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Soil and Nutrient Loss from Hill as Affected by Different Cropping and Mulch Practices in Hilly Area of Bangladesh

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Authors' contributions

This work was carried out in collaboration between both authors. Author MZ designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the analyses of the study. Author AJMSK managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Soil and nutrient loss is a multifactor threat to crop production and the environment in hilly area of Bangladesh. Most studies on soil erosion characterization have not focused on soil and nutrient loss associated with erosion which were affected by different cropping and mulch practices. The demand for food is expected to significantly increase with continued population growth over the next 50 years, indicating that agricultural efficiency should be simultaneously stabilized and enhanced. The experiments was 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 the soil and nutrient loss from hill as affected by different cropping and mulch practices. The experiments were laid out in randomized complete block design (RCBD) with three replications. The treatments for the experiment were: T_1 Mulch (20 t/ha with rice straw) and T_2No mulch in maize and turmeric field. Turmeric and maize cultivation showed economically better under mulch condition in hilly region. More nutrient depletion took place in no mulch condition under the

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cultivation of turmeric and maize crops. Due to non-mulching, the productivity loss in maize and turmeric was 1.37 and 2.56 t/ha, respectively. Turmeric showed higher benefit-cost ratio (BCR) in mulch practice (2.64) than in non-mulch (1.63) cropping.

Keywords: Soil and nutrient loss; mulch practice; economics.

1. INTRODUCTION

A mulch is a layer of material applied to the surface of soil. Reasons for applying mulch include conservation of soil moisture, improving fertility and health of the soil, reducing weed growth and enhancing the visual appeal of the area. A mulch is usually, but not exclusively, organic in nature. It may be permanent (e.g. plastic sheeting) or temporary (e.g. bark chips) [1]. The process is used both in commercial crop production and in gardening, and when applied correctly, can dramatically improve soil productivity. Many materials are used as mulches, which are used to retain soil moisture, regulate soil temperature, suppress weed growth, and for aesthetics. They are applied to the soil surface, around trees, paths, flower beds, to prevent soil erosion on slopes, and in production areas for flower and vegetable crops. Mulch layers are normally 2 inches (5.1 cm) or more deep when applied [2,3]. It includes all spatial and temporal aspects of managing an agricultural system. Historically, cropping systems have been designed to maximize yield, but modern agriculture is increasingly concerned with promoting environmental sustainability in cropping systems [4]. Soil erosion is the displacement of the upper layer of soil, it is one form of soil degradation. This natural process is caused by the dynamic activity of erosive agents, that is, water, ice (glaciers), snow, air (wind), plants, animals, and humans [5]. Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing a serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks. Soil erosion could also cause sinkholes [6,7]. Over the past 50 years, great achievements in food and agriculture have been attained around the world. Continuing population growth is expected over the next 50 years, suggesting that there will be increased competition for land, water, and nutrients to meet the simultaneously rising demand for food [8,9]. This will necessitate an increase in agricultural production per unit of land. Mulching has played an important role in agricultural practices, and large amounts of mulching in hilly area have been used to increase food production [10]. There is an urgent need to reduce the soil and nutrient loss of the rapid development of agriculture. Therefore, the effects of mulching and different cropping on the soil environment associated with crop plants need to be discussed. Soil erosion reduces the agricultural value of lands via physico-chemical degradations. Soil nutrient loss through runoff and sediment, is a major driver for soil fertility decline [11]. The eroded sediments or soil are highly concentrated with crop nutrients, which are washed away from farmlands. Erosion-based constraints coupled with unfavorable climatic conditions define significantly the productivity of farming systems in hilly area of Bangladesh. Soil erosion leads to extreme losses of economic and environmental resources which negatively impact the economies of affected regions [12]. The nutrients transported through plant harvest (yield and crop residues) coupled with nutrient loss through erosion (runoff and sediment) are important threats to soil nutrient depletion in hilly area and defines the state of soils within the region [13,14]. As a result, most soils in Bandarban are highly degraded such that specific integrated management practices involving different cropping and mulch practices are required. The nutrients lost to soil erosion process can be expressed economically to reflect the impact of erosion on different cropping and mulching. The loss of soil nutrients through erosion indicates significant cost because of the need for replacement to enhance sustainability of cropping systems. Here, we will discuss the effects of mulch and cropping on the soil environment in hilly area of crop plants and analyze how mulch and cropping effects hilly area cultivation. Based on the current knowledge, we suggest some approaches that could cropping pattern in the future through mulching and different cropping. However, only few studies are devoted to the economic implications of soil fertility erosion under different cropping systems and fertility management practices compared to other soil erosion characteristics such as sediment and runoff. To bridge this gap in knowledge, nutrient loss via sediments and runoff pathways of erosion were studied under selected cropping systems in hilly area of Bandarban. The aim of the study was to quantify soil and nutrient loss and the associated costs due to erosion under specific crop and soil management practices.

2. MATERIALS AND METHODS

A field experiment was conducted at Gethsemane para in Bandarban Sadarupazila to develop a suitable crop production technique and soil erosion technique by using mulch practice under different crop cultivation during the kharip season in 2016-2017.

2.1 Soil Characteristics

The General Soil Type of the experimental plot was Brown Hill Soil collected from Tiger Para, Bandarban (AEZ 29). Morphological of the experimental soils are described in Tables respectively.

2.2 Treatments

The experiment was laid out in a Randomized Complete Block Design with three replications. The treatment details are given below.

2.3 Crop

Maize and turmeric were used as test crops in the experiment.

2.4 Experimental Setup

2.4.1 Selection of research site

This experiment was also conducted at the farmer's field,Doyal Bom' at' Gethsemane Para, Bandarban Sadar.

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.

2.4.3 Initial soil samples

Two initial soil samples were collected from both the surface (0-15 cm) and sub-surface region (15-30 cm) of the soil profile of each spot 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. The individual plots were prepared by putting a one feet high tin fence surrounding each plot. This was done to restrict the transfer of water and eroded soil from outside to inside the plot and vice-versa. The dimension of each plot was 22×5 m^2. A pit having the size of 5 × 1 ×1 m^3 was made at the foot of each plot and wrapped by black polyethylene sheet for collecting eroded soil from the plot.

2.4.6 Seed sowing and management practices

After preparation of all experimental plots, seeds of BARI Hybrid Maize-02 and rhizome of local turmeric variety were sown on 02 June 2016 by the dibbling method.

2.4.7 Spacing

The spacing for maize experiment was 25 cm for the seed to seed distance and row to row distance was 60 cm. In case of turmeric experiment, seed to seed distance was 25 cm and row to row distance was 50 cm.

2.4.8 Fertilizer application

The Maize plot was fertilized as follows: $N_{,25}P$,$_{115}$ $_{20}S$ $_{,40}Kkg/ha$. In case of Turmeric:$N_{140,}$ $P_{53,}K_{116}kg/ha$ was applied. of urea and third-One gypsum MoP and ,all doses of TSPfertilizerswere applied by the dibbling method as per treatment 3 days before of sowing in the maize experimental plot. On the other hand, TSP fertilizer was applied 03 days before in the turmeric plot.

2.5 Intercultural Operations

2.5.1 Management practices

In case of maize experiment,urea fertilizer was applied treatment wise at 22 days after sowing

(DAS) and 56 DAS by the dibbling method. On the other hand, urea and MoP fertilizer were used by the dibbling method in turmeric plot at 50 DAS, 80 DASand 110 DAS respectively. The experimental field was monitored frequently and necessary management actions such as weeding and application of pesticides were done whenever requirement.

2.6 Harvesting and Eroded Soil Collection

Maize was harvested from the experimental field on 31 August 2016 and Turmeric was harvested on 15 February 2017, then brought for processing at the Farmyard of HCRC, Balaghata, Bandarban. The amount of eroded soil was collected from catch pit and calculated by the electric balance on dry basis.

2.7 Yield and Yield Contributing Data

After threshing and cleaning, crop yield and yield contributing data like: plant height, plant diameter, ear length, ear width, number of grains/cob, grain wt.(g) /cob, thousand grain weight, cob yield, grain yield, plant stroveryield for maize and plant height of mother plant, height of finger plant, no. of leaves/mother plant, no. of finger leaves/plant, no. of tillers/mother plant, no. of tillers/finger plant, no. of mother rhizomes/plant, no. of finger rhizomes/plant, wt. of mother rhizomes, wt.of finger rhizomes, rhizome yield and plant yield for turmeric were collected in time.

2.8 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.

2.9 Plant Analysis

After harvest, plant samples from each pot were collected and divided into, 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.

2.10 Apparent Nutrient Balance

The apparent nutrient balance was estimated considering the total amount of nutrients added to the soil through different sources of nutrient management and the total amount of nutrient uptake by the crops (main product and by-product) in the pattern. The apparent nutrient balance was expressed in kg/ha/yr.

2.11 Economic Analysis

Economic analysis was performed to identify the economically viable treatment. The analysis was done following the principle of partial budget analysis. Benefit-cost ratio (BCR) is the indicative of the superior treatments. Only variable costs i.e. labor, chemical fertilizer and seed were taken into account as added cost for each crop. The benefit was calculated based on yield.

Table 1. Soil morphological characteristics of experimental fields

Characteristics	Description
Location	Getsimani Para, Bandarban
Geographic position	$22^0$08.195' N Latitude
	92^0 13 .708' E Longitude
	318 m height above sea level
Slope	19% Moderate Slope
Agro-ecological zone(FAO and UNDP, 1988)	Northern and Eastern Hills (AEZ 29)
General Soil Type	Brown Hill Soil
Soil color	Brown

Chart 1. The treatment details

Code	Treatments	Crop
T_1	Mulch (with rice straw)	Turmeric
T_2	No Mulch	
T_3	Mulch (with rice straw)	Maize
T_4	No Mulch	

2.12 Statistical Analysis

Data on different parameters were compiled and tabulated in proper form for statistical analysis. Statistical analysis was done by 'Statistics 10'program. The mean effects were adjudged by LSD.

3. RESULTS

The experiment was conducted to assess soil and fertility losses under mulch practices with maize (BARI Hybrid Maize-2) and turmeric (local variety) crops in a hilly area of Bandarban. Results of the present experiment have been presented in Tables 2 to 6.

3.1 Maize

3.1.1 Plant height

Plant height of maize was significantly favored by mulch. Mulching resulted in taller plant height (181.8 cm) than that of non-mulched treatment (164.9 cm) (Table 2). Mulching might have conserved soil moisture for use by the crop during the dry period.

3.1.2 Plant diameter

Plant diameter was significantly influenced by mulch practices. Mulch effect hada thicker diameter (7.9 cm) than that (6.2 cm) found in no mulch treatment (Table 2).

3.1.3 Ear length

Mulching had favored ear length of maize. Mulched plot exhibited higher ear length (18.3 cm) as compared to the non-mulched plot (15.00 cm) but the difference was not significant (Table 4).

3.1.4 Ear width

Ear width was also favored by mulching practice but the variation was not significant (Table 2). Higher ear width (15 cm) was recorded under mulched treatment as compared to that noted in no mulch treatment (11.0 cm).

3.1.5 Number of grains/cob

A significant effect of mulching had been observed on the number of grains/cob of maize (Table 4). Mulching gave 78% higher number of grains/cob (559.2) than that (314.1) of no mulch treatment.

3.1.6 Grain weight/cob

Mulching had a significant effect on grain weight/cob of maize (Table 2). The grain weight/cob of maize under mulching (141.07 g) was recorded to be 120% higher than that found (64.0 g) in non-mulched treatment.

3.1.7 Thousand grain weight

Though there was no significant difference in weight of 1000 grainof maize, the higher weight of 1000 grains (254.68 g) was recorded under the mulched condition as against the lower weight of 214.26 g. The difference is 19%.

3.1.8 Grain yield

Grain yield of maize was significantly increased by mulching and Table 2). Mulched treatment gave higher grain yield (4.04 t/ha) which was 51% higher than that found (2.67 t/ha) in plots where no mulching material had been used.

3.1.9 Cob yield

Cob yield was significantly influenced by mulching at 5% level of significance. The cob yield of maize (5.10 t/ha) was higher in mulch than that (3.34 t/ha) of no mulch (Table 2).

3.1.10 Stover yield

Stover yield of maize was significantly increased by mulching the plots with rice straw (Table 2). The straw yield of the crop under mulching was 7.1 t/ha as compared to the lower value (5.0t/ha) recorded in non-mulched treatment. The yield difference was 46%.

3.2 Turmeric

3.2.1 The height of turmeric mother plant

The height of mother plant differed significantly by adopting the mulching practice. The mulched plot had taller plant height (99.83 cm) than that (66.10 cm) of no mulch practice (Table 3). Mulched plant heights were 51% taller than the non-mulched plants.

3.2.2 Height of finger plant

Finger plant height was significantly increased by mulch (Table 3). Mulch had taller plant height (67.083 cm) than that (56.94 cm) of no mulch practice. Heights of mulched finger plants were 18% taller than that of non-mulched plants.

Table 2. Maize plant growth and development under mulch condition

Treatments	Plant height (cm)	Plant diameter (cm)	Ear length (cm)	Ear width (cm)	No. of grains/cob	Grain wt.(g) /cob	1000-grain wt.(g)	Cob yield (t/ha)	Grain yield (t/ha)	Plant Stover yield (t/ha)
Mulch	182[a]	7.9[a]	18[a]	15[a]	559[a]	141[a]	255[a]	5.1[a]	4.04[a]	7[a]
No Mulch	165[b]	6.2[b]	15[a]	11[a]	314[b]	64[b]	214[a]	3.3[b]	2.7[b]	5[b]
CV %	1.98	3.28	17.60	17.51	15.80	18.76	10.08	10.35	10.59	7.20

Note: Different letters in a column indicate statistically significant difference at 5% level, Here CV means: Co-efficient of Variance

Table 3. Physical growth parameters of above-ground parts of turmeric plants

Treatments	The height of mother plant (cm)	The height of finger plant (cm)	No. of leaves/ mother plant	No. of finger leaves/ plant	No. of tillers / mother plant	No. of tillers / finger plant
Mulch	99.8[a]	67[a]	6.5[a]	9.3[a]	1.1[a]	2.5[a]
No Mulch	66[b]	56.9[b]	6.2[a]	4.3[b]	1.1[a]	1.9[b]
CV %	7.85	3.58	3.99	11.51	16.43	5.75

Note: Different letters in a column indicate statistically significant difference at 5% level, Here CV means: Co-efficient of Variance

3.2.3 No. of leaves/mother plant

There was no significant effect of mulching on the number of leaves/plant of turmeric, but the higher value (6.53) was documented in mulched plots (6.53) (Table 5) than that (6.23) of no mulch (Table 3).

3.2.4 No. of finger leaves/ plant

A significant difference on the number of finger leaves/plant was observed due to mulching practice (Table 3). Mulched treatment gave 9.3 finger leaves/plant as against 4.33 in no–mulched treatment having 115% difference between the two treatments.

3.2.5 No. of tillers/ mother plant

Mulching could not play a significant role in increasing the number of tillers mother/plant, but the slight difference was observed from mulching (1.1) as compared to the non-mulch treatment (1.06) (Table 3).

3.2.6 No. of tillers/ finger plant

No. of tillers in finger/plant was significantly influenced by mulch practices. Mulch gave a higher number of finger leaves/plant (2.52) than that (1.92) of no mulch (Table 3).

3.2.7 No. of mother rhizomes/ plant

Mulching had resulted in significant increase in a number of mother rhizome/plant (Table 4). Mulching practice gave a higher number of finger leaves/plant (2.93) as compared to that (2.23) of no mulch treatment.

3.2.8 No. finger rhizomes/ plant

Mulching had created a significant impact on increasing the number of finger rhizome/plant (Table 6). Mulching treatment gave a higher number of finger leaves/plant (19.7) than that of no-mulch treatment (11.6).

3.2.9 Weight of mother rhizomes/plant

The weight of mother rhizome/plant was significantly influenced by mulch practices. Mulch gave 90% higher weight of mother rhizome/plant(117 g) than that of no mulch (61.9 g) (Table 4).

3.2.10 Weight of finger rhizomes/ plant

The weight of finger rhizome/plant was significantly increased by introducing mulch practice (Table 4). Mulch gave the higher weight of finger rhizome/plant (86.6 g) than that of no mulch treatment (47.9 g) the difference was 81%.

3.2.11 Plant yield

Plant yield t/ha was not significantly affected by mulch practices (Table 4). Mulching gave 32% higher plant yield (4.9t/ha) than that of no mulch treatment(3.7 t/ha).

3.2.12 Rhizome yield

Rhizome yield was significantly favored by mulch practices (Table 4). Mulch gave 84% higher rhizome yield (5.6 t/ha) than that of no mulching (3.1 t/ha).

3.3 Soil Loss

Fig. 1 shows the distinct variation of soil loss due to mulching treatments under turmeric and maize crop. In case of turmeric cultivation, mulching practice led to reduced soil loss of 1.16 t/ha as compared to 2924% more soil loss (35.08 t/ha) under no mulch treatment. Similarly, with maize cultivation, minimum soil loss of 5.18 t/ha was recorded with mulching as against a huge soil loss of 688% more under no mulch condition (40.81 t/ha).

3.3.1 Reduction of soil loss

It revealed from Fig. 2 that mulching has led to a huge reduction (97%) of soil loss (33.9t/ha) in turmeric cultivation and 35.6t/ha (87%) in maize cultivation.

3.4 Nutrient Loss

The nutrient losses under different mulching treatments were directly related to the intensity of soil loss. So, remarkably higher amount of plant nutrients were lost under no-mulch treatment in both the crops (Table 5). The losses of OM, total N, P, K and S in turmeric cultivation under no mulch treatments were 362.77, 69.11, 0.298, 9.71 and 0.414 kg/ha, respectively against comparative minimum nutrient losses of 71.75, 1.95, 0.016, 0.231 and 0.009 kg/ha for OM, N, P, K and S, respectively. A similar trend was observed in case of maize cultivation where a huge quantity of plant nutrients was depleted from the soil under no-mulch condition. The losses of OM, N, P, K, and S under no-mulch treatment were 1009.6, 118.76, 0.820, 6.526, and 0.592 kg/ha, respectively as against reduced losses of 48.92, 9.74, 0.076, 0.768, and 0.068 kg/ha of the same nutrients, in the respective order under mulched condition. The result indicated that mulching practice promotes a significant reduction in soil loss and nutrient depletion during crop cultivation in hill soils.

4. DISCUSSION

Mulching treatment has created a significant positive influence on the number of grains/cob of maize. These results are also in consonance with Bhatt [15] and Khurshid [16] stated that mulching with crop residue at the rate of 4 and 6 t/ha not only favored both physical and chemical properties of the soil but also maintained good grain yield. Better performance under mulched treatment may be attributed to the higher soil moisture reserves in the mulched plots. Since higher soil moisture is known to enhance efficient

Table 4. Effect of mulching practices on nutrient loss

Management practice	Soil loss	Nutrient loss (kg/ ha)				
	(kg/ ha)	OM	N	P	K	S
Turmeric (Mulch)	1160	71.8	1.95	0.016	0.231	0.009
Turmeric (No Mulch)	35080	362.8	69.11	0.298	9.71	0.414
Maize (Mulch)	5180	48.9	9.74	0.076	0.768	0.068
Maize (No Mulch)	40810	1009.6	118.76	0.820	6.526	0.592

Table 5. Assessment of productivity loss under mulch and no mulch conditions

Management Practices	Yield (t/ha)		Productivity loss (t/ha)
	Turmeric	Maize	
Turmeric (Mulch)	5.61	-	-
Turmeric (No mulch)	3.05	-	2.56
Maize (Mulch)	-	4.04	-
Maize (No mulch)	-	2.67	1.37

Table 6. Economic performance of turmeric and maize cultivation under mulch and no mulch condition

Treatments	Turmeric (t/ha)	Maize (t/ha)	Gross return (Tk./ha)	Total variable cost (Tk./ha)	Net return (Tk./ha)	BCR
Turmeric (Mulch)	5.613	-	224520/-	85,000/-	1,39,520/-	2.64
Turmeric (No mulch)	3.050	-	1,22,000/-	75,000/-	47,000/-	1.63
Maize (Mulch)	-	4.04	64,640/-	31,400/-	33,240/-	2.06
Maize (No mulch)	-	2.67	42720/-	21,400/-	21,320/-	1.99

Price of maize 16 Tk. /kg; Turmeric 40 Tk. /kg

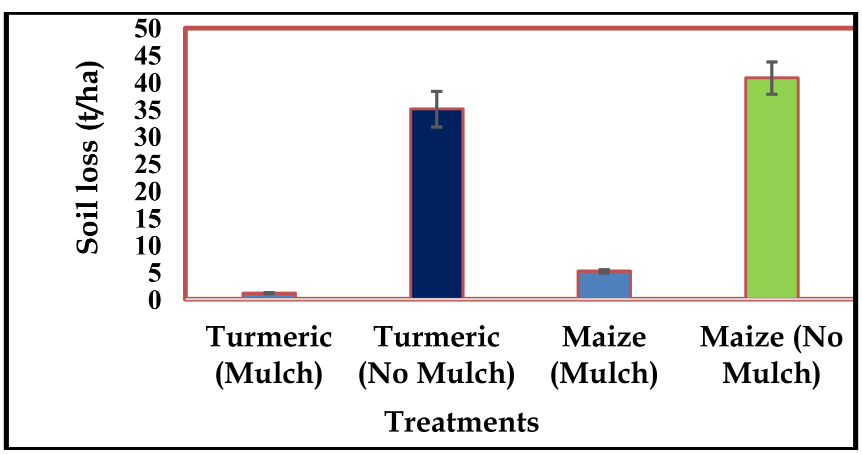

Fig. 1. Effects of straw mulch on soil erosion (t/ha) for different crops

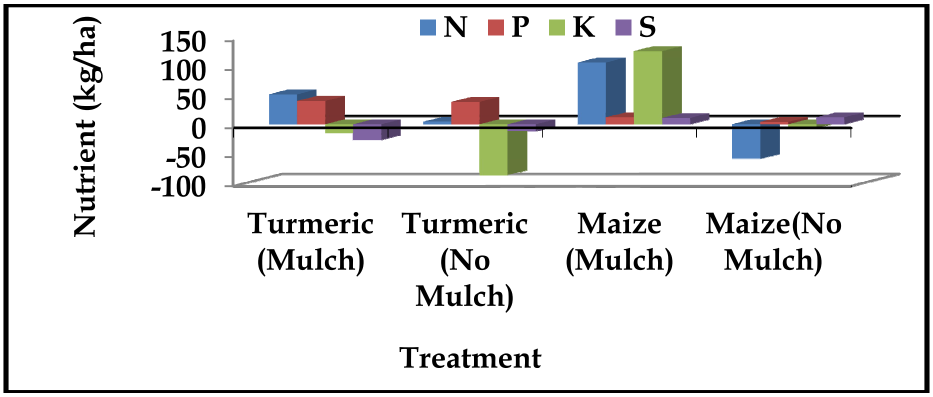

Fig. 2. Assessment of apparent nutrient balance in different crops under mulching in hilly area

use of fertilizer while the excellent solar radiation during the growth seasons encouraged higher photosynthetic rates which culminated in the higher yields of maize. There was a significant positive effect of mulching on the grain weight/cob. Grain yield was significantly favored by mulching. Cob yield of maize was also significantly favored by mulching. The soil moisture, organic matter, plant height, total dry matter, number of cobs per plant, number of grains per cob, and 1000-grain weight of maize were maximum when mulch was applied @12 Mg/ha, while maximum values of grain yield was obtained when mulch was applied @ 8 Mg/ha and in control. Plant yield of maize was significantly increased by varieties mulching. These results are in agreement with those of Wicks [17], who concluded that early maize growth was retarded by increasing mulch levels due to reduced soil temperature, but after tassel formation maize grew taller under greater mulch levels because of increased soil moisture. They also reported that stover dry matter and total DM (hence plant height) increased with increasing mulch levels.

There was a no significant influence of mulch on the number of leaves mother/plant. Mishra et al. [18] reported that the yield attributes of turmeric were improved by mulch application, and mulch applied at the rate of 5 tones farmyard manure along with 30:30:30 kg of NPK/ha, respectively, produced highest germination percentage of 88 per cent including maximum plant height, number of leaves/mother plant, number of primary and secondary fingers per plant as well as the yield per plant. There was a significant increase in the number of leaves/finger plant due to mulching practice. Kumar et al. [19] reported that yield contributing characters and yield of turmeric was maximum when the plots were mulched by paddy straw. Paddy straw mulch significantly increased the number and weight of finger rhizomes and weight of mother rhizome by 35.6, 25 and 33%, respectively over control treatment. The maximum finger size was recorded in plots with paddy straw mulch followed by grass mulch and the minimum in the control. Significantly higher yield of turmeric was recorded in plots with paddy straw mulch applied @ 1 kg/m2 which was 56.7% more over control. There was a significant influence of mulch on the number of mother rhizome/plant. Islam et al. [20] reported that mulching influenced the growth and yield of ginger rhizome. The rice straw mulch gave the highest yield of ginger rhizome. Increase in the paddy straw mulch levels from no mulch to 6.25 t/ha and then from 6.25 to 9.38 t/ha significantly decreased weed population and resulted in better growth parameters, yield attributes and mother, primary and secondary rhizome yield. Mulching could significantly favored the number of finger rhizome/plant. Mulch conserves soil moisture that might have helped to produce more number of finger rhizome per plant. Plant yield was not significantly influenced by mulch practices. Mohanty et al. [21] also observed similar results in case of the yield of turmeric, the paddy straw mulch gave maximum yield (169.33 q/ha) followed by mulching with dry grass (131.33 q/ha). These two treatments were found as better treatments compared to other treatments at farmer's field. Rhizome yield was significantly increased by mulch practices.

4.1 Soil Loss

The most apparent damage caused by water erosion is the removal of soil from eroding surfaces. Effect of mulch showed the distinct variation of soil loss under Turmeric-Maize crop cultivation. Soil loss was more pronounced with no mulched condition in both the crops. It might be due to the direct hit of the rain splash on the topsoil in no mulch treated plot and accompanied by surface runoff carried the soil particles away in the downwards direction. According to soil loss tolerable range, crop combination with mulch should be encouraged for reducing soil erosion. Crop residue mulch, applied as a layer at the soil-air interface, protects the soil against raindrop impact, decreases runoff velocity and its shearing strength, and reduces runoff amount and rate. Mulching decreased the rate of soil structure by improving soil moisture and temperature regimes [22], stimulating the activity of soil fauna and decreasing runoff and soil erosion. Low runoff and soil erosion were reflected in higher clay and silt contents of the surface horizons of plots receiving high mulch rates. Plots receiving high mulch rates were also characterized with high soil moisture retention at low suctions. Improvements in soil moisture characteristics by mulching are due to favorable soil organic matter content and high activity of soil fauna, e.g., earthworms and termites

4.2 Minimization of Soil Loss

Soil loss is a natural process. It cannot be entirely prevented. Therefore, it must be minimized through different conservation practices to save natural resources. Mulch application and crop combination minimized soil loss appreciably. Mulch application solely reduced 96% soil loss over no mulched practice. Thus mulch application is effective to minimize the soil erosion as an indigenous technology for crop production. Sole crop cultivation accelerated soil erosion. Crop combination decreased soil erosion, simultaneously increased crop productivity. Mulching reduced 87% of soil loss over no mulch maize cultivation practice.

4.3 Loss of Nutrients

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 considerable differences in nutrient status between application of mulch practice and different cover crop practices. 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. Analytical values of OM and other nutrients are presented in Table 4. Losses of base cations (e.g., Ca, Mg and K) lead to soil acidity and infertility in one hand and rise in toxicity factors on the other [23]. The result agrees with Gafur et al. [24] who reported that runoff sediment lost from Jhum field contained 4 times higher nutrient than the original condition of the soil. Thus, it revealed in the study that nutrient losses from soil erosion could be minimized through the use of mulching.

4.4 Productivity Loss

Losses of soil materials, nutrients, and deteriorating structures reduce productive potential. Turmeric cultivation showed yield potentiality as high under mulched condition. Yield reduction was observed in non-mulched condition due to excessive nutrient losses. This result confirmed the findings of LRMP [25] as reported that loss of topsoil has affected the soil fertility and reduced the inherent productivity of land through loss of nutrients and degradation of soil physical structure.

4.5 Economics

The cultivation of turmeric under mulching recorded higher monetary advantage than no mulch cropping. Similarly, maize production under mulching was a higher monetary advantage than no mulch condition. Maize cultivation is a significant enterprise in the hilly area. Community people get fresh maize as edible purpose. Family income increased from the sale of maize. Hilly people consume it for their food habit. Women involve themselves and get employed in the marketing of maize.

4.6 Apparent Nutrient Balance

Partial nutrient balances at plot level were estimated by separating inputs and outputs to the system. The main inputs included were N, P, K and S from inorganic fertilizer and crop residues. Nutrient losses from the plots occurred through crop harvest, crop residues and soil erosion. A partial nutrient balance (N, P, K and S) was calculated by subtracting nutrient outflow (losses) from the total nutrient added to the treatment plots. Nutrient balance exercises may serve as instruments to provide indicators for the sustainability of agriculture systems and improvement for nutrient management [26,27]. There were considerable differences in nutrient status between adoptions of mulch practice and with no mulching turmeric cultivation. All the nutrients i.e. N, P, K and S were positively balanced after harvesting of maize under mulch condition and N and P were positively balanced in turmeric under mulch condition. But it was negatively balanced under non-mulch condition. This might be due to the mulching effects in the hilly land, which retained significantly more nutrients in soil. It indicated that more nutrient depletion or loss was occurred in no mulch condition where maize crop was used. The exchangeable K remained highly negatively balanced in all aspects except maize under mulching condition. Thus, it can be concluded that mulching practice is superior to non-mulching for crop production. It retains nutrient in the soil resulting more yield. Nutrient balance in mulch condition was much better than no mulch condition.

5. CONCLUSION

Soil erosion based on nutrient loss characteristics were, influenced by cropping systems and soil amendments. Mulching practices showed positive effect on soil and nutrient loss reduction which was lower sole under different cropping systems. Cropping systems associated with soil nutrient addition are therefore multipurpose methods to improve crop production as well soil nutrient loss reduction. Monetary value of nutrient loss was affected by the different management practices imposed. Cropping systems without any amendment suffered more economic loss due to nutrient loss. Soil amendments under mulching cropping systems reduced soil nutrient loss with least economic loss. These findings give a new opportunity to highlight the importance of sustainable crop management to reduce nutrient loss on croplands in hilly area of Bangladesh.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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