Introduction of Quesungual Slash and Mulch Agro-forestry System (QSMAS) for Enhancing Crop Yields and Soil Quality in Chittagong Hill Tracts

Hossain, M.A.[1*], Hossain, M.F.[2], Islam, M.M.[2]

[1] Principal Scientific Officer, Soil Resource Development Institute, Ministry of Agriculture, Krishi Khamar Sarak, Dhaka, Bangladesh
[2] Scientific Officer, Soil Resource Development Institute, Ministry of Agriculture, Krishi Khamar Sarak, Dhaka, Bangladesh

Email Address

altajolly63@yahoo.com (Hossain,M.A.)
*Correspondence:altajolly63@yahoo.com

Received: 20 December 2017**; Accepted:** 2 January 2018**; Published:** 15 January 2018

Abstract

The Chittagong Hill Tracts region is of great importance for growing various crops, which are different from the plains. Farmers practice traditional Jhum culture for their livelihood. They slash and burn the vegetation on hills and go for Jhum cultivation which contributes to soil and nutrient loss. It can also lead to land degradation if population pressure reduces the fallow periods needed for the recovery of natural resources. The Quesungual Slash and Mulch Agro-forestry System (QSMAS) is a smallholder production system with a group of techniques for the sustainable management of vegetation, soil, and water resources in drought-prone hillsides is an alternative to traditional and widespread slash and burn agriculture. The present research work was undertaken to introduce an eco-friendly productive crop production system in sloping lands of CHT which will mitigate the process of land degradation due to Jhum culture as well as take care of food security of Hill people. The experiment was conducted in moderate hill slope of Soil Conservation and Watershed Management Center, SRDI, Bandarban. Experimental site comprised of four plots- QSMAS model, modern Jhum with hedge row, traditional Jhum and control (secondary forest). From two years data it was observed that system productivity of QSMAS was much higher than that of Jhum with hedge row and traditional Jhum. Total soil loss and surface run off was much lower in QSMAS model than Jhum with hedge row and traditional Jhum. Soil organic matter and CEC was increased over initial status in QSMAS and secondary forest. Micro-watershed based agro-forestry system may be an alternate option to replace Jhum culture for livelihood security of Hill dwellers in Chittagong Hill Tracts.

Keywords:

Jhum; Slash and Mulch, Agro-forestry

1. Introduction

The Chittagong Hill Tracts comprising the three districts of Bandarban, Rangamati and Khagrachhari has an area of 13181sq km endowed with natural beauty and high economic potentiality. The tribal along with the Bengali people are living there for long maintaining their distinct socio-cultural identities and harmony. The area is hilly with mild to very steep slopes (from 15% to over 70%) often breaking or ending in cliffs. More than 90 percent of the area is covered by hills with only 129,000 hectares (ha) of cropped land. About 87 per cent of the land is covered with forest (totaling 11,475 sq.km) mostly owned by the government [1]. Presently, it is increasingly becoming denuded due to unplanned management of hills and agricultural practices at steep slope without any conservation measure. The total annual precipitation is also high (2000-3550mm). Continuous depletion of soil fertility is the major constraint to sustainable crop production in the hilly areas of Bangladesh. According to Banglapedia (2009) about 20,000 hectares of land are being brought under Jhum cultivation every year [2]. Jhum cultivation, sloppiness, heavy rainfall and improper management of soil enhanced nutrient depletion through erosion. Accelerated soil erosion is the greatest hazard for the long term maintenance of soil fertility. Gafur *et al*. (2003) carried out a research to find out runoff and losses of soil and nutrients from small watersheds under shifting cultivation in the CHT [3]. Borggaard *et al*. (2003) carried out a study to analyze the sustainability appraisal of shifting cultivation in CHT [4]. The Chittagong Hill Tracts region is of great importance for growing various crops, which are different from the plains. But unfortunately few eco-friendly sustainable agriculture practices for CHT have so for been developed.

Slash and burn practices, also known as **shifting cultivation, swidden agriculture**, or simply **jhum chash**, is an ancient form of agriculture practiced by 200 to 500 million people around the world currently. The people in the uplands of eastern Bangladesh have been practicing shifting cultivation from time immemorial and it is closely related with their socio-cultural identity [5]. However, in the past, they practiced shifting cultivation in the same area with a fallow period of 15–20 years, which ensured the long-term sustainability of soil fertility, and ensured forest regrowth. With the rapid growth in population, the fallow period has been dramatically reduced to 3–4 years, allowing very little time for soil or vegetative regeneration [6]. The decrease in fallow period has led to the deterioration of faunal and microbial organisms, top soil loss, and erosion during periods of heavy rainfall [7]

The two key components of slash and burn agriculture are the use of fire to prepare fields for cultivation and the subsequent abandonment of those fields as productivity declines. The inevitable decline in productivity is a result of the depletion of soil nutrients and also a result of the invasion of weed and pest species . Slash and burn contributes to global warming by acting as a major source of greenhouse gas emissions, and by depleting reserves of carbon both above and below-ground. It can also lead to land degradation if population pressure reduces the fallow periods needed for the recovery of natural resources. With the increasing population pressure several alternatives to shifting cultivation have been suggested [8] which include: (1) tree crop plantation, (2) agro-forestry, (3) planted fallow system (tree and shrub fallows plus arable crop sequence), (4) livestock production, and (5) special commercial horticulture.

Eco-efficient agriculture uses resources more efficiently to achieve sustainable increases in productivity, reduces the degradation of natural resources, and creates opportunities for boosting incomes and employment in rural areas. The Quesungual Slash and Mulch Agro-forestry System (QSMAS) is one example of eco-efficient crop production for tropical sub-humid regions. It has reduced erosion and improved crop yields and quality of life for over 6,000 local families while allowing regeneration of about 60,000 hectares of secondary forest [9]

QSMAS is a smallholder production system with a group of techniques for the sustainable management of vegetation, soil, and water resources in drought-prone hillsides. The system was developed in the early 1990s in close collaboration with farmers and technicians from FAO and other institutions, as an alternative to traditional and widespread slash and burn agriculture. It has had an extraordinary impact on the livelihoods of farmers growing maize, beans, and sorghum in Central America, and has great potential to be used in other regions.

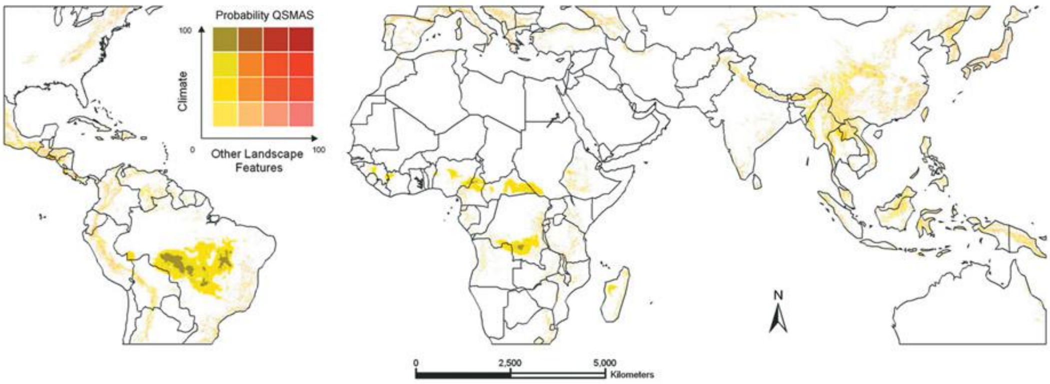

Figure 1. *Site similarity analysis: bivariate map showing potential areas for targeting QSMAS across the developing countries in the tropics (performed by combining Bayesian and frequency probability statistical analyses).*

Past research reports indicate that little work has been undertaken so far on replacing the traditional Jhum system with modern techniques to reduce soil erosion, biodiversity loss, deforestation, factors that contribute to environmental degradation and impacts on environment due to shifting (Jhum) cultivation practice.

Keeping the above views in mind the present research work was undertaken to introduce an eco-friendly productive crop production system in sloping lands of CHT which will mitigate the process of land degradation due to Jhum culture as well as take care of food security of Hill people.

Goal: Introduce an eco-efficient crop production system in sloping lands of CHT

Objective (s):
i) Establish Quesungual Slash and Mulch Agro-forestry System (QSMAS) in CHT.
ii) To improve both the productivity and economic returns of land currently engaged in slash and burn agriculture.
iii) To create awareness about soil conservation and watershed management among hill dwellers.

2. Methodology

To validate the principles of Quesungual agro-forestry system in Soil Conservation and Watershed Management Centre, SRDI, Bandarban watershed four land use systems were established: traditional Jhum (slash-and-burn), Jhum with modern management, Quesungual slash and mulch agro-forestry systems (QSMAS), and demarcated areas of secondary forest as a control. Crops like rice, maize; millet, cotton, sesame and common beans, marfa, yard long bean, sweet gourd, ginger and turmeric were accommodated in a traditional system, application of slashed vegetation/crop residues as mulch and QSMAS, to measure and compare differences among production systems. Soil sampling for initial fertility assessment and determine change in fertility status after each cropping season for three years.

Soil sampling consisted of digging test pit of 50 cm depth and sampling of soil at 0-13, 13-43, 43-63 cm depths just before sowing every year. Composite soil samples will be collected from each plot for fertility determination. Chemical characterization included determination of pH, organic matter (OM), N, P, K, S, Zn, B, Ca, Mg, Mn, Fe, and Cu. In the field, productivity of rice, maize; cotton, sesame and common beans, marfa, sweet gourd, ginger and turmeric were evaluated in three cropping seasons, from 2014 to 2017.

Statistical analyses of soil fertility and crop yields data were done to determine the change in soil fertility and crop productivity over the years.

Layout of experimental plots

Experimental site: SCWMC, Meghla, Bandarban

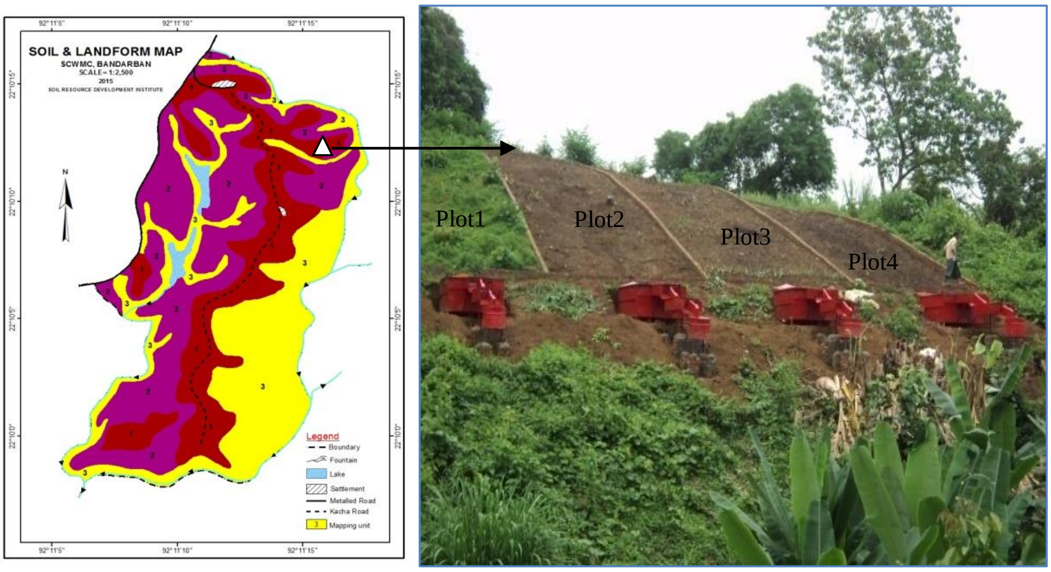

Figure 2. *Layout of experimental site (moderate slope;Plot size (5mX20m)=100m^2).*

2. Results and Discussion

3.1. Soil fertility Status

Initial fertility status was compared with fertility status of each plot after crop harvest. Soils are mostly highly acidic to slightly acidic in nature. Initial Organic matter status was low to medium while it was high to medium after crop harvest. Initial Nitrogen status was very low to low while it was low to medium after crop harvest. Phosphorus status was very low. Initial Potassium status is medium to optimum while it was medium to very high after crop harvest. Sulfur status was reduced from medium - low range to low - very low range. Zinc status was also reduced from initial status i.e. low to medium. Boron status reduced from very high to low – medium range. Calcium, Magnesium, Copper, Iron and Manganese status is

DOI: 10.31058/j.as.2017.11004

remained almost unchanged (Table 1). Physical analysis was done to determine the soil texture (Table 2). CEC, which indicates soil fertility, seems to be improved over time under QSMAS and secondary forest system. Highest CEC increase was observed in QSMAS plot (Figure 3). Whereas, CEC was reduced in Jhum with hedge and Traditional Jhum system.

Table 1. *Initial soil fertility status and fertility status after crop harvest.*

Plot No./Year	Depth of soil sample	pH	OM (%)	N (%)	P	K	S	Zn	B	Ca	Mg	Cu	Fe	Mn
					meq/100gsoil		µg/gsoil			meq/100gsoil		µg/gsoil		
1/2015	0-13	4.9	1.82 M	0.10 L	2.85 VL	0.33 O	15.0 M	1.10 M	0.93 VH	2.53 L	1.40 O	1.06 VH	75.93 VH	15.18 VH
1/2016		4.5	4.13 H	0.24 M	5.32 VL	0.52 VH	6.05 VL	1.01 M	0.18 L	5.82 O	2.46 VH	0.72 H	71.80 VH	11.22 VH
2/2015	0-13	5.7	1.62 L	0.09 VL	1.21 VL	0.35 O	8.17 L	0.64 L	0.86 VH	1.77 L	1.16 M	0.81 VH	76.28 VH	12.67 VH
2/2016		4.5	2.88 M	0.17 L	3.88 VL	0.26 M	6.08 VL	0.09 VL	0.22 L	2.20 L	1.08 M	0.42 M	11.72 O	2.34 H
3/2015	0-13	4.9	1.32 L	0.07 VL	1.38 VL	0.32 O	9.17 L	0.88 L	0.92 VH	3.21 M	1.37 O	0.99 VH	86.34 VH	10.20 VH
3/2016		4.5	3.12 M	0.18 L	6.86 VL	0.42 H	7.35 VL	0.96 M	0.16 L	2.50 L	1.17 O	0.44 M	43.8 VH	14.3 VH
4/2015	0-13	4.9	1.10 L	0.06 VL	2.19 VL	0.26 M	5.20 VL	0.78 L	0.79 VH	2.18 L	1.16 M	0.88 VH	81.15 VH	7.80 VH
4/2016		4.5	3.24 M	0.19 M	6.80 VL	0.46 VH	8.42 L	1.02 M	0.21 M	1.25 VL	1.04 M	0.14 VL	42.2 VH	2.80 O

Note: VL=very low; L=low; M=medium; O=optimum; VH=very high

Table 2. *Mean, standard error, correlation coefficient and significance of soil fertility indicators over time.*

Soilnutrients	Mean ±SE		Correlation	significance
	2015	2016		
pH	5.10±0.20	4.50±0.00	0.00	0.00
OM	1.47±0.16	3.34±0.27	0.53	0.47
N	0.08±0.01	0.20±0.02	0.53	0.47
P	1.91±0.38	5.72±0.71	0.19	0.81
K	0.32±0.02	0.42±0.06	-0.49	0.51
S	9.39±2.05	6.98±0.57	-0.73	0.27
Zn	0.85±0.10	0.77±0.23	0.72	0.28
Ca	2.42±0.31	2.94±1.00	0.24	0.77
Mg	1.27±0.07	1.44±0.34	0.71	0.29
Cu	0.94±0.06	0.43±0.12	0.68	0.32
Fe	79.93±2.45	42.38±12.27	0.01	0.99
Mn	11.46±1.59	7.67±3.01	0.28	0.72

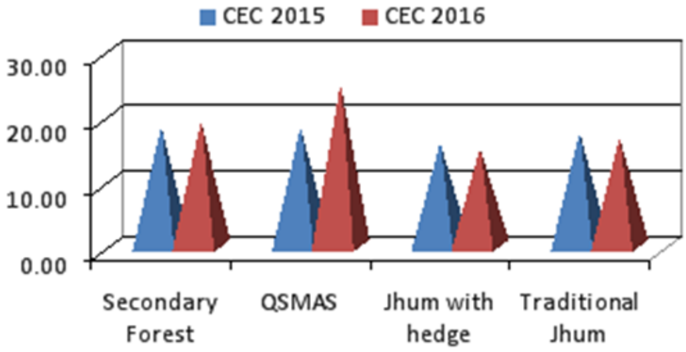

Figure 3. *ComparativeCECofexperimentalplotsovertime.*

3.2. Crop Yield and System Productivity

Each plot had the same crop combination except control (secondary forest). Rice (local), maize (local), sesame, millet, sweet gourd, chilly, marfa, yardlong bean, country bean, cotton, ginger, turmeric were planted in mixture. But in QSMAS model the crops were arranged in sub plots within the main plot. Grafted fruit trees-mango, carambola and seedlings of papaya were planted in the plot.

After harvestings crop yield data were recorded and analyzed. It was observed that rice yield was higher in traditional Jhum practice than other practices. But system productivity of QSMAS model plot was much higher than other plots (Table 4 & 5). Comparative yield and economic data of component crops are shown in Tables 6 and 7.

Table 4. *Yield(kg/100sqm)andreturn(BDT)ofcropsharvestedfromexperimentalplots(2015).*

Sl.No	Yield (kg/100sqm)				Price (BDT/Kg)	Return in BDT			Remarks
	Crops	Traditional Jhum	Jhum with hedgerow	QSMAS model		Traditional Jhum	Jhum with hedgerow	QSMAS model	
1	Rice(local)	15.00	10.00	6.00	15.00	225.00	150.00	90.00	QSMAS plot out yielded all the other plots
2	Maize(local)	3.00	5.00	6.00	50.00	150.00	250.00	300.00	
3	Sesame	1.00	1.50	1.50	60.00	60.00	90.00	90.00	
4	Millet	1.00	0.50	0.60	80.00	80.00	40.00	48.00	
5	Sweetgourd	4.00	5.00	6.00	35.00	140.00	175.00	210.00	
6	Chilly	0.40	0.50	0.50	120.00	48.00	60.00	60.00	
7	Marpha	3.00	4.00	4.00	40.00	120.00	160.00	160.00	
8	Yardlongbean	4.00	5.00	6.00	40.00	160.00	200.00	240.00	
9	Countrybean	-	-	6.00	60.00	-	-	360.00	
10	Cotton	1.50	2.00	3.00	200.00	300.00	400.00	600.00	
11	Ginger	3.00	5.00	7.00	60.00	180.00	300.00	420.00	
12	Turmeric	12.00	15.0	17.00	20.00	240.00	300.00	340.0	

			0					0	
13	Mango(4)*							-	No fruiting was observed
14	Papaya(5)							-	
15	Carambola (3)							-	
Total						1703.00	2125.00	2918.00	

**Figures within parenthesis indicate number of plants.*

Table 5. *Yield(kg/100sqm)andreturn(BDT)ofcropsharvestedfromexperimentalplots(2016).*

Sl. No	Yield(kg/100sqm)				Price(BDT/Kg)	ReturninBDT			Remarks
	Crops	Tradi-tional Jhum	Jhum with hedge row	QSMAS model		Tradi-tional Jhum	Jhum with hedge row	QSMAS model	
1	Rice (local)	14.00	13.00	8.00	15.00	210.00	195.00	120.00	QSMAS model out yielded all the other plots
2	Maize (local)	3.00	5.00	4.00	50.00	150.00	250.00	250.00	
3	Sesame	0.80	1.00	0.90	60.00	48.00	60.00	54.00	
4	Millet	0.90	0.80	0.50	80.00	72.00	64.00	40.00	
5	Sweetgourd	3.50	4.00	5.00	35.00	122.00	140.00	175.00	
6	Chilly	1.20	1.00	0.70	80.00	96.00	80.00	56.00	
7	Marpha	2.50	4.00	3.00	40.00	100.00	160.00	120.00	
8	Yardlongbean	5.00	9.00	6.00	35.00	175.00	315.00	210.00	
9	Country bean	-	-	4.00	40.00	-	-	160.00	
10	Cotton	1.00	1.50	1.20	200.00	200.00	300.00	240.00	
11	Ginger	3.00	6.00	4.00	50.00	150.00	300.00	200.00	
12	Turmeric	12.00	17.00	14.00	10.00	120.00	170.00	140.00	
13	Mango(4)	-		2.00	80.00	-	-	160.00	
14	Papaya(5)	-		40.00	15.00	-	-	600.00	
15	Carambola(3)	-		3.00	10.00	-	-	30.00	
Total						1443.00	2034.00	2505.00	

Table 6. *Comparative yield of component crops over time.*

Crops	Mean ±SE		Correlation	Sig.
	2015	2016		
Rice	10.33 ±2.60	***11***.67 ±1.86	0.91	0.28
Maize	4.67 ±0.88	4.00 ±0.58	0.66	0.55
Sesame	1.33 ±0.17	0.90 ±0.17	0.87	0.33
Millet	0.70 ±0.16	0.73 ±0.12	0.55	0.63
Sweetgourd	5.00 ±0.58	4.17 ±0.44	0.98	0.12
Chilli	0.47 ±0.03	0.97 ±0.15	-0.80	0.41
Marpha	3.67 ±0.33	3.17 ±0.44	0.76	0.45

Yardlongbean	5.00±0.58	6.67±1.20	0.24	0.85
Cotton	2.17±0.44	1.90±0.56	-0.85	0.36
Ginger	5.00±1.15	3.67±1.45	0.60	0.59
Turmeric	14.67±1.45	14.33±1.45	0.50	0.67

3.3. Soil Loss from Experimental Plots

As Bandarban is a high rainfall area if the soil surface is exposed due to deforestation it becomes vulnerable to water erosion. Soil loss from hills depends on surface cover, rainfall intensity, nature of slope and aspects of slope. Bandarban experienced a significant amount of rain every year though its distribution uneven over months. Rainfall intensity is higher in the months of May to August (Figure 4). Multi-slot divisor was established at the bottom of each plot. Total surface run–off and total soil loss was calculated per shower and cumulative figure was made by adding each observation. In 2015, it was observed that highest total soil loss (39.17t ha^{-1} y^{-1}) occurred in traditional Jhum plot followed by Jhum with hedge and mulch and QSMAS model (Figure 5). Highest soil loss was observed in the month of June irrespective of land use (Table 8).

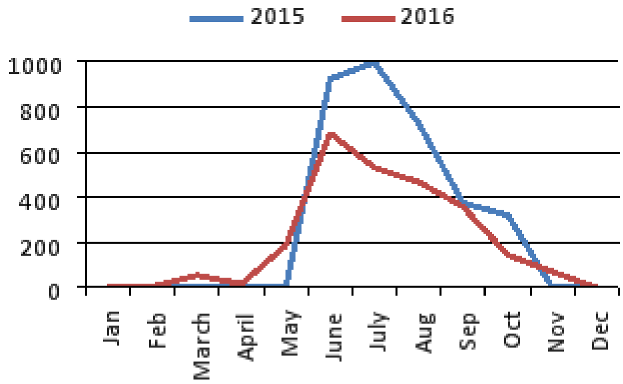

Figure 4. *Monthly distribution of rainfall in experimental area overtime.*

The lowest total soil loss (12.14t ha^{-1} y^{-1}) was observed in control plot (secondary forest). In 2016 similar trends were observed. This result is in conformity with findings CIAT, 2009 [9]. Gafur *et al.* (2003) conducted a research to find out the runoff and losses soil and nutrients from small watersheds under shifting cultivation in the Chittagong Hill Tracts [3]. In similar studies, Shoaib *et al.* (1998) recorded total soil loss to be 40-45t $ha^{-1}y^{-1}$ in traditional Jhum culture highest being observed in steep slope and the lowest in gentle slope [10]. There is evidence that the use of contour hedgerows on steep slopes (40-50%) can reduce erosion by 55-80% and run off by 30-70% compared to shifting cultivation. It was observed that QSMAS protects soil by markedly reducing soil erosion (Figure 5) in comparison to Jhum plots. This result is in conformity with the findings of CIAT (2009) [9] (Figure 6).

Table 7. *Total soil loss from experimental plots ($tha^{-1}y^{-1}$) in 2015 and 2016.*

Particulars		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total ($tha^{-1}y^{-1}$)
Control	2015	-	-	-	-	0.80	3.32	3.12	3.14	1.09	0.67	-	-	12.14
	2016	-	-	-	-	-	2.28	1.53	0.83	0.52	0.63	-	-	5.79

QASMAS	2015	-	-	-	-	1.68	6.18	4.52	4.49	1.52	1.65	-	-	20.04
	2016	-	-	-	-		4.55	2.57	1.63	0.96	0.72	-	-	10.43
Jhum with hedge row	2015	-	-	-	-	2.15	7.84	5.58	5.67	1.96	1.90	-	-	25.10
	2016	-	-	-	-	-	7.01	4.34	1.89	1.06	0.86	-	-	15.16
Traditional Jhum	2015	-	-	-	-	2.68	10.52	9.18	9.49	4.07	3.23	-	-	39.17
	2016	-	-	-	-	-	9.4	8.4	2.77	1.25	1.36	-	-	23.18

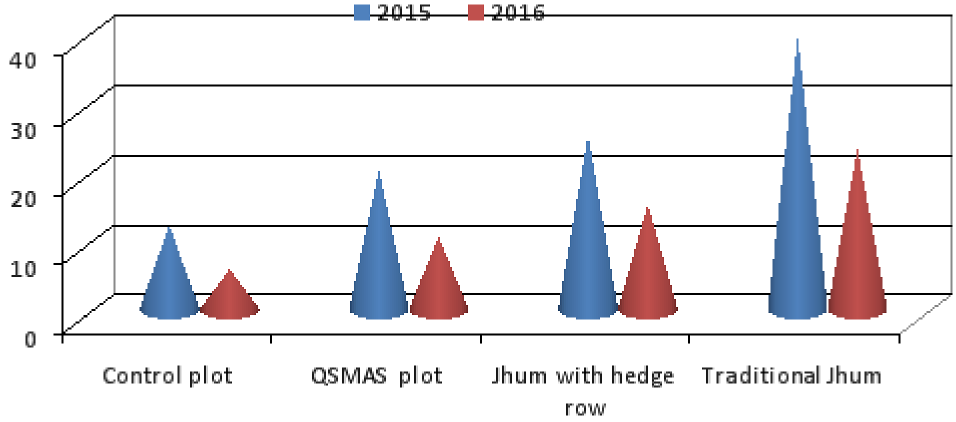

Figure 5. *Reduction of soil loss over time under different land use systems*

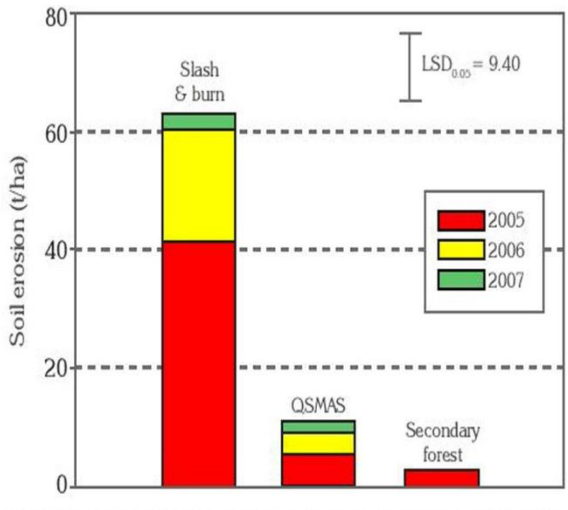

Figure 6. *QSMAS protects soil by markedly reducing soil erosion (87%, 84% and 67% less after 1,2 and 3 years, respectively) compared to slash and burn system.*

Generally, 11.2 Mg ha^{-1} yr^{-1} is considered as permissible erosion limit based on the assumption that this rate of erosion equals soil formation. However, the actual erosion occurring in different sites sometimes goes far beyond this assumption. Thus, considering a single value approach as critical limit for soil erosion would be misleading [11].

3.4 Runoff and sediment load

The total runoff per hectare during 2015 and 2016 cropping season was highly variable between experimental plots, although there was no difference in terms of the rainfall received during the same period. The distribution of runoff during the years is shown in Table 8as monthly values. The distribution of runoff follows the rainfall amount and intensity pattern with the maximum monthly runoff occurring in June, irrespective of land use. On average, the highest runoff volume was from traditional Jhum (Table 8). The runoff from the watersheds and the sub-watersheds seems to have been influenced by factors such as topographic characteristics, land use and management practices implemented [12,13].

Table 8. *Total surface run off (%) from experimental plots in 2015 and 2016.*

Particulars		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Control	2015	-	-	-	-	4.40	35.61	65.30	41.74	47.40	17.73	-	-
	2016	-	-	-	-	-	35.92	29.65	30.17	29.40	50.43	-	-
QSMAS	2015	-	-	-	-	4.87	46.05	67.41	51.63	57.71	21.80	-	-
	2016	-	-	-	-	-	41.17	47.90	39.53	30.84	35.63	-	-
Jhum with hedge row	2015	-	-	-	-	5.18	50.31	69.22	60.62	66.73	22.82	-	-
	2016	-	-	-	-	-	44.73	55.74	47.30	32.28	40.57	-	-
Tradi-tional Jhum	2015	-	-	-	-	5.87	52.19	71.03	72.90	75.76	23.84	-	-
	2016	-	-	-	-	-	49.20	64.54	51.65	33.72	45.50		

3.5. Nutrient Loss Through Surface Runoff and Erosion

The impact of soil erosion on the productive potential of agricultural lands is well known [14], but the magnitude depends on local circumstances. One of the most vital negative environmental impacts of shifting cultivation is the damage that causes to the soil system. It accelerates the soil erosion manifold. Besides causing air pollution due to burning, shifting cultivation is responsible for loss of soil nutrients and useful soil fauna and microbes. Burning of slash lowers soil acidity, organic matter and total nitrogen, but enhances phosphorus and cations [15]. In the study areas, the organic matter depletion was also observed irrespective of land use (Table 9). The loss of the essential plant nutrients (N, K, S, Zn, B, Ca, Mg and Mn) in association with the suspended sediments and runoff during the measurement period was remarkable. The selective erosion of plant nutrients in runoff is a well-known phenomenon [16], and the sediment lost from the experimental plots on the micro-watershed was clearly enriched in all elements except P, relative to the topsoil of the watershed. The highest loss was displayed by Mn, Zn and S possibly resulting from reductive dissolution of oxides caused by sudden saturation of the soils in the earlier heavy rainfalls of the season. The results are in partial conformity with Gafur *et al*. (2003) [3]. This suggests that soil conservation control efforts should be prioritized in areas with high soil and nutrient loss potential so that their productivity is maintained.

Table 9. Nutrient loss (t ha^{-1}) from plots under different land use (2016).

Particulars	N	P	K	S	Zn	B	Ca	Mg	Cu	Mn
Secondary forest	5.40	0.04	0.65	0.88	0.18	0.01	5.1	0.25	0.024	0.093
QSMAS	4.00	0.04	0.44	0.54	0.16	0.02	2.0	0.21	0.031	0.178
Jhum with hedge	4.80	0.60	0.26	0.94	0.17	0.01	2.1	0.19	0.031	0.154
Traditional Jhum	4.80	0.04	0.26	0.56	0.17	0.01	1.7	0.26	0.028	0.193

It was observed that highest nitrogen loss i.e. 5.4t ha^{-1}occurred from secondary forest plot and the lowest (4.0tha^{-1}) from QSMAS plot along with other nutrient elements. In case of Jhum with hedge and Traditional Jhum plot nitrogen loss was 4.8t ha^{-1} along with other nutrient elements (Table 9). Gafur (2001) found that in each year, the eroded soil from all the Jhum fields in CHT carries out about 4,309 tons of nitrogen along with other nutrients and about 14,071 tons of commercial fertilizers would be required to replace nutrients in eroded soil that would cost approximately US $1.8 million annually [7]. The evidence indicates that lands of low agricultural quality are more likely to move into and out of intensive agricultural uses and are also more sensitive environmentally based on some indicators of erosion, nutrient losses to water, and proximity to imperiled species [17].

4. Conclusions

Fertility status was observed to be improved due to improved land use and management system.

System productivity of QSMAS plot was much higher than that of other plots. It was observed that highest total soil loss occurred in traditional Jhum plot followed by Jhum with hedge row and QSMAS model. The lowest total soil loss was observed in control plot (secondary forest).

Therefore, effective measures should be taken to discourage slash and burn shifting cultivation and upscale farmers knowledge base and information for awareness building along with other supports to enable them to adopt agro-forestry as a sustainable land-use system.

Agro-forestry is considered as one of the major strategies for sustainable forest management as well as poverty reduction in Bangladesh, where there is obvious priority for food crop production. Farmers need technical know-how, capital investment, marketing facilities and institutional supports (mainly title to their land) to move from Jhum to sedentary farming practices such as agro-forestry. Micro-watershed based agro-forestry system may be an alternate option for Jhum culture for livelihood security of Hill dwellers in Chittagong Hill Tracts. Government should design necessary program to address the needs of upland farmers, e.g., substantial initial investment, to support them to move from shifting cultivation to agro-forestry systems.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

References

[1] Dasgupta, S.; Ahmed, F.U. Natural resource management by tribal community: a case study of Bangladesh. 1998, 52-55.

[2] Banglapedia(2009). Population-Banglapedia. Available online: http://en.banglapedia.org/index.php?title=Population (accessed on 20 December 2017).

[3] Gafur, A.; Borggaard, O.K.; Jensen,J.R.; Peterson, L. Run off and loses of soil and nutrients from watershed under shifting cultivation (Jhum) in the Chittagong Hill Tracts of Bangladesh. *J. Hydrol.* 2003, 279, 293-309. https://doi.org/10.1016/S0022-1694(03)00263-4.

[4] Borggaard, Ole K.; Gafur, A.; Peterson, L. Sustainability appraisal of shifting cultivation in the Chittagong Hill Tracts of Bangladesh. *Ambio.* 2003, 32(2), 118-123. https://doi.org/10.1579/0044-7447-32.2.118.

[5] Miah M.A.M.; Islam S.M.F. Shifting cultivation and its alternatives in Bangladesh: productivity, risk and discount rates. SANDEE working paper no. 24-07, Nepal. 2007.

[6] Riessen AV (2000) Chittagong Hill Tracts region developmentplan.Interim report no. 7. Sociology and IndigenousPeople, Asian Development Bank, Bangladesh.

[7] Gafur A (2001) Effects of shifting cultivation on soil properties, erosion, nutrient depletion, and hydrologicalresponses in small watershed of the Chittagong Hill Tractsof Bangladesh. PhD Dissertation, The Royal Veterinaryand Agricultural University, CopenhagenHousehold Income and Expenditure Survey Analysis Report. 2005. Bangladesh Bureau of Statistics, Dhaka, Bangladesh.

[8] FAO. Improved Production system as An Alternative to Shifting Cultivation. FAOSoils Bull. 1984, 53, 201.

[9] CIAT. Quesungual slash and mulch agro-forestry system (QSMAS): Improving crop water productivity, food security and resource quality in the subhumid tropics. CPWF Project Report. Cali, Colombia. 2009, 65.

[10] Shoaib, J.U.; Mostafa, G.; Rahman, M. A Case Study on Soil Erosion Hazard in Hilly Regions of Bangladesh, Annual Report, SRDI.Dhaka. 1998.

[11] Lakaria, B.L.; Mandal, D.; Biswas, H. Permissible soil erosion limits under different landscapes of Chhattisgarh. *Indian Journal of Soil Conservation*, 2010, 38(3), 148-154.

[12] Hartantoa, H.; Prabhub, R.; Widayat, A.; Asdakd, C. Factors affecting runoff and soil30 erosion: plot-level soil loss monitoring for assessing sustainability of forest management. *Forest Ecol. Manag.* 2003, 180, 361-374.

[13] Gary, W.C.; Carmen, V. Impacts of land use changes on runoff generation in the eastbranch of the brandywine creek watershed using a GIS-based hydrologic model. *Middle States Geographer,* 2007, 40, 142-149.

[14] Pathak, P.; Wani, S.P.; Singh, P.; Sudi, R. Sediment flow behavior from small agricultural watersheds, Agr. *Water Manage,* 2004, 67, 105-117.

[15] Das, S.; Das, M.D. Shifting Cultivation in Tripura – A Critical Analysis. *Journal of Agriculture and Life Sciences*, 2014, 1(1), 48-54.

[16] Sharpley, A.N. The selective erosion of plant nutrients in runoff. *Soil Sci. Soc. Am. J.* 1985, 49, 1527-1534.

[17] Lubowski, R.N.; Shawn Bucholtz; Roger Claassen; Michael J. Roberts; Joseph C. Cooper; Anna Gueorguieva; Robert Johansson. Environmental Effects of

Agricultural Land-Use Change:The Role of Economics and Policy, Economic Research Report Number 25 United States Department of Agriculture. 2006.

© 2017 by the author(s); licensee International Technology and Science Publications (ITS), this work for open access publication is under the Creative Commons Attribution International License (CC BY 4.0). (http://creativecommons.org/licenses/by/4.0/)