Original Research Article

Effect of slope length on the soil and nutrients loss from the upland (hill) of Bangladesh

ABSTRACT

The experiments were conducted in the hill district of Bangladesh (CHTs) i.e Bandarban, under the AEZ 29 (Northern and Eastern Hills Tract) during March 2016 to November 2017 to study effect of slope length on the soil and nutrients loss from the upland (hill) of Bangladesh. The experiments were laid out in randomized complete block design (RCBD) with three replications. The treatments for the experiment were: T_1 30m slope length, T_2 20m slope length, $T_3$10m slope length and $T_4$5m slope length. The highest soil loss of 50.0 t/ha/yr was recorded in treatment L1 having the slope length of 30 m and the plot size 150 m^2 (30 m × 5 m). The lowest soil erosion was noted (4.75 t/ha/yr) for L4 treatment with the 5m slope length having area coverage area of 25 m^2. The amount of soil loss in L2 (20 m length) and L3 treatments (10 m length) were 42.7 and 21.9 t/ha/yr, respectively. Nutrient depletion increased with the increasing lengths of the hilly land along the slope. The highest depletion of OM and plant nutrients were recorded under the maximum slope length of 30 m (L1) being followed by the losses observed in L2 (20 m), L3 (10 m) and L4 (5 m) plots respectively. The maximum losses of OM, total N, P, K, Ca, Mg and S were 2542, 93.1, 0.295, 2.73, 35.2, 20.6, and 1.34 kg/ha/yr, respectively for L1 (30 m) plot. Slope length created a very positive impact on yield of Jhum rice. The maximum yield of Jhum rice was produced under 30m slope length (2.25 t/ha). Slope length had considerable influence on the performance of Jhum crops like sweet gourd, marpha, maize, white gourd and cowpea.

Key words: Slope length, Soil loss, Nutrient loss, upland (hill)

1. INTRODUCTION

Bangladesh is situated between 20º34′ and 26º38′ north latitude and 88º01′ and 92º41′ east longitude. It is the fifth most populous country in Asia and ranks eighteenth in the global context. Topographically, Bandarban Hill District is a continuation of the Himalayan Tract. About 90% of the total area of the district is hilly, 4% covers villages, rivers and marshes, and the remaining 6% represents valley suitable for intensive agricultural production [1, 2]. The effective land area is roughly 12.31 m ha of which presently 7.85 m ha are under cultivation [3]. In hilly area 'jum' is the predominant farming system in Chittagong Hill Tracts (CHTs), which in the past has been well adapted to the lives and livelihood of tribal people with little adverse effect on the ecology of the region. Increasing population pressure coupled with a shortage of suitable uplands reduced the shifting cycle from 15−20 years in 1900 to 3−5 years in the 1990s in the absence of regulations to prevent deforestation, soil erosion, nutrient loss and environmental degradation [4, 5]. During the fallow period, lands are left for natural regeneration with no treatment to improve fertility of the degraded land, mainly due to lack of ownership [6]. In the conventional shifting cultivation system, sowing and weeding are done without major topsoil disturbance. Slope length is the ratio of soil loss from the field to that from a 72.6-foot (22.1-meter) length on the same soil type and gradient. Slope length is the distance from the origin of overland flow along its flow path to the location of either concentrated flow or deposition [7, 8]. It may be due to a direct hit of the raindrop at the soil surface that disintegrates soil particles and washed away the surface soil through runoff of rainwater along the slope down the hills [9]. It is more and more agreed that soil degradation is a major threat to the Earth's ability to feed itself as nearly 40% of the world's agricultural land is seriously degraded [10]. Soil erosion in hilly area is one of the major causes of soil loss, nutrient loss and soil degradation. In the recent years, intensive crop cultivation using high yield varieties of crop with imbalanced fertilization has led to mining out scarce native soil nutrients to support plant growth and production, the dominant soil ecological processes that severely affected the soil fertility status and production capacity of the major soils in Bangladesh. Available data indicated that the fertility of most of our soils has deteriorated over the years which is responsible for national yield stagnation and in some cases, even declining crop yields. Considering these facts as stated, the present study will be undertaken to assess soil fertility degradation as affected by slope length.

2. MATERIALS AND METHOD

In the hilly areas, soil erosion varies upon slope length. A huge amount of soils are eroded every year from the long slope. Soil erosion depends upon hill slope length. At the same time, lot of soil nutrients are lost from hill soil. Taking into account of this idea, this experiment was conducted at Hill Cotton Research Centre, Bandarban to determine soil nutrient loss as affected by slope length in a hilly area of CHT in 2016-2017. The method was found by previous research and also inspired. [11] Biswas S, Swanson ME, Shoaib JUM, Haque SMS. 2010. Soil Chemical properties under modern and traditional farming systems at Bandarban, Chittagong Hill District, Bangladesh. Journal of Forestry Research.

2.1 Soil characteristics

The General Soil Type was Brown Hill Soil, collected from Balaghata, Bandarban (AEZ 29). Morphological and general characteristics of the experimental soils are described in Tables respectively.

Table 1. Morphological characteristics of soil of experimental fields

Characteristics	Description
Location	Balaghata, Bandarban
Geographic position	22.13^0.060'N Latitude 90.12^0.303'E Longitude 43 m height above sea level
Slope	46.63% Steep slope

Agro-ecological zone(FAO and UNDP, 1988)	Northern and Eastern Hills (AEZ29)
General soil type	Brown Hill Soil
Soil Group	Suvolong
Parent material	Sedimentary rocks (Titan formation)
Drainage	Highly drained
Flood level	Above flood level
Land type	High land
Soil color	Brown

Table 2. Soil physical and chemical characteristics of experimental fields (Mean value; n=18)

Characteristics	**Depth of Soil**	
	0-15 cm	**15-30 cm**
Texture	Clay Loam	Clay
pH	4.9	5.0
OM (%)	1.82	1.08
Exchangeable Ca (cmol/kg)	8.21	6.29
Exchangeable Mg (cmol/kg)	3.81	2.12
Exchangeable K (cmol/kg)	0.165	0.17
Total N (%)	0.091	0.054
Available P (mg/kg)	3.35	2.01
Available S (mg/kg)	1.57	0.21
Available Zn (mg/kg)	3.55	3.66
Available Mn (mg/kg)	6.76	7.15
Available Fe (mg/kg)	67.45	70.03
Available Cu (mg/kg)	0.70	0.68
Available B (mg/kg)	0.02	0.14

2.2 Treatments

The experiment was set up in Randomized Complete Block Design (RCBD) with three replications. The treatment details are given below.

Chart 1: The treatment details

Code	**Length × Width**
L_1	30m×5m
L_2	20m×5m
L_3	10m×5m
L_4	5m×5m

2.3 Crop

Jhum crops were used in the experiment namely Jhum rice, marpha, sesame, maize, yard-long bean, sweet gourd, cowpea etc.

2.4 Experimental setup

2.4.1 Selection of research site:

Th The site for this experiment was chosen at the hilly area of HCRC, Balaghata, Bandarban in consultation with the CDB authorities.

2.4.2 Climate

Bangladesh has a sub-tropical humid climate. Heavy rainfall occurs in the monsoon and scanty in the other seasons. The mean annual rainfall recorded at the Soil Conservation and Watershed Management Center (SCWM), SRDI, Bandarban, nearest to the experimental sites was 3010.9 mm and the annual average temperature was 31.63°C as maximum and 21.46°C as a minimum. Meteorological data like rainfall, temperature and relative humidity during the study period.

2.4.3 Initial soil samples

Two composite initial soil samples were collected from surface (0-15cm) and sub-surface depths (15-30 cm) with the help of an auger and core sampler. Collected soil samples were analyzed for determining soil pH, and the contents of organic matter, total N, P, K, Zn, B, Ca, Mg and S and other basic soil physical properties.

2. 4.4 Slope percentage, elevation, longitude and latitude

Hillslope was measured by Abney Level. Elevation, longitude and latitude were determined by the GPS meter.

2.4.5 Land preparation

After selection of experimental sites, hill bushes and weeds were cleaned by cutting and burning. Experimental plots of different sizes (30×5 m^2, 20×5 m^2, 10×5 m^2 and 5×5 m^2) were made according to treatments. The plots were prepared by putting a one feet high tin fence surrounding each plot. This was done to restrictwater movement and eroded soil from outside to inside the plot and vice-versa. A pit having the dimension of 5×1×1 m^3 was made at the foot of each plot and wrapped by black polyethylene sheet to collect eroded soil from the plots.

2.4.6 Seed sowing and management practices

After preparation of all experimental plots, lands were tilled as per treatment and Jhum seeds were sown by a dibbling method on 05 June 2015. Fertilizers were applied according to farmer's practice.

2.5 Intercultural operations

2.5.1 Management practices

The experimental field was frequently monitored and necessary management practices such as weeding, pesticide application and earthening were done as required.

2.5.2 Harvesting and eroded soil collection

Jhum crops were harvested on 14 October 2015 from the experimental field and brought them to the Farm yard of HCRC, Balaghata, Bandarban. The eroded soil was collected from catch pit and calculated by the electric balance on dry basis.

2.5.3 Yield and yield contributing data

The yield and yield contributing data are recorded on Initial & post-harvest physical and chemical properties of soil, Slope (%), Date of sowing and harvesting of crop, Initiation of runoff after rain, Intensity of rain and total rainfall, Sediment yield, Organic matter and nutrients content of sediment and Crop yield.

2.6 Soil analysis

About 02 initial, 24 post-harvest soils and 12 eroded soil were collected, cleaned, and dried and stored for analysis. Soil analysis includes pH, organic matter, total N, exchangeable K, Ca, Mg, Na, and available P, S, B, Mn, Zn and Cu contents.

2.7 Plant analysis

After harvest, plant samples from each plot were collected and were divided straw and grain. The samples were cleaned, dried and kept for chemical analysis. The collected plant samples were then oven dried at 65°C for 24 hours. To obtain a homogeneous powder, the samples were finely ground by using a Grinding-Mill to pass through a 60-mesh sieve. Plant samples were digested with di-acid mixer (HNO_3:$HClO_4$ = 5:1) for determination of N, P, K and S concentrations.

2.8 Statistical analysis

Statistical analysis was done by ‘Statistics 10’program. The mean effects were adjudged by LSD.

3. RESULTS

The present study was accomplished through survey and some field experiments. All these works were done in Bandarban hills under Northern and Eastern Hills (AEZ 29). The objective was to assess soil fertility degradation as affected by slope length Jhum cultivation system. The field experiments were carried out at farmers’ fields in Bandarban Sadar Upazila. Results of these experiments are presented in different tables and figures. Description of experimental results is made under various sub-sections, as follows.

3.1 Soil loss

The most apparent damage caused by water erosion is the removal of soil from eroding surfaces.

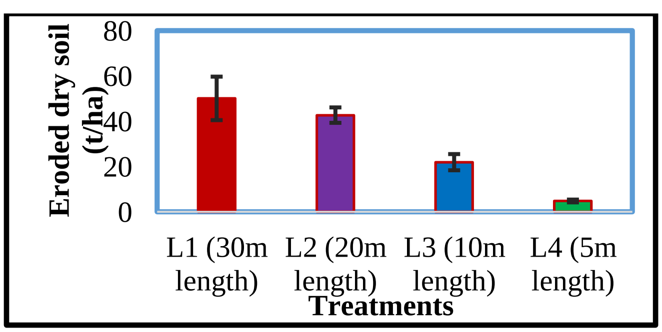

Fig 1. Eroded dry soil from different slope length (t /ha)

Fig.1. showed the distinct variation of soil loss due to different slope lengths under Jhum crop cultivation. The highest soil loss of 50.0 t/ha/yr was recorded in treatment L_1 having the slope length of 30 m and the plot size 150 m^2 (30 m × 5 m). The lowest soil erosion was noted (4.75 t/ha/yr) for L_4 treatment with the 5m slope length having area coverage area of 25 m^2. The amount of soil loss in L_2 (20 m length) and L_3 treatments (10 m length) were 42.7 and 21.9 t/ha/yr, respectively. The experimental results indicate that intensity of soil erosion increased with the increasing of soil length because the eroded water-soil mixture get more driving momentum under the higher length of sloppy hills to draw it from the top hill to the bottom.

3.2 Loss of nutrients

The eroded topsoil of the experimental plot was accumulated in the reservoir at the bottom end of the hill contained a considerable amount of OM and plant nutrients (Table). Nutrient depletion increased with the increasing lengths of the hilly land along the slope. The highest depletion of OM and plant nutrients were recorded under the maximum slope length of 30 m (L_1) being followed by the losses observed in L_2 (20 m), L_3 (10 m) and L_4 (5 m) plots respectively. The maximum losses of OM, total N, P, K, Ca, Mg and S were 2542, 93.1, 0.295, 2.73, 35.2, 20.6, and 1.34 kg/ha/yr, respectively for L_1 (30 m) plot.

In case of L_2 (20 m) plot, nutrient losses were 1420, 76.8, 0.157, 1.83, 23.0, 9.83 and 1.23 kg of OM, N, P, K, Ca, Mg and S per hectare, respectively (Table 4.3.1). Nutrient depletion as recorded in L_3 (10 m) treatment were 627.9, 36.3, 0.175, 2.99, 16.4, 7.48 and 0.74 kg/ha/yr, respectively. The minimum loss of nutrients was noted in L_4 (5 m), the values 239.4, 8.79, 0.016, 0.69, 5.34, 2.79 and 0.13 kg/ha/yr of OM, N, P, K, Ca, Mg and S per hectare. These results indicated that intensity of soil erosion increased with the increasing of soil length.

Table 3. Effect of slope length on nutrient loss

Treatments	**Soil loss (kg /ha)**	**Nutrient loss(kg/ha)**						
		OM	N	P	K	Ca	Mg	S
L_1(30m length)	50,040	2542	93.1	0.295	2.73	35.2	20.6	1.34
L_2 (20m length)	42650	1420	76.8	0.157	1.83	23.4	9.8	1.23
L_3 (10m length)	21880	628	36.3	0.175	2.99	16.4	7.5	0.74
L_4 (5m length)	4750	239	8.8	0.016	0.69	5.34	2.8	0.13

Table 4. Changes of pH and nutrient status in soil (Mean value, n=4)

Soil parameters	**Initial soil status**		**Post-harvest soil status**	
	0-15 cm	**15-30 cm**	**0-15 cm**	**15-30 cm**
Soil pH	4.9	5.0	5.9	6.2
Organic Matter (%)	2.65	2.60	1.82	1.08
Total N (%)	0.16	0.14	0.09	0.05
Available P (mg/kg)	3.35	2.01	3.55	2.92
Exchangeable K (meq/100g)	0.17	0.16	0.07	0.08

Exchangeable Ca (meq/100g)	8.21	6.29	2.92	2.19
Exchangeable Mg (meq/100g)	3.81	2.55	2.68	2.12
Available S (mg/kg)	7.31	5.20	5.23	3.86

Table 5. Effect of slope length on the yield performance of Jhum crops

Crop/Item	**Treatments**			
	L_1 30 m Slope (t/ha)	**L_2 20 m Slope (t/ha)**	**L_3 10 m Slope (t/ha)**	**L_4 5 m Slope (t/ha)**
Rice	2.25	2.07	1.75	1.80
Straw	3.89	3.29	2.43	2.50
Sweet Gourd	0.19	0.10	0.18	0.17
Marpha	0.95	0.10	1.05	0.05
Maize	0.06	0.04	0.02	0.03
White Gourd	0.90	0.40	0.35	0.09
Cow pea	0.04	0.06	-	0.05

3.3 Changes in soil fertility

It was observed that soil pH increased markedly from 4.9 to 5.9 at 0-15 cm and 5.9 to 6.2 at 15-30 cm depths. There was a marginal decrease in exchangeable K, Ca and Mg contents over the year. Organic carbon in soil decreased after burning. It ranged from 2.60-2.65 percent before Jhuming and 1.08-1.82 percent after Jhum harvesting. Similarly, total N in soil decreased in post-harvest situation which ranged from 0.14-0.16 percent before Jhum and 0.05-0.09 percent after harvest of Jhum. The amount of exchangeable K decreased substantially after harvest. It ranged from 0.16-0.17 cmol/kg at initial stage and 0.07-0.08 cmol/kg at post-harvest stage. The amount of P ranged between 2.01 and 3.35 mg/kg before Jhuming and 2.92 and 3.55 mg/kg after Jhum harvest. Similar trend was observed in case of S. Available S was found between 5.20 and 7.31 mg/kg initially and 3.86 and 5.23 mg/kg at post-harvest stage.

3.4 Performance of rice yield under Jhum

Data on the influence of slope length on yield and yield contributing characters of Jhum rice are presented in Table and Fig. Slope length created a very positive impact on yield of Jhum rice. In most cases, crops yields were high under the maximum length of hilly land. The maximum yield of Jhum rice was produced under 30m slope length (2.25 t/ha). The second highest yield was recorded in treatment L_2 treatment. The lowest yield of Jhum rice was produced in plot where 5m slope. Similar response was found in case of straw yield. About 3.89 t/ha straw yield was found in L_1 treatment, whereas 2.43 t /ha in L_3 treatment.

3.5 Performance of other crops

Slope length had considerable influence on the performance of Jhum crops like sweet gourd, marpha, maize, white gourd and cowpea (Table and Fig.). The highest yield of sweet gourd

(0.19 t/ha) was produced under long slope (L_1) condition, while the lowest value (0.17 t/ha) being documented in short length (L_4) condition.

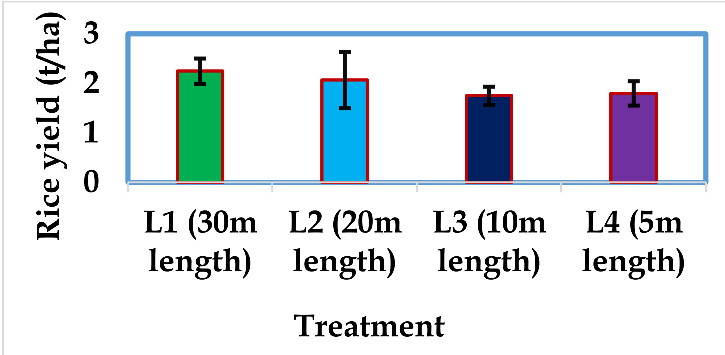

Fig. 2. Performance of rice grain yield under different slope length

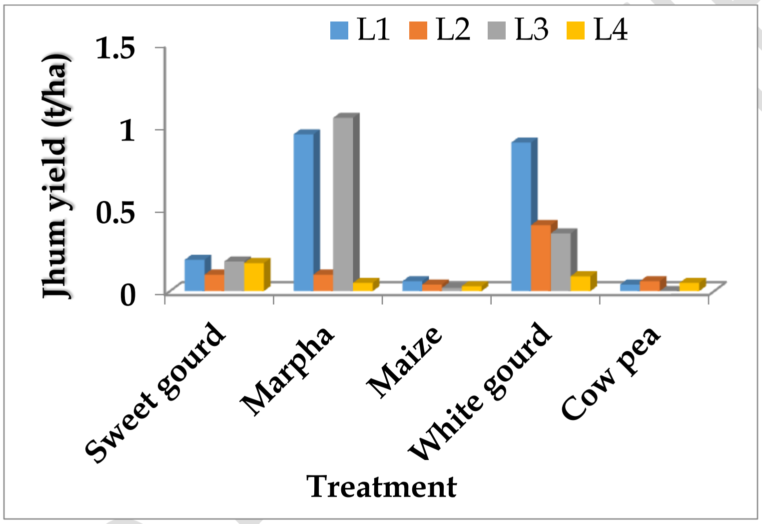

Fig. 3. Performance of different crops under different slope length

Marpha yield (1.05 t/ha) was highest in L_3 treatment, the lowest yield (0.05t/ha) was recorded in short length plot (L_4). The second highest yield of marpha was produced in L_1 plot (0.95t/ha). The highest yield of maize (0.06 t/ha) was obtained in L_1 plot but the lowest (0.02 t/ha) under L_3 treatment. The maximum yield of white gourd (0.90 t/ha) was noted in L_1 plot whereas the minimum (0.09 t/ha) in L_4 plot. The second highest value being produced in L_2 plot (0.40 t/ha). The highest yield (0.06 t/ha) of cowpea was produced under 20 m slope length (L_2), the lowest (0.04 t/ha) was in L_1 (30 m slope length).

4. DISCUSSION

The most apparent damage caused by water erosion is the removal of soil from cultivated land surfaces. It may be due to a direct hit of the raindrop at the soil surface that disintegrates soil particles and washed away the surface soil through runoff of rainwater along the slope down the hills. Slope length being a major factor of soil erosion, the longer the slope length the stronger is the driving capacity of runoff and the soil erosion. Because soil erosion accelerated due to the increased driving momentum created under the higher length of sloppy hills to drive it from the top hill to the bottom. Higher erosion on longer slopes may be due to increased runoff velocity creating a greater momentum for carrying away soil particles along the slope [12, 13]. Chundawat, B.S. (2001) [14], observed a linear increase in soil erosion with an increase in slope length. Islam, M.F. and M.F. Haq. (2013) [15] reported that the magnitude of the slope length exponent depends on slope gradient. In Rasul, G. and Thapa, G. B. (2002) [16] observed that on bare uncultivated slopes, soil erosion increased with an increase in slope length. Rasul, G. and Thapa, G. B. (2002) [17] reported that soil loss tolerances ranged from 4 to 13 t/ha/yr. This general range of tolerable losses was accepted by the 'Soil Conservation Services' (SCS) research officers of United States (US), but later it was agreed that 11 t/ha/yr should be the maximum rate and that there were some soils so fragile that a rate of only 2 t/ha/yr should be added. According to the soil loss tolerable range, crop combination with mulch should be encouraged for reducing soil erosion. Erosion removed the topsoil, which is the part of the soil containing the highest concentration of nutrients.

Change of nutrient status was observed before and after heavy rainfall which caused plant nutrient depletion. There were appreciable differences in nutrient status among the different slope lengths under Jhum crop. Under heavy rainfall, the released nutrients are removed with runoff water, rapidly leached and lost to the lower strata of the sailor to the groundwater. The nutrient recycling chain is broken, and the released nutrients do not remain in the soil. A very important consequence of rapid disposal is the leaching of soluble nutrients. Losses of base cations (e.g., Ca, K and Mg) lead to soil infertility on one hand and rise in soil acidity and toxicity factors on the other [18]. It indicated that more nutrient depletion was occurred in longest slope (L1) plot where the cover crop was same. The result of the present study was in line with Gafur et al. (2003) [19] who reported that runoff sediment lost from Jhum field contained 4 times higher nutrient than the original condition of the soil. Thus, it revealed from the study that nutrient losses from soil erosion could be minimized through the use of cover crops.

An assessment of the changes in chemical properties of the soil over the year was made by sampling 0-15 cm and 15-30 cm depths at the beginning of the study in 2015, and 0-15 and at its end in 2016 to make an approximate comparison of the soil parameters. Though one year is quite insignificant to find any appreciable changes in fertility, some changes on soil parameters were observed which was more in the surface soil layer than in the lower depth. Reduction in organic carbon at the initial stages was observed by Dhyani, S, et al. (2009) [20] Gruhn, P., F. et al (2000) [21] in India and in Bangladesh due to faster decomposition of litter owing to better soil tilt and acceleration of microbial activities in the surface soil. However, the nutrient contents at the subsurface soil layer (15-30 cm) were much low as compared to the surface (0-15 cm) soil Roy, R.N. (2013) [22]. This was because the residues of leaf fall and other left-over materials of the cover crop remained on the soil surface and couldn’t transfer to the subsurface layer of soil.

Though increased slope length favors soil erosion, the yield of Jhum crops increased with increase in slope length. It might be due to higher soil moisture at the tail end of the longer lengths of the sloppy lands that might have fulfilled the water requirement of the crop to some extent and led to higher crop yield under longer lands along the slope. It is logical that longer sloppy lands having greater erosion of top fertile soils may lead to poor crop performance as compared to shorter plots, but the availability of higher soil moisture is also a big factor in improving crop performance. The longer sloppy plots contained comparatively higher moisture at the tail end of the plot that might have led the crops to receive not only the higher moisture but also the availability of higher nutrients and root growth and ultimately better crop performance.

5. CONCLUSION

Bangladesh has opted for an agricultural development policy that gradually moved farmers away from the traditional and rather static agriculture dependent on native soil fertility to a dynamic judicious fertilizer dependent farming. CHT is the home to a large number of small ethnic communities with their distinct cultures, livelihoods and identities. The extent of poverty is high in the CHT. About half of the population or more are poor. Due to huge loss of soil and nutrient in hilly area of Bangladesh crop productivity of Jhum decreased. That's why from the experimental we need more conscious about hilly area of Bangladesh to sustain livelihood of Jhumia families.

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