945), NH_4OAc extractable K (Jackson 1973), DTPA extractable Fe, Mn, Cu, Zn (Lindsay and Norvell 1978) and hot water soluble B (Berger and Truog 1939). Initial, final and sedimented soil texture was determined by using a Bouyoucos hydrometer (Bouyoucos 1927).

Statistical analysis

The data on yield and yield attributes of soybean were analyzed in a randomized block design with five treatments by using statistical software Indostat (v.13.0). The statistical analysis of the erosion and soil nutrient loss data was performed using SPSS statistical program (v.16.0).

Results and Discussion

Measurement of runoff and soil erosion

The total monthly rainfall during the erosion period (April to September) was recorded 1834 mm and 1827 mm with 146 and 129 nos. of rainy-days with rainfall ranged from 1 to 42 mm during the year 2013 and 2014, respectively (data not shown). The monthly average runoff percentage in the control plots (T_1) varied between 3.35 to 4.28%, decreasing from 0.41% (T_2) to 3.41% (T_5) in the treated plots (Fig. 2) during the period of study. The runoff during April 2014 was recorded nil which was mainly because of very little (only 4 mm) rainfall during that period. In 2014, the annual runoff was also more or less similar to the year 2013, but in the second year (2014) water runoff percentage was little higher than the first year (2013) in both the control and the treated plots because the amount of average rainfall event during the monsoon period was higher in the year 2014 (14.7 mm) as compared to the year 2013 (12.8 mm).

In the 1st year (2013), month-wise water runoff percentage (Fig. 2) in control (T_1) ranged between 1.60 to 5.22%, decreasing from 0.09 to 4.11% in the treated conservation plots (T_2-T_5). In the same year, month-wise soil erosion in the untreated plots (T_1) varied between 1.68 to 24.6 t ha^{-1}, whereas in the treated plots, it was only from 0.02 to 8.33 t ha^{-1} (Table 2). The annual soil erosion measured was the highest (70.1 t ha^{-1}) in treatment T_1 followed by T_5 (25.2 t ha^{-1}), T_4 (13.5 t ha^{-1}), T_3 (6.20 t ha^{-1}) and T_2 (0.94 t ha^{-1}). In 2013, the annual performance of the conservation plots among the all treatments ranging from 64% (T_5) to 98.7% (T_2) over the control (T_1) plot. In the year 2014, monthly water runoff percentage (Fig. 2) in the untreated plots (T_1) ranged between 3.85 to 6.34% with a mean value of 4.28%, decreasing from 0.79 to 5.13% in the treated conservation plots (T_2-T_5). The conservation practice also reduced the annual soil erosion and follow the order T_1 (50.7 t ha^{-1}) < T_5 (20.3 t ha^{-1}) < T_4 (8.92 t ha^{-1}) < T_3 (4.62 t ha^{-1}) <T_2 (0.54 t ha^{-1}). Month-wise

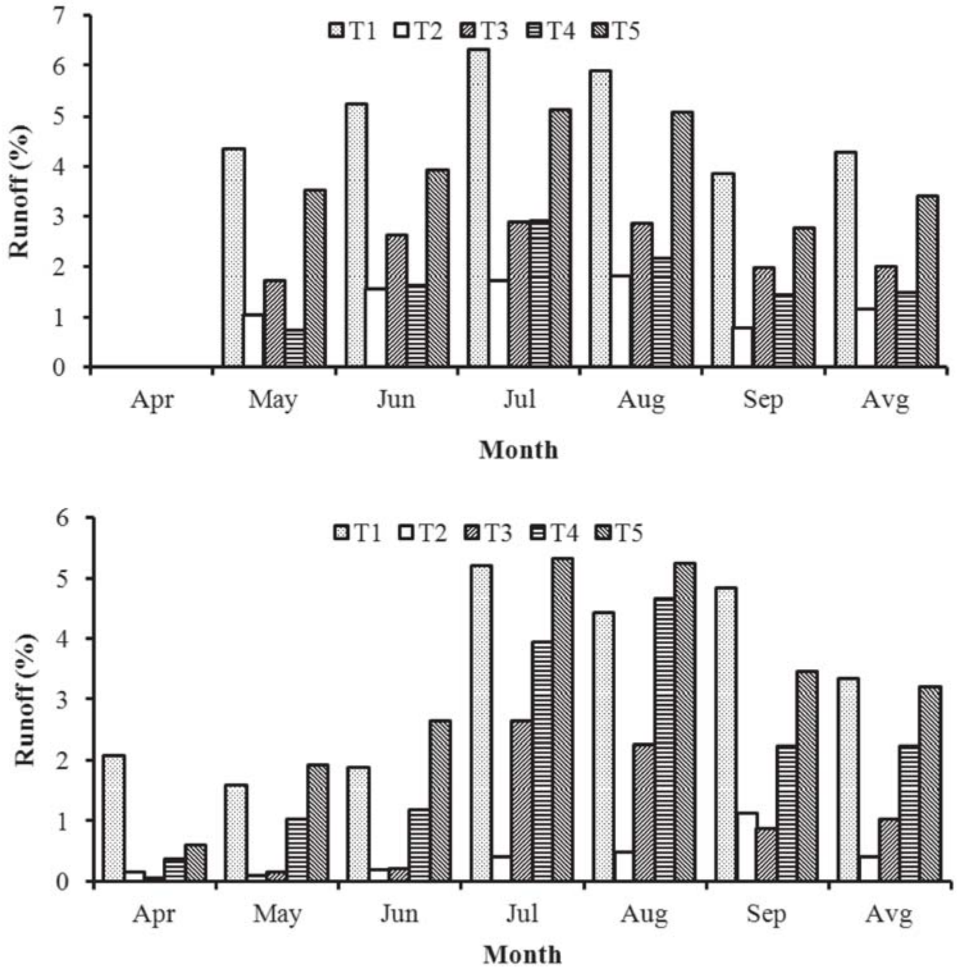

Fig. 2. Monthly and average runoff variation during the study period (2013-2014)

Table 2. Month-wise and annual variation in soil erosion under different conservation treatments under study

Month	Year-I ($t\ ha^{-1}$)					Year-II ($t\ ha^{-1}$)				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
April	1.68	0.02	0.07	0.38	0.61	-	-	-	-	-
May	6.13	0.04	0.16	1.19	1.92	3.92	0.04	0.30	0.75	1.59
June	6.46	0.08	0.21	3.95	2.64	7.84	0.09	0.75	1.64	2.94
July	24.6	0.24	2.64		8.33	17.25	0.18	1.51	2.90	6.98
August	20.8	0.27	2.25	4.67	8.26	14.12	0.17	1.31	2.18	6.08
September	10.5	0.29	0.87	2.23	3.47	7.61	0.06	0.75	1.45	2.75
Total	70.1	0.94	6.2	13.5	25.2	50.7	0.54	4.62	8.92	20.3
SE	0.24	0.01	0.04	0.11	0.13	0.22	0.01	0.02	0.09	0.04
CD (P<0.05)	0.74	0.037	0.11	0.33	0.39	0.66	0.02	0.07	0.28	0.13

soil erosion varied between 3.92 to 17.3 $t\ ha^{-1}$ at the control plots (T_1), and from 0.04 to 6.98 $t\ ha^{-1}$ in the treated plots (Table 2). The results of the soil erosion losses indicated that the conservation practices may reduce the loss of soil below the threshold value (at the rate of 10 $t\ yr^{-1}$) of the soil loss rate to maintaining productivity (Polyakov and Lal 2003). Bench terracing (T_2) conservation measures caused a significantly higher reduction in percentage water runoff which might be more suitable for greater infiltration of runoff obstructed and retained on the upstream side of the barrier in the soil. Bench terracing controls soil erosion by limiting runoff speed, by increasing the infiltration of the surface water into the soil

(Widomski 2011). Because of that terracing is promoted as the best management practice for effective soil and water conservation in many places (Wheaton and Monke 2001). Bamboo acts as soil binder which facilitates soil nutrient recovery and creates microhabitats for regeneration of shade-loving species (Rao and Ramakrishnan 1989). It also checks the runoff water as well as soil erosion by heavy rain.

Soil particle losses

The losses of clay soil particles (Table 3) vary significantly among the different conservation practices and the quantity of clay particles losses was directly associated with total soil runoff losses of the treatments. The percentage of the clay particle losses in sediment (Table 3) from the total soils within different treatments varied widely from 30.1 to 55.6% during the study period. In both the year of observation, the percentage clay particle losses were found to be lowest with T_2 (30.1% in 2013 and 30.2% in 2014). Nevertheless, in the year 2013, loss of clay particles was little higher than the year 2014 in most of the treatments which may be due to the presence of the more fine clay particles in the surface soils. In both the year, percentage losses of silt particles (Table 3) through runoff was much lower than the percentage loss of clay particles. However, the ratio of silt particle losses as the percentage among the different treatment varied, considerably from 28.9 to 42.0% in the two years of experiment. The percentage loss as sand particles (Table 3) with runoff was much lower than the loss percentage of clay and silt particles. In the year, 2013, the percentage losses of sand particles varied from 9.6 to 27.2% and in 2014 the loss percentage was from 15.3 to 30.4%, respectively and found relatively higher with untreated plots. Conservation measures increase the water infiltration rates, thereby minimize the soil particle loss as compared to control. The loss of sand particles was relatively less as compared to the clay and silt particle as these particles are fine and medium in nature and more easily eroded with runoff. The higher OC losses (609 to 912 kg ha^{-1}) was observed (Table 3) with non-conservation plot (T_1) and the lowest was found with the T_2 (7.8 to 14.4 kg ha^{-1}) conservation plot. The SOC loss followed a similar trend in both the year, although the quantity of SOC losses was comparatively higher in the year, 2013 than the year, 2014. This study indicated that the bench terracing is competent enough in arresting the loss of SOC, then the other conservation measures. Dass *et al.* (2011) reported soil OC losses from 50.0 to 102.1 kg ha^{-1} under different conservation practices. Relatively higher magnitude of soil loss was held responsible for the higher loss of soil OC from the soils.

Nutrient losses

The average loss of soil nutrients at different conservation measures are shown in table 4. Higher N losses (5.2 to 7.6 kg ha^{-1}) were observed in untreated (T_1) plots for both the year of study. Bench terracing conservation (T_2) was able to arrest available N from 98.5 to 98.5 per cent over to the control (T_1). Different conservation practices can arrest the nutrient losses from the sloppy soils as compared to control for both the year of experimentation. Nitrogen is the most important essential plant nutrient. It is highly prone to losses through the surface and sub-surface runoff in sloppy areas and causes the contamination of the surface water streams. The higher level of soil loss was directly responsible for the larger loss of soil available N. Prasad *et al.* (2005) and Bhanavase *et al.*

Table 3. Quantitative and percentage losses of soil particles (clay, silt, sand) and soil organic carbon (SOC) at different conservation measures

Treatments	Year-I (kg ha^{-1})				Year-II (kg ha^{-1})			
	Clay	Silt	Sand	SOC	Clay	Silt	Sand	SOC
T_1	29414	22355	17441	912	18801	21208	10128	609
	(41.9)	(31.9)	(24.9)	(1.30)	(37.1)	(42.0)	(20)	(1.20)
T_2	284	387	256	14.4	161	203	162.1	7.75
	(30.1)	(41.2)	(27.2)	(1.53)	(30.15)	(38.04)	(30.36)	(1.45)
T_3	2981	2518	598	103	1879	1821	829	102
	(48.1)	(40.6)	(9.64)	(1.65)	(40.59)	(39.32)	(17.90)	(2.20)
T_4	7483	3881	1881	205	3832	3446	1512	130
	(55.6)	(28.9)	(14.0)	(1.53)	(42.97)	(38.63)	(16.95)	(1.45)
T_5	12505	9348	3008	359	8590	8369	3111	265
	(49.6)	(37.1)	(11.9)	(1.42)	(42.24)	(41.16)	(15.30)	(1.30)

*Values in parentheses indicates percentage of total soil loss

(2007) also reported more or less similar N losses (3.04 to 5.72 kg ha^{-1}) under various grass barriers conservation plots. Significantly higher available N status in T_3 is attributed to the lowest loss of nutrient.

Among the different conservation treatments, there was relatively much lower loss of soil P with T_2 (0.01 kg ha^{-1}) and T_3 (0.04-0.06 kg ha^{-1}), compared to the other treatments (0.07-0.61 kg ha^{-1}). Mechanical soil conservation practices decreased the loss of soil P from the sloppy field of shifting cultivation as compared to the other conservation measures. The annual loss of soil P was negligible, as P is relatively less soluble, fixed strongly by the soil particles and leached slowly from the soils at a very much slower rate than the other nutrients (Shuman 2001; Dass *et al.* 2011). Maximum decline of available soil P was observed in T_2 and minimum in T_3. The contrast results in respect to the loss of soil available P in bench terracing (T_2) may be due to the maximum mixed up of surface and sub-surface soils during the construction stage of bench terraces and get less exposed.

Annual K nutrient loss (Table 4) through runoff was minimized by the involvement of the conservation practices (Table 4) compared to the loss of K in control plot (10.3-18.8 kg ha^{-1}). In the year, 2013, bench terracing (T_2), contour bunding (T_3), bamboo fence (T_2) and wood log (T_3) reduced the annual available K loss of 0.25, 1.31, 3.58 and 7.27 kg ha^{-1}, respectively. Like N, K is readily soluble in water and prone to high loss (Dass *et al.* 2011). The higher K loss was found in control, as the K is readily soluble in water. The different conservation practices also significantly reduced K losses in the year, 2014 and maintained the similar order as the year, 2013, but relatively lower losses were observed (2014) with range value from 0.14 (T_2) to 5.86 (T_5) kg ha^{-1}.

The highest annual losses of DTPA-Fe was 103.7 g ha^{-1} (T_5) in 2013. On the contrary, the highest (118.2 g ha^{-1}) loss of DTPA-Fe was found when no conservation measures were taken up (T_1) in 2014. In this study, Fe loss was affected by different conservation practice and the lowest loss was observed in bench terracing (T_2) (2.20 to 4.91 g ha^{-1}) for both the year. The annual DTPA extractable-Mn loss ranged from 1.28 to 64.3 g ha^{-1} soil. It was observed that the mechanical conservation practice was more useful to reduce Mn losses and among them, bench terracing was the most effective method. Comparatively higher losses of Mn were observed in 2013 than 2014 for all the treatments. In both the year, minimum runoff loss of Cu was found in T_2

Table 4. Average annual losses of primary nutrients and micronutrients in soil at different conservation measures

Treatments	Year-I									Year-II								
	Primary nutrients (kg ha^{-1})			Micronutrients (g ha^{-1})					Total (kg ha^{-1})	Primary nutrients (kg ha^{-1})			Micronutrients (g ha^{-1})					Total (kg ha^{-1})
	N	P	K	Fe	Mn	Cu	Zn	B		N	P	K	Fe	Mn	Cu	Zn	B	
T_1	7.56	0.61	18.8	85.6	38.6	28.1	21.7	35.8	27.1	5.19	0.35	10.4	118.2	48.2	25.9	21.3	11.2	16.2
T_2	0.11	0.01	0.25	4.91	1.98	0.48	0.73	0.42	0.38	0.08	0.01	0.14	2.20	1.28	0.49	0.61	0.32	0.23
T_3	0.78	0.06	1.31	19.3	12.7	6.88	8.43	1.30	2.21	0.70	0.04	1.51	14.9	11.9	4.12	5.65	1.53	2.29
T_4	1.85	0.14	3.58	74.2	47.8	8.74	11.7	6.72	5.72	1.07	0.07	2.38	36.4	29.1	9.28	7.76	4.64	3.60
T_5	3.83	0.23	7.27	103.7	64.3	13.9	13.1	13.1	11.5	2.53	0.14	5.86	78.9	43.5	12.4	11.4	5.08	8.69
SE	0.16	0.01	0.41	2.04	1.20	0.53	0.66	0.67		0.10	0.02	0.22	3.33	1.49	0.46	0.46	0.30	
CD (P<0.05)	0.50	0.05	1.34	6.64	3.90	1.72	2.15	2.18		0.33	0.05	0.72	10.9	4.86	1.51	1.48	0.98	

(0.48 to 0.49 g ha^{-1}), while the maximum runoff loss of Cu was detected in control (25.9 to 28.1 g ha^{-1}). Loss of DTPA extractable-Zn was found highest in untreated (T_1) plot (21.3 to 21.7 g ha^{-1}). The annual loss of hot water soluble B was lowest in T_2 (0.32-0.42 g ha^{-1}). The higher losses of B might be due to its higher solubility and mobility in the soil, as B is transported to the surface of plant roots by the movement of water (mass flow). Conversely, no significant loss in Fe, Mn and Cu was recorded, as the experimental period was probably not long enough for encountering considerable loss of this nutrient. Overall, the annual total nutrient losses varied considerably with values from 0.38 to 27.1 kg ha^{-1} in the year 2013, and 0.23 to 16.2 kg ha^{-1} in the year 2014.

Mechanical and scientifically modified ITKs conservation practices were the key factors to bring down the total nutrient losses by 85.9 to 98.6 per cent, and 46.3 to 78.9 per cent compared to the nutrient loss in control/non-conservation plots, respectively. Correlation studies in both the year of the experiment indicated that the loss of soil clay particles was positively associated (data not shown) with all the nutrients. Results signify the arresting of fine clay particle by adopting conservation practice may an important mechanism to hold all the essential plant nutrients in the sloppy hill soils.

Loss of price money in terms of fertilizer cost as nutrients

It was estimated that the loss of money in terms of fertilizer cost (Table 5) varied from Rs.12.5 to 863 ha^{-1} in 2013 and Rs. 10.0 to 583 ha^{-1} in 2014 among the different treatment combinations and maximum loss of money as fertilizer price was observed with control (T_1) plots and minimum with T_2 conservation plot for both the year of experimentation (Anonymous 2015). It was also found that the loss of money in terms of only nitrogenous and potassic fertilizers were contributed 74.9 to 83.2% in 2013 and 50.7 to 70.8% in 2014, respectively. The loss of price money in terms of micronutrients fertilizer cost varied from 13.3 to 21.4% and 11.1 to 16.0% for the two years, respectively. Overall, conservation measures saved Rs. 590 to 851 ha^{-1} in 2013 and Rs. 225 to 573 ha^{-1} in 2014, respectively.

Soil conservations and soybean yield performance

Conservation practices showed strong positive influence of the yield (Table 6) of soybean. Yet, the maximum yield of soybean (1.32 t ha^{-1}) was obtained

Table 5. Consequence of soil conservation measures on losses of nutrients in terms of fertilizer price (Rs. ha^{-1})

Treatments	Year-I (Rs. ha^{-1})									Year-II (Rs/- ha^{-1})								
	Urea	SSP	MOP	$FeSO_4$	$MnSO_4$	$CuSO_4$	$ZnSO_4$	Borax	Total	Urea	SSP	MOP	$FeSO_4$	$MnSO_4$	$CuSO_4$	$ZnSO_4$	Borax	Total
T_1	105	30	613	6.8	10.1	22	4.1	71.5	863	72	18	341	9.3	13	21	4.1	22	583
T_2	1.5	0.5	8.2	0.4	0.5	0.4	0.1	0.8	13	1.1	0.3	4.6	0.2	0.3	0.4	0.1	0.6	10.0
T_3	11	3.1	43	1.5	3.3	5.4	1.6	2.6	71	9.7	2.2	49	1.2	3.1	3.3	1.1	3.1	95.5
T_4	26	6.9	117	5.9	12.5	6.9	2.2	13.4	191	15	3.7	78	2.9	7.6	7.3	1.5	9.3	182.1
T_5	53	12	238	8.2	17	11	2.5	26.2	367	35	7.2	192	6.2	11	9.8	2.2	10	358

Source: Anonymous (2015) Fertilizer price in Indian National Rupee ((Rs,) and nutrient content (%)

Table 6. Effect of soil conservation measures on average performance of soybean growth

Treatments	Year-I					Year-II				
	Yield (t ha^{-1})	No. of pod plant^{-1}	No. of nodule plant^{-1}	No. of filled grain pods^{-1}	1000-grain weight (g)	Yield (t ha^{-1})	No. of pod plant^{-1}	No. of nodule plant^{-1}	No. of filled grain pods^{-1}	1000-grain weight (g)
T_1	0.74	16.7	8.7	1.7	120.0	0.65	11.3	5.3	1.7	119.2
T_2	0.94	19.7	9.7	3.0	119.9	1.03	19.3	9.3	3.3	121.4
T_3	1.32	28.0	22.0	3.7	122.2	1.38	26.3	23.0	3.7	123.2
T_4	1.07	28.3	21.3	3.3	122.4	1.12	23.7	18.3	3.0	121.5
T_5	1.02	19.3	11.0	3.3	121.4	0.96	16.3	12.7	2.7	120.1
SE	0.006	0.823	0.813	0.422	0.501	0.023	0.789	0.711	0.269	0.597
CD (P<0.05)	0.02	2.69	2.65	1.38	1.64	0.08	2.57	2.32	0.88	1.95

in T_3 in 2013. Similarly, other yield attributes like number of nodule per plant (22), number of filled grain per pods (3.7) and test weight (122.2 g) also found higher in contour bunding (T_3), but number of pods per plant (28.3) was found highest in T_4. Among the conservation plots, it was also observed that the lowest yield was received with bench terracing plots (T_2). Conservation practices showed strong positive influence of the yield of soybean as compared to the non-conservation plots. Among the conservation plots, it was also observed that the lowest yield was recorded in bench terraces (T_2), and the reason might possibly be the disturbance of surface soil and exposure of less fertile bottom layers during the construction of bench terraces. The yield of soybean in 2014 was considerably increased in T_4 (9.15%), T_2 (4.9%) and T_3 (4.24%) while decreased in T_1 (13.04%) and T_5 (6.48%) plots as compared to the yield in 2013. The entire yield attribute parameters were found superior in T_3. The correlation coefficient indicated (Table 7) that the annual soil erosion, clay particle, OC, available N, P, K and micronutrient losses through erosion had significantly negative influence on the performance of soybean yield in 1st year (2013) and also pursued the similar trends in 2nd year (2014) of cultivation, except the soil available P nutrient losseswhich clearly indicated that the lesser erosion losses of native soil nutrients improved itsuse efficiency and helped to increase yield of soybean.

Consequences on soil fertility status

The pH of the soil decreased significantly in all the treatments from its initial value (5.23). The lowest soil pH (4.75) was recorded in control. The EC decreased (13.3 to 94.7%) considerably from the initial value of 0.26. Implementation of different conservation measures (Table 8) helps to hold the OC by 45.9 to 58.2 per cent over the control. The highest OC (2.45%) was recorded in contour bunding, which was significantly higher than the other treatments. The available soil N status does not change much in T_3 (216 kg ha^{-1}) compared to its initial value, however, large variation was observed in other treatments particularly in control. The two years of experiment marginally modify the soil available P status by 6.7 to 33.3 per cent from the initial soil P status (18.8 kg ha^{-1}), whereas the maximum decline of available soil P was observed in T_2 and minimum in T_3. The K status decreased considerably for all the treatments by 48.5 to 74.4 per cent as compared to the initial K status (539 kg ha^{-1}), and the maximum K was observed in T_3 (278 kg ha^{-1}). However, there was no significant

Table 7. Relationship between soybean yield and soil and nutrient losses

Yield	Annual erosion	Clay loss	SOC loss	N loss	P_2O_5 loss	K_2O loss	Micronutrient loss
Year-I	-0.73**	-0.43*	-0.71**	-0.70**	-0.72**	-0.74**	-0.47*
Year-II	-0.84**	-0.43*	-0.67**	-0.69**	-0.72**	-0.67**	-0.63**

*Significant at 5% level of significance, **significant at 1% level of significance

Table 8. Consequence of soil conservation measures on soil fertility after two years of experimentation

Treatment	pH	EC (dS m^1)	OC (%)	N	P	K	Fe	Mn	Cu	Zn	B
				(kg ha^{-1})			(mg kg^{-1})				
T_1	4.75	0.13	1.03	122.5	16.8	138	3.48	1.88	0.98	0.55	0.38
T_2	5.01	0.23	2.11	178.5	12.6	248	4.58	2.01	1.05	0.62	0.55
T_3	4.88	0.22	2.45	216.3	17.6	278	4.62	1.78	1.12	0.77	0.45
T_4	4.82	0.17	1.97	189.5	17.0	220	4.22	1.77	1.02	0.68	0.42
T_5	4.77	0.14	1.89	164.6	15.4	189.5	4.55	1.69	1.13	0.57	0.51
SE	0.027	0.001	0.02	4.20	0.26	1.88	0.018	0.021	0.032	0.012	0.013
CD (P<0.05)	0.087	0.004	0.07	13.7	0.84	6.15	0.06	0.07	0.10	0.04	0.041

Table 9. Expenditure involvement for soil and water conservation (SWC) measures and economic analysis during the study period

Treatments/ conservation measures	Required man-days for SWC (Nos. ha^{-1})	Materials cost (Rs.)	Total cost for SWC (Rs. ha^{-1})	Cost of crop cultivation for 2 years (Rs.)	Gross revenue of two years (Rs.)	Net revenue (Rs.)	Input: output ratio
T_1	0	0	0	28,436	69,420	40,984	1:2.44
T_2	497	0	82,502	25,614	98,300	-9,816	1:0.91
T_3	42	0	6,972	29,100	1,34,900	98,828	1:3.74
T_4	20	12,400	15,720	28,270	1,09,550	65,560	1:2.49
T_5	7	18,600	19,762	28,436	98,770	50,572	1:2.05

change in DTPA-extractable Fe, Mn, and Cu residual micronutrients, the values did not alter considerably from the initial values. However, the DTPA extractable Zn decreased by 16.3 to 40.2 per cent from its initial value (0.92 mg kg^{-1}) and relatively higher reduction was observed in T_1 (0.55 mg kg^{-1}) and T_5 (0.57 mg kg^{-1}). Conservation treatments reduced the loss of B by 4.0 to 17 per cent compared to the control. The meaning of soil conservation now-a-day expanded to protect the soil from physical loss by erosion and chemical deterioration. Adopting watershed as a basic unit of development soil and water can be conserved effectively.

Economic analysis for soil and water conservations

Among the different conservation treatments (Table 9), bench terracing required the highest manpower (497 man-days) followed by contour bunding (42 man-days), bamboo fence (20 man-days) and wooded logs (7 man-days). Accordingly, the total cost of construction for different conservation measures ranged from Rs. 6,972/- ha^{-1} (contour bunding) to Rs. 82,502/- ha^{-1} (bench terracing). Contour bunding construction cost was found lowest (Rs. 6,972/- ha^{-1}) among all the conservation measures but relatively higher conservation cost was identified for the bamboo fence (Rs. 15,720/- ha^{-1}) and wooded logs (Rs. 19,762/- ha^{-1}). The highest net revenue was found in contour bunding (Rs. 98,828/- ha^{-1}). Negative net revenue of Rs. -9,816/- ha^{-1} was found in bench terracing ever after two years of cultivation.

Bench terracing conservation measures required higher manpower due to the involvement of cutting and filling method and thereby increased total expenditure. The construction cost of contour bunding was found the lowest among all (Krishnagowda *et al.* 1990). Relatively higher cost was involved in making bamboo fence and wooded logs due to higher involvement for materials cost like bamboo and wood logs. The highest net revenue was calculated in contour bunding, while negative net revenue was computed in bench terracing, ever after two years of cultivation. High cost of construction, decline soil fertility and poor crop performance were identified as the major constraints in bench terracing and these are the sole reasons for negative net return and input output ratio.

Shifting cultivation is a unique method of farming in the north-east region, it is criticized for low productivity and adverse environmental imbalances (Sachchidananda 1989). Pre-monsoon and monsoon water plays a significant role in growing crops under shifting cultivation system. Indigenous conservation practices for increasing water use efficiency and reduce runoff have been practised from ancient times in north-east India. This system is basically managed using the locally available resources such as bamboo, wood, boulders, *etc*. and also cost-effective. With the advent of time mechanically improvised agricultural conservation technologies are to be adopted for the conservation of soil erosion and water loss. Population explosion, increase in food demand, industrialization, and social change now pushing the farmers of the north-east to follow improvised conservation techniques.

Conclusions

The result of the study indicates that different conservation practices influence runoff and soil losses. Mechanical and indigenous technical knowledges conservation technologies minimize the fine particle loss, primary and micronutrient losses compared to the non-conservation plots. The loss of soil and nutrients was observed highest in the month of July for both the year of experiment and therefore a special attention on conservation measures should receive in this particular month to control the losses and to sustain yield. This study concluded that introduction of different conservation measures enhanced the prevention of soil erosion loss by significantly reducing the flow velocity of runoff in a more effective way than untreated plots. Considering all treatments across the years, bench terracing across the slope (T_2) is found the most suitable for conserving both the soil and water on the hill slopes. However, considering the better yield of the crop in the contour bund, in an economic point of view, this treatment may be considered as the most suitable for this region. Looking into the poor socio-economic condition of the farmers and less initial cost, contour bund may be recommended for this region.

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