CROP AGRICULTURE OF CHITTAGONG HILL TRACTS: REVIEWING ITS MANAGEMENT, PERFORMANCE, VULNERABILITY AND DEVELOPMENT MODEL

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ABSTRACT

This paper presents the crop production systems with their impacts on environment in Chittagong Hill Tracts (CHTs) of Bangladesh. Boro-fallow-T. aman, fallow-fallow-T. aman and fallow-aus+non-rice (jhum) are the major cropping patterns in CHTs. Crop agriculture in hill is mainly divided into two systems i.e. plain land plough agriculture and non-plough slope agriculture. In valley and foothill, irrigated seasonal and annual crops are cultivated extensively. In hilly slope; shifting cultivation, horticultural plantation, agroforestry and mixed fruit gardening are practiced in Bangladesh. Shifting cultivation (jhum) is a traditional system being practiced in the CHTs by the tribal communities. An increasing trend of fruit cultivation and production is observed in CHTs. Agroforestry and perennial fruit gardening showed lucrative economic benefits with environmental stability in this region. Extensive jhum practice creating a dilemma in conserving nature and food production. Soil erosion is extensive in CHTs due to shifting cultivation and monocropping systems. Tobacco and, slash and burn method of cultivation are very destructive to land and forest ecosystems. Sustainable alternate land use of jhum farming including multistorey agroforestry and multistrata fruit orchard have evolved in some areas of CHTs. Although alternate land use practices started, extensive expansion should be ensured rapidly for the development of agricultural production and environmental conservation.

Keywords: Hill slope, Plough agriculture, Shifting cultivation, Agroforestry, Fruit orchard, Environment

1. INTRODUCTION

Chittagong Hill Tracts (CHTs) comprise 10% of country's landmass, is located at southeastern parts of Bangladesh characterized by alternating beds of little-consolidated sands and shale providing a basis for the formation of complex mixtures of deep and shallow soils (Zakaria and Majumder, 2019; Hossain, 2011). Bandarban, Khagrachari and Rangamati districts are called together Chittagong Hill Tracts. The CHTs comprising 70% of the hilly areas of Bangladesh and covers 13,184 km², of which 90% are sloping lands (Hossain *et al.*, 2017). The area is mild to very steep ranging from 15% to over 70% slope, often breaking or ending in cliffs (SRDI, 2018). High hills ranged from 200-1000 m and lower hills from 15-200 m above the mean sea level (Hossain *et al.*, 2017).

Agriculture is the main source of livelihood of the majority of CHTs dwellers. Agricultural activities include ploughing lands, shifting cultivation, fruit gardening, paid wage labor, timber production, livestock and poultry rearing, and free fishing. More than 35 crop species are cultivated annually in CHTs (Ahammad and Stacey, 2016). Crop agriculture including fruits and trees provide both subsistence needs and cash incomes of both Bengali and ethnic communities in hilly areas. Agriculture in the hilly area is greatly rainfed. Hills are highly susceptible to erosion and difficult to irrigate. The monsoon rainfall is very high, more than 2200 mm annually. Valleys and floodplains of the CHT are suitable for plough agriculture using mainly for cultivation of rice, maize, tobacco, potato, cotton, papaya, sugarcane, pineapple, turmeric, ginger, aroid and others vegetables (Ahammad and Stacey, 2016). The hill slopes are suitable for growing a number of high value fruits such as banana, pineapple, papaya, mango, litchi, jackfruit, orange, guava, dragon fruit and lemons. The CHTs region is one of the richest fruit production regions in Bangladesh. At least 25% of households of CHTs produce banana in their annual farming plots and home yards (Khan *et al.*, 2012). Distinctive climatic conditions of CHTs provides a great diversity and variety for fruit production, and orchard fruit production system comprises the largest fruit sector of Bangladesh (Dewan *et al.*, 2015). Tree based crop production systems either with fruit or timber plantations have increased in CHTs which are more economically attractive and environmentally sound (Bala *et al.*, 2013). There is tremendous potential for growing high value crops such as fruit, vegetables, medicinal plants and aromatic plants under agroforestry system in hilly areas (Rasul and Tripura, 2016).

Shifting cultivation (Jhum) is a form of customs and rituals of tribal which governs hill agriculture in a cultural and sustainable way where land is cleared by controlled fire, used only for subsistence farming and then natural fallow phase employed long enough to be dominated by

woody vegetation (Bhagawati *et al.*, 2015). Even though Jhum has considerably declined in recent years but still a dominant land-use system in the hilly terrain and has been practiced by local indigenous groups of CHTs for centuries (Khisa and Mohiuddin, 2015). Many studies on CHTs indicated that short-rotation in shifting cultivation for annual cropping has negative impacts on ultimate food production capacity of the lands and environment (Bala *et al.*, 2010; Rahman *et al.*, 2012; Rahman *et al.*, 2014).

Crop production, soil erosion, land and forest degradation are intertwined with climate change in hilly regions. Human induced land degradation in the form of water erosion through unsustainable crop production is severe in the hills (Hossain, 2011). Besides, recently large-scale tobacco cultivation in the valley of the CHTs demands a huge amount of fuelwood for its curing, and imposing threat to the forest landscapes of hills (Bala *et al.*, 2010). Crop productivity in jhum has declined due to soil erosion and associated reduction in essential soil nutrients (Karim and Mansor, 2011). On an average $40\text{--}45\text{ t ha}^{-1}\text{yr}^{-1}$ soil is eroded from due to shifting cultivation, the highest erosion was observed in steep slopes (33–42%) and the lowest in gentle slopes (15%) (Shoaib *et al.*, 1998). Conservation of natural resources and sustainable crop production are twin development issues in the CHTs. Government, NGOs and some foreign agencies have been trying for about 20 years to promote alternative land uses in the CHTs for restoring natural resources and biodiversity, and improving the livelihoods of the hill dwellers (Kibria *et al.*, 2015). In some areas of CHTs, alternative land uses such as agroforestry, multistoried fruit orchard, tree farming, and mixed horticulture are practiced as well as livestock are integrated to farming system.

However, there is very limited and scattered information on crop agriculture in the CHTs. A study was therefore, undertaken to accumulate the information on crop agriculture of CHTs with an aim to elucidate the existing crop production systems and their performances, impacts of hill agriculture on environment, and the suitable cropping system for sustainable agricultural production in CHTs.

2. CROP AGRICULTURE SYSTEM IN CHTs

Agriculture is the main source of livelihood and the incidence of poverty is very high in CHTs (Ahammad and Stacey, 2016). About two thirds of rural households are farming households (Barkat *et al.*, 2009) including 19% jhum households, 34% field cropping (plough cultivation) households, and 9% field and jhum agriculture; rest 38% households non-agricultural in CHTs (Ullah and Shamsuddoha, 2014). The two main land forms in the hilly areas are the hills and the valleys. The cultivation technologies practiced in CHTs for crop culture are plough and jhum, depending upon the suitability of the land. In CHTs, 35.87% land uses for forest, 27.60% for horticultural crops, 16.22% plough land, 15.52% Jhum land and rest 4.79% for settlements

(Figure 1). Hill dwellers of CHTs mainly engage in fruit orcharding and shifting cultivation (jhum). Generally, valley dwellers engage in the plough cultivation of rice and tobacco, along with a few amounts of vegetable and fruit production (Nathan *et al.*, 2013).

Figure 1: Land use patterns of the Chittagong Hill Tracts (Bala *et al.*, 2013).

Distribution of agricultural income is varied by season in CHTs, total income is high in the wet season when households can collect grain crops, fruits and vegetables (Rahman *et al.*, 2014). Agricultural income of the farmers of CHTs was higher during June to November (wet season) and lower during December to May (cool and dry season) (Rahman *et al.*, 2014). During winter and dry seasons farmers of the area cannot grow any crop due to lack of water, only banana can be harvested at this time.

2.1 Cropping Patterns in CHTs

Annual crop based top cropping pattern in the CHTs was Boro-Fallow-T. Aman which accounts 15.07% NCA of CHTs followed by Fallow-Fallow-T. Aman (13.68% of NCA), Fallow-Aus+Non-rice (shifting cultivation 9.24% of NCA) and others (Table 1).

Table 1: Major cropping patterns in CHTs

SL.	Cropping pattern	Practicing site	Area (ha)	% of NCA of CHTs
1	Boro-Fallow-T. Aman	floodplains	19400	15.07
2	Fallow-Fallow-T. Aman	valley	17610	13.68
3	Fallow-Aus+Non-rice (Jhum)	hill slope	11900	9.24
4	Vegetable-Fallow-Fallow	floodplains	6310	4.90
5	Vegetable-Fallow-T. Aman	valley	5450	4.23

6	Boro-Fallow-Fallow	floodplains	4950	3.85
7	Vegetable-Vegetable-Fallow	valley	4890	3.80
8	Tobacco-Aus-Fallow	valley	2250	1.75
9	Vegetable-Vegetable-T. Aman	valley	1850	1.44
10	Tobacco-Fallow-T. Aman	valley	1540	1.19
11	Fallow-Aus-T. Aman	valley	1320	1.03

NCA: Net Cropped Area.

Source: Quais *et al.*, 2017.

2.2 Plain land Plough Agriculture

Plain land basically occupies valley bottoms, river bank and lower slopes in the CTH which are suitable for plough agriculture. Valleys and floodplains suitable for plough agriculture cover only 3.2% (270812 ha) of the total land in CHTs. About 7% of the plough land produces three crops, 25% produces two crops, and 68% produces one crop per year (Olarieta *et al.*, 2007). Rice, tobacco, sugarcane, potatoes, bilatidhonia, maize, cotton, groundnuts, beans, different vegetables and fruit species are cultivated with the plough technology in the plain lands. The rice productivity of plough land in the CHTs is much higher (3.4 t ha^{-1}) than shifting cultivation (1.5 t ha^{-1}); rice cultivation in the valleys of the CHTs can yields higher profit than cultivated on the plain land of the country (Nathan *et al.*, 2013).

2.2.1 Tobacco

Tobacco is also one of the most important cash crops and largely grown as a monocrop by intensive farming in almost all areas of CHTs (Motaleb and Irfanullah, 2011). Tobacco cultivation started after 1990 with assistance from some local and multinational companies in this area. Presently, at least eight multinational companies are involved in tobacco cultivation and they motivate the farmers by offering incentives in cash. Most of the farmers in CHTs have been losing their interests in cultivating indigenous crops like paddy, banana, maize, sesame, cotton etc. and at least 7000 farmers are involved in tobacco cultivation (Ullah and Shamsuddoha, 2014). About 3918 ha of land produced 6326 MT tobacco in CHTs and Cox'Bazar districts during 2017-18, of which 2660 ha of land occupied cultivation only in Bandarban (BBS, 2019). Farmers cultivate tobacco during October-November and harvest during April-May of the following year.

2.2.2 Spiny Coriander

Spiny coriander (*Eryngiumfoetidum*) is a shade tolerant plant is commonly known as Bilatidhonia suited to climatic conditions of Chittagong Hill Tracts. Cultivation of Spiny coriander is increasing in CHTs as the net benefit of this farming is very high (4022680 Tk/ha). A Study in two village of CHTs found that the majority of farmers (86%) preferred to cultivate

spiny coriander (Hossain *et al.*, 2017). It is an annual crop with a cropping cycle of 8-10 months and the cycle starts in January and continues until October (Figure 2). Field study on Spiny coriander reported that the average yield was 59.22 t ha⁻¹ in CHTs and on average spiny coriander cultivation per household earned 472345 Tk. in every year (Table 2).

Figure 2: Spiny coriander production cycle in CHTs (Hossain *et al.*, 2017).

2.3 Slope Agriculture

2.3.1 Shifting Cultivation (Jhum) in CHTs

Jhum cultivation is a special kind of subsistence farming on sloppy hills of the indigenous hilly people in CHTs. This method of cultivation is also known as “*Slash and Burn*” or “*Swidden*” cultivation. About 60000 families engaged in shifting cultivation in CHTs (Khan and Alam, 2015). The major steps of Jhum cultivation including land selection, land preparation, sowing and planting, weeding, pest management, harvesting, threshing and storing (Figure 3). Land preparation usually starts from March for jhum cultivation. At first, the standing vegetation are slashed and allowed to dry during the dry period. The dried vegetation and the fallen logs are burnt in the month of April and May. The partially burnt or unburned logs are then dragged out of the Jhum land and piled up. The land is ready for crop establishment at the first shower, which usually occurs in April or May. Sowing commences as soon as the monsoons starts and the ground is saturated, generally in the months of May and June. Seeds of different crops are sown combinedly in single hill as per the cultivator’s provision. Harvesting starts from July and continued to December.

Figure 3: Jhum cropping calendar in CHTs(Chakma and Ando, 2008).

2.3.1.1 Jhum Cycle Practices Field Size of Shifting Cultivation

Jhum cycle means the fallow period of shifting cultivation. Jhum cycle period is reduced over times and in present situation practiced fallow period 2-3 years only for shifting cultivation. In the past (before 2000) farmers followed a cycle of more than 5 years (Table 3). The jhum cycle period is reduced due to establishment of hydroelectric dam, settlement of plain land people in hills, demographic pressure, declaring of forest protected areas, and increasing new plantation area. Before creation of Kaptai Dam the jhum cycle was 10 to 20 years or even more (Chakma and Ando, 2008).

Table 3: Trend of reduction of Jhum cycle period for shifting cultivation

Period	Fallow period	Causes for reduction of fallow period
1990-2000	5-10 years	Because of construction of hydroelectric dam, many lowland people moved to high hill
2000-2005	4-5 years	Because of huge settlement of plain land people
2005-2010	3-4 years	Because of increasing population and declaring of protected areas
2010 to till date	≤3 years	Because of increasing population and plantation forest

Source: Karim and Mansor, 2011; Chakma and Nahar, 2012; Hossain and Ahmed, 2017.

A study on jhum cultivation in Bandarban hill district found that 48% jumia (Jhum farmers) cultivated 101-200 decimal, 27% cultivated 0-100 decimal, 19% cultivated 201-400 decimal, and only 6% cultivated more than 400 decimals of jhum land (Hossain and Ahmed, 2017). In Rangamati, most of the jumia (60%) have only 1-2 acres of land for jhum cultivation and 25% of the Jumia have 2.1-3 acres of land (Chakma and Nahar, 2012).

2.3.1.2 Crops and yield potentials of Shifting Cultivation

Jhum farmers cultivate crops whatever they need including cereals, vegetable, pulse, oilseed, spices, fruits and fiber. Previously, 15-20 crops used to be grown together, now 5-8 crops were usually grown in a Jhum field (Chakma and Ando, 2008). Generally, flat to moderate-sloping land is used for annual crops such as upland rice, ginger, turmeric, chilli, cassava, cucurbits, pigeon pea, sorghum, maize; steep-sloping land for growing different annual crops but with the maintenance of vegetative covers such as contour bio-hedgerows of leguminous plants and trees to protect top soil; and very steep land is used for growing jackfruit, guava and lemon while the north, east and north east slopes were used for planting local varieties of banana and plantain (*Musa paradisiaca*) (Table 4). Rice is the major crop component of jhum field and average yield 1.15 t ha^{-1} , though rice grown as main crop banana provides the maximum yield of 108 t ha^{-1} (Jamaluddin *et al.*, 2010). Yields of different crops in jhum plots greatly varied due to rainfall variability, number of crops sown and management practices. However, in recent times few Jhum cultivators is more interested to produce cash crops like ginger and turmeric rather than paddy.

Table 4: Basic sloping-land farming practices in jhum plots of CHTs

Slope Category	Crop type					
	Annual cereal/tuber	Annual vegetable	Annual pulse	Annual spice/herb/oilseed/other	Annual fruit	Perennial fruit
Moderate slope (0-35 degree)	Rice, Sorghum, Millet, Maize, Cassava	Cucurbits	Pigeon pea	Ginger, Turmeric, Chilli, Sugarcane, Sesame, Tobacco, Cotton	Melons	Mango, Wood apple
Steep slope (36-65 degree)	Rice, Sorghum, Maize, Cassava	Cucurbits	Pigeon pea	Ginger, Turmeric, Chilli, Cotton		Leguminous tree species, Aonla
Very steep slope (>65 degree)	-	-	-	-	Banana, Plantain	Jackfruit, Guava, Lemon

Source: Misbahuzzaman, 2016.

2.3.1.3 Improved Jhum Cultivation

Generally, farmers use local cultivars without any fertilizer and rarely manage diseases and insect's pest in jhum cultivation. Only 50-60% farmers use synthetic fertilizer and Pesticides, and 8% of the farmers applied in jhum fields (Olarieta *et al.*, 2007). In improved method of jhum

farming farmer uses high yielding varieties, chemical fertilizers and pest management for obtaining higher yield. Field study on improved jhum produced the higher yields of different crops than traditional local jhum (Table 5). About 40% higher Rice Equivalent Yield (REY) was recorded in improved jhum (6786.8kg/ha^{-1}) than local jhum (4339.8kg/ha^{-1}). Rate of return of improved jhum was higher (2.15) than traditional jhum (1.56).

Table 5: Yields of different component crops and total REY of improved and traditional jhum practice

Jhum System	Rice grain yield (kg/ha)	Seed cotton yield (kg/ha)	Sesame seed yield (kg/ha)	Maize green cob yield (kg/ha)	Chilli fruit yield (kg/ha)	Marfa fruit yield (kg/ha)	Total Rice Equivalent Yield (REY) (kg/ha)	% Increase over traditional jhum	Benefit Cost Ratio
Improved	3113	456	478	627	-	-	6786.8	40.23%	2.15
Traditional	2007	287	206	393	146	600	4339.8	-	1.56
LSD (0.05)	120.89	99.52	44.5	32.74	-	-	-	-	-
CV%	19.25	17.67	12.73	10.34	-	-	-	-	-

Source: Mahmud *et al.*, 2018.

2.3.1.4 Advantages and Disadvantages of Shifting Cultivation

Despite having some advantages of jhum cultivation there are many disadvantages. Traditional and easy method of cultivation with low investment, locally available planting materials and short rotation are the key benefits of jhum farming (Aktar *et al.*, 2019; Nath *et al.*, 2016b). In contrast soil erosion, biodiversity loss, deforestation, land degradation, very high dependency on nature, lower yield, fertilizer and pesticides requirement, little profit margin, negative response from government authority etc. are disadvantages of jhum farming (Nath *et al.*, 2016a; Aktar *et al.*, 2019).

2.4 Monocropping System of High value crops

The CHTs has a favourable agro-climatic environment for cultivating a number of high-value crops. This region is suitable for growing high value crops like turmeric, ginger, pineapple, aroids, papaya, banana (Rasul and Tripura, 2016). Cultivation of turmeric and ginger on hill slope has become a potential factor for the tribe to earn cash income which has brought a positive change on their livelihood in the CHTs; and hilly farmers have been gaining economic stability through cultivating turmeric and ginger (The Dhaka Tribune, 2014). Almost all the traditional farmers grow turmeric as it is more profitable than any other crops like paddy and banana (Chakma, 2008). In CHTs, about 8000 ha of land are being used to cultivate turmeric and ginger, and together produces almost 50000 Metric ton of fresh rhizome in every year (Figure 4).

Being an exhaustive crop and intensive monocropping practice the production of turmeric are reducing in recent years (Figure 4). There are also increasing levels of pineapple cultivation as vital source of cash flow, particularly in the last two decades (Ahhammad and Stacey, 2016). In recent years, more than 2700 ha land are used for growing pineapple and 40000 metric ton fruits are produced every year (Table 6).

Figure 4: Trend of turmeric and ginger growing area and production in CHTs (BBS, 2020; BBS, 2017; BBS, 2014; BBS, 2012)

Table 6: Area and production of pineapple in CHTs

Year	Area (ha)				Production (M. Ton)			
	Bandarban	Khagrachari	Rangamati	Total CHTs	Bandarban	Khagrachari	Rangamati	Total CHTs
2009-10	604	686	1278	2568	7074	6399	22209	35682
2010-11	610	707	1278	2595	7336	7942	22056	37334
2011-12	574	737	1281	2592	6778	7497	24670	38945
2012-13	579	736	1283	2598	6839	7494	25000	39333
2013-14	387	734	1274	2395	3891	7624	24070	35585
2014-15	601	811	1319	2731	6399	10682	25173	42254
2015-16	607	828	1328	2763	6256	10142	24661	41059
2016-17	610	800	1343	2753	6316	6645	25027	37988
2017-18	618	810	1338	2766	6204	7290	25044	38538
2018-19	619	832	1347	2798	6215	7596	25235	39046

Source: BBS, 2020; BBS, 2017; BBS, 2014; BBS, 2012.

2.5 Modern Land use in CHTs

There are many alternate modern farming systems in the CHTs including Multi-storey Fruit Garden (MSFG), Multi-strata Agroforestry System (MAFS), Sloping Agricultural Land Technology (SALT), Modern Agricultural Technology (MATH), and Contour Hedgerow Intercropping Agro-forestry Technology (CHIAT). Both Bengali and ethnic indigenous farmers are now very interested in fruit production and agroforestry practices. Since 1860 efforts were made to control shifting cultivation and promote alternative farming systems in CHTs (Rasul *et al.*, 2004). Over last couple of decades, alternative land uses with perennial horticultural species with or without timber trees have increased in CHTs.

A pair-wise comparison of three factors of sustainability (social, economic and environmental) study to evaluate farmer's preference for land uses in CHTs revealed that participants emphasized most on the economic (75%) aspect over social (17%) and environmental (8%) aspects (Table 7). In respect to social and economic aspects, the priority vector was the highest (0.628 and 0.618) in orchards. The environmental priority vector was the highest (0.44) for agroforestry. By considering overall priority, it was observed that orchards were the most preferred land use with a composite weight of all priority vectors (0.60 or 60 % preference) followed by agroforestry (0.25) among the four land uses (Table 7). Bala *et al.*, (2013) reported that at least 30% of total land uses cover different types of fruit plantation in the CHTs. Fruits production is increasing day by day in CHTs. Many commercial fruit gardens of mango, sweet orange, litchi, pineapple, dragon fruit etc. has been established in this area.

Table 7: Land use priority in CHTs by considering the sustainability factors

Land use category	Contribution to Household income (%)	Weight			Composite weight
		Social (0.17)	Economic (0.75)	Environmental (0.08)	
Fruit orchard	62	0.628	0.618	0.308	0.595
Agroforestry	55	0.174	0.246	0.447	0.250
Shifting cultivation	48	0.046	0.090	0.066	0.080
Village common forest (VCF)	35	0.152	0.046	0.179	0.075

Source: Kibria *et al.*, 2015.

2.5.1 Multi-storey Fruit Garden (MSFG)

Multi-storey fruit gardening is getting popularity in the CHTs. Different fruit species have gradually replaced shifting cultivation due to increasing demand for cash incomes (Ahammad and Stacey, 2016). A good number of fruit species are produced in different vertical strata of the orchards. A holistic comparison of performances of MSFG with sole cropping is shown in Table

8. The economic analysis revealed that the maximum gross margin was calculated from MSFG (TK. 12, 47,085) followed by sweet orange (TK 9, 04,687) and the lowest from litchi (TK. 88,836) (Table 9). The highest BCR 6.79 was also recorded in MSFG followed by sweet orange orchard (5.47) and coconut orchard (3.46). The LER (2.6) of MSFG was much higher than sole orchards. Higher production and benefits from MSFG might be due to maximum complementary use of different growth resources. MSFG system has been found suitable for preventing soil erosion and forest degradation, and in boosting the cropping intensity in hilly areas (Paul and Hossain, 2001).

Table 8: Performance of different fruits in multi-storey fruit garden and sole cropping system in CHTs

Systems	Coconut		Litchi		Malta		Pineapple	
	Single nut weight (kg)	Yield per plant	Fruits per plant	Yield per plant (kg)	Fruits per plant	Yield per plant (kg)	Single fruit wt. (g)	Fruit yield (t ha ⁻¹)
MSFG	1.25	81.09	599.55	9.90	106.15	24.78	560.0	31.25
Sole	1.45	119.27	658.62	11.94	113.0	24.87	530.0	29.50
t test	**	**	**	*	ns	ns	**	**

ns = non-significant, * indicates significant at 5% level of probability ** indicates significant at 1% level of probability.

Source: Rahman *et al.*, 2014.

Table 9: Cost-return analyses of different fruit crops as sole and their combination in multi-storey fruit garden

Systems	Gross return (Tk. ha ⁻¹ yr. ⁻¹)	Total variable cost (Tk. ha ⁻¹ yr. ⁻¹)	Gross margin (Tk. ha ⁻¹ yr. ⁻¹)	Benefit-Cost Ratio (BCR)	Land Equivalent Ratio (LER)
Multi-storey Fruit Garden (MSFG)	14,62,534	2,15,451	12,47,083	6.79	2.6
Coconut (sole)	4,00,000	1,15,520	2,84,479	3.46	1.0
Litchi (sole)	2,08,593	1,19,756	88,836	1.74	1.0
Sweet orange (sole)	11,06,875	2,02,187	9,04,687	5.47	1.0
Pineapple (sole)	3,64,583	2,07,673	1,56,909	1.76	1.0

Source: Rahman *et al.*, 2014.

2.5.2 Agroforestry System (AFs)

Jhum land has been gradually replaced by agroforestry and tree-based land uses in CHTs. Farmers moved toward market-oriented horticultural crop-based agroforestry system for cash income generation. In CHTs, different crops, fruits and timber species are grown under different

slope of agroforestry systems (Table 10). Uses and planting of medicinal plants in CHTs are the old-age practices over there.

Table 10: Agroforestry based farming practices in different slopes of CHTs

Slope category (%)	Component types		
	Crop species	Fruit species	Forest species
Up to 5% (Level to gentle sloping)	Upland rice, Vegetable, Ginger, Turmeric	Banana, Pineapple, Lemon, Guava, Papaya, Custard apple, Areca nut	-
5-15% (Sloping)	Upland rice, Legume, Vegetable, Ginger, Turmeric	Banana, Pineapple, Lemon, Guava, Papaya, Custard apple, Areca nut	-
15-30% (Moderate steep)	Upland rice	Banana, Pineapple, Litchi, Jackfruit, Mango, Amra, Wood apple, Areca nut	-
30-60% (Steep)	Upland rice	Banana	Bamboo, Teak, Gamar, Koroi, Cassia, Acacia, Leucaena
Above 60% (Very steep)	Upland rice	Banana	

Source: Rahman *et al.*, 2012.

2.5.2.1 Multi-strata Agroforestry System (MAFS)

Mostly multi-storey agroforestry systems in CHTs consists of vegetables, spices and fruits. The under storey comprises of various annual crops, the middle of shrubs like banana, papaya, lime, guava and the upper storey with timber and fruit species (Table 11). Farmers grow up to 15 species of seasonal crops together in their agroforestry fields for their own consumption and for sale. Benefit-cost analysis showed a significant increasing net-benefit as the number of crop species used in agroforestry system increased, while a reverse trend was showed for production cost (Figure 5a). In studied multistorey agroforestry system, under-storied crops provided 77% net-benefits and the overall BCR of the system was 3.03 (Table 11).

Table 11: Benefit-cost analysis of multi-storey agroforestry plots in CHTs

Strata	Component crops	Costs (BDT) (%)	Benefits (BDT) (%)	Net-Benefits (BDT) (%)	BCR
Under storey	Vegetables, Tuber crops, Pineapple	22,661 (81)	66,379 (78)	43,718 (77)	2.93
Middle storey	Cassava, Banana, Lemon, Papaya, Guava, Malta	3231 (11)	12,900 (15)	9669 (17)	3.99
Upper storey	Wood apple, Litchi, Mango, Orange, Drum stick, Teak, Acacia	2118 (8)	5480 (7)	3362 (6)	2.59
Total		28010 (100)	84759 (100)	56749 (100)	3.03

Source: Nath *et al.*, 2016b.

2.5.3 Sloping Agricultural Land Technology (SALT)

Bangladesh Forest Research Institute (BFRI) has developed Sloping agricultural land technology (SALT) in the hills for sustainable land management. In SALT, annual crops are grown between hedgerows in bands measuring 40-50 m wide. There are four popular model of SALT including Sloping Agricultural Land Technology (SALT-1), Sloping Agroforest Land Technology (SALT-2), Sloping Agro-livestock Land Technology (SALT-3) and Sloping Agro-fisheries Livelihood Technology (SALT-4) are effectively practiced in CHTs (Khan and Alam, 2015). The SALT increases soil fertility status, decreases erosion and slows the flow of rainfall down the slope.

2.6 Impacts of Hill Agriculture on Environment

Shifting cultivation and plough agriculture on slopping area accelerates land degradation, forest degradation, and biodiversity destruction in hilly region through deforestation and burning. As a result, the whole environment is disrupted. Among all practices, plough cultivation and tobacco cultivation are posing a great threat to the agriculture, forests, and environment in hilly areas. Indiscriminate tobacco cultivation leaves a negative impact on soil fertility and once tobacco is cultivated it is difficult to grow other crops on the same land, it's a great threat for agro-biodiversity, as this limits farmers' freedom of choice for crop production (Akhter *et al.*, 2014; Islam *et al.*, 2010). At least 60000-70000 MT of fuelwood are being burnt in 2000 tobacco processing kilns every year, causing depletion of natural forests, threatening environment and biodiversity in the hills (Ullah and Shamsuddoha, 2014). About 13-14 tons of fuelwood is needed to process tobacco leaves grown on one hectare of land. Indigenous farming methods for growing different annual crops in hill slope and improper management of soil enhanced soil erosion and created negative impact on soil productivity. Chakma and Nahar (2012) reported the negative impacts of jhum cultivation on environment which are listed below:

- Loss of forest area (Deforestation)
- Loss of top soil
- Increase landslide
- Loss of animal biodiversity
- Loss of plant biodiversity
- Decrease environmental balance
- Source of forest fire
- Increase temperature
- Decrease biomass and soil carbon storage
- Decrease soil productivity

Extensive farming activities like heavy spading, crop cultivation along with slope, earthing up, slush, and burning caused soil erosion from the hill slope. Mono-cropping of turmeric, ginger, pineapple, aroids, rubber plants, and other crops, has increased runoff soil erosion and loss of essential nutrients and biodiversity (Khisa and Mohiuddin, 2015). Losses of top soil from hill causes organic matter depletion and resulting nutrient exhaustion in soil. Thus, hill cultivation degrades land productivity and causes excess runoff. The CHTs receives 250-375 cm rain annually. High intensity rainfall and heavy shower accelerates the rate of soil erosion at the beginning of the monsoon when the sloping land has been cleared for Jhum and remains bare or sporadically covered with newly emerging seedlings. In CHTs, the maximum soil loss was recorded in annual crops cultivation without mulching ($99.15 \text{ t ha}^{-1}\text{yr}^{-1}$) followed by shifting cultivation ($41.23 \text{ t ha}^{-1}\text{yr}^{-1}$) where least ($10 \text{ t ha}^{-1}\text{yr}^{-1}$) soil loss occurs for agroforestry and orcharding (Table 12). The factors influencing soil loss are rainfall, land slope, slope length, land management practices, vegetation cover density etc.

Table 12: Soil erosion under different agricultural land use system in CHTs

Land use		Average soil Loss ($\text{t ha}^{-1}\text{yr}^{-1}$)	Natural rate of soil formation ($\text{t ha}^{-1}\text{yr}^{-1}$)	Net soil loss ($\text{t ha}^{-1}\text{yr}^{-1}$)
Annual crops: mainly root crops such as Ginger, Turmeric, Mukhikachu	Conventional tillage: hoeing without mulch	99.15	15	-84.15
	Conventional tillage: hoeing with mulch	35.16	15	-20.16
Pineapple		18.05	15	-3.05
Shifting Cultivation		41.23	15	-26.23
Agroforestry, tree farming, mixed plantation		10	15	+5

Source: Khan and Alam, 2015; Rasul., 2009.

2.7 Sustainable Farming Model for Hilly Areas

In the background of land and forest degradation along with demographic pressure three tree-based sustainable farming models i.e. multistorey agroforestry system (MAFS), Multi-strata fruit

orchards (MSFO) and complex fruit and timber-based mixed agroforest (SALT) are identified and suggested for hilly areas to maintain agricultural production and environmental gradient. Multistorey agroforestry system for the agricultural and shifting cultivation fields close or adjacent to the depleted natural forest areas (Figure 5a). This system is already practiced by few farmers in CHTs, and is well suited for regeneration of forest vegetation in the jhum fields close to villages. The system is based on fruits and timber trees in upper storey, shrubby and medium sized fruit species in middle storey together with vegetables, medicinal plants and tuber species in lower storey. Multi strata fruit orchards (MSFO) by arranging pineapple and papaya in lower strata, lemon, orange and guava in middle strata, mango and litchi in upper strata, and coconut and betel nut in top strata.

Figure 5: Recommended sustainable tree-based land use system for hilly areas (Rahman *et al.*, 2014).

The other is the complex fruit and timber-based mixed conservation agroforest which can be established in the large depleted landscapes (Figure 5b). Timber species with bamboo could preserve hilltops by forming a mini forest with hydrological functions. Fruit trees can be planted next to the natural forest. For the purpose of food security, upland rice and maize can be intercropped with acacia, teak and fruit trees for the first 6 years. Subsequently, shade tolerant pineapple can be planted under fruit trees which can produce fruit after one year. Papaya, banana, lemon, guava, orange etc. can be planted next to fruit tree plantation. Mung bean and black beans can be intercropped with these at the foot of the hilly slope.

3. CONCLUSION

Overall, the study indicates that farming practices in the CHTs have undergone significant changes with the incorporation of new techniques and varieties into existing practices. In Chittagong Hill Tracts (CHTs) region of Bangladesh agriculture is the prime sources of livelihood. Rice, Maize, vegetables, spices, and tobacco are the major crops in valley of hilly

areas. In sloppy land shifting cultivation is the main cropping system, of which upland rice is the major crop components. Agroforestry, annual horticultural crops, and fruit orcharding are secondary land use system in CHTs. In terms of economic and environmental suitability agroforestry and fruit gardening were found to be sustainable. Natural resources specially land and forests are degrading gradually due to unsustainable agricultural land use practices in hilly areas including very short rotation shifting cultivation, tuber crops cultivation without mulching, tobacco cultivation etc. Extensive jhum practice influences the risk of forest fire during dry season and land slide during monsoon. Sustainable crop production to secure food stocks and reduce forest degradation is a challenge in hilly region. Tobacco cultivation in valley and floodplain should be replaced by high value annual crops. Tree based land use through agroforestry and fruit farming in CHTs are the viable strategy to protect natural forest and poverty reduction. Farmers can achieve direct benefits from agroforestry and orchards, in the form of food, fuelwood and cash income, and receive significant indirect environmental benefits.

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