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Scenario of Hill Agriculture in Bangladesh[1]

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ABSTRACT

This paper presents the traditional and modern crop production systems with their impacts on environment in hill ecosystems of Bangladesh. Most of the hill dwellers depend on agriculture for livelihood. Boro-fallow-T. aman, fallow-fallow-T. aman and fallow-aus+non-rice (jhum) are the major cropping patterns in Chittagong Hill Tracts (CHT). Crop agriculture in hill is mainly divided into two systems i.e. plain land plough agriculture and non-plough slope agriculture. In plain land under 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 is a traditional system being practiced in the southeast part of the country by the tribal communities. Mostly 2-3 acres sized jhum cultivation are now being practiced, following a short rotation period of 1-2 years only. On an average, jhum farming provides rice yield by only 1.15 t ha^{-1}. About 40% yield could be increased by improving traditional jhum plots. However, extensive jhum practice creating a dilemma in conserving nature and food production. An increasing trend of fruit cultivation and production is observed in all hilly areas. Agroforestry, perennial fruit gardening and sloping agricultural land technology (SALT) showed lucrative economic benefits with environmental stability in hilly regions. In northeast hill, betel leaf based agroforestry is extensively practiced by rural farmers including Khasi community. Soil erosion is extensive in CHT due to shifting cultivation. 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 CHT. 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

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CHAPTER I

INTRODUCTION

Hilly area constitutes about 12% of total land located mainly in the eastern and 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). High hills ranged from 200-1000 m and lower hills from 15-200 m above the mean sea level (Hossain *et al.*, 2017a). The hilly land spreads over Chittagong Hill Tracts (Bandarban, Khagrachari and Rangamati), parts of Chittagong, northern and southern parts of Sylhet division, and northern parts of Mymensingh, eastern border of Cumilla and north eastern strip of Feni district. The Chittagong Hill Tracts (CHT) comprising 70% of the hilly areas of Bangladesh and covers 13,184 km^2 (10% of total country area), of which 90% are sloping lands (Hossain *et al.*, 2017a). The area is mild to very steep ranging from 15% to over 70% slope, often breaking or ending in cliffs (SRDI, 2018).

Agriculture is the main source of livelihood of the majority of hill 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 hilly areas (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 hilly areas 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, guava, and lemons. The CHT region is one of the richest fruit production regions in Bangladesh. Distinctive climatic conditions of CHT 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 CHT which are more economically attractive and environmentally sound (Bala *et al.*, 2013) In northeastern hill, agroforestry system is most dominant farming practices by hill dwellers (Mukul, 2014; Haider *et al.*, 2013; Nath and Inoue, 2009). 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 CHT for centuries (Khisa and Mohiuddin, 2015). Many studies on CHT 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 CHT 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 40-45 t $ha^{-1}yr.^{-1}$ 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 hilly areas. Government, NGOs and some foreign agencies have been trying for about 20 years to promote alternative land uses in the CHT for restoring natural resources and biodiversity, and improving the livelihoods of the hill dwellers (Kibria *et al.*, 2015). In some areas, alternative land uses such as agroforestry, multistoried fruit orchard, tree farming, and mixed horticulture are practiced as well as livestocks are integrated to farming system.

Considering the above facts, the following objectives were undertaken:

- To review the existing crop production situation in hilly areas and their performances;
- To assess the impacts of hill agriculture on environment; and
- To identify the suitable cropping system for sustainable agricultural production.

CHAPTER II

MATERIALS AND METHODS

This seminar paper is exclusively a review paper. So all of the information has been collected from the secondary sources. Data were obtained through literature review from relevant scientific papers, project reports, peer-reviewed journals, books, proceedings, available in the libraries of BSMRAU. I have also searched related internet web sites to collect information and reviewed relevant documents of Ministry of Agriculture; People's Republic of Bangladesh. Valuable suggestion and information were taken from my major professor and course instructors. After collecting all the available information, I myself compiled and prepared the seminar paper.

CHAPTER III
REVIEW OF FINDINGS

3.1 Hills of Bangladesh

Hills of Bangladesh are broadly classified in two classes based on the formation of Dupitila (43%) and Tipam-Surma (57%) distributed in different districts (Table 1). Chittagong Hill Tracts (CHT) (Rangamati, Bandarban and Khagrachari hill districts) covers major hilly areas (69.93%) of the country followed by Chittagong (17.68%) and Sylhet (11.49%). Greater Mymensingh, Cumilla and Noakhali collectively covers less than 1% of total hilly areas of Bangladesh.

Table 1. Distribution of high and low hills in Bangladesh

Greater District	High Hills (ha) Tipam-surma formation (57%)		Low Hills (ha) Dupitila formation (43%)		Total (ha)
CHT	650887	86.0%	279461	48.7%	930348 (69.93%)
Chittagong	100516	13.3%	134700	23.5%	235216 (17.68%)
Sylhet	5284	0.7%	147638	25.7%	152922 (11.49%)
Mymensingh	-	-	7567	1.4%	7567 (0.57%)
Cumilla	-	-	3120	0.5%	3120 (0.23%)
Noakhali	-	-	1226	0.2%	1226 (0.09%)
Total	756687	100	573892	100	1330399 (100%)

Source: Hossain 2011.

3.2 Crop Agriculture System in Hilly Area

Agriculture is the main source of livelihood and the incidence of poverty is very high in hilly areas (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 CHT (Ullah and Shamsuddoha, 2014). The two main land forms in the hilly areas are the hills and the valleys. The cultivation technologies practiced in CHT for crop culture are plough and jhum, depending upon the suitability of the land. In CHT, 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 (Fig. 1). Hill dwellers of CHT mainly engage in shifting cultivation (jhum), with some fruit horticulture. Valley dwellers engage in the plough cultivation of paddy rice, along with a fair amount of vegetable and fruit cultivation (Nathan *et al.*, 2013). Other hills except CHT, are used for growing many high value commercial crops like tea, rubber, lemon, orange, pineapples, banana and other fruits in Sylhet and Chittagong in addition to forest species (Hossain, 2011). Distribution of agricultural income is varied by season in CTH, 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 CHT 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 hilly areas cannot grow any crop due to lack of water, only banana can be harvested at this time.

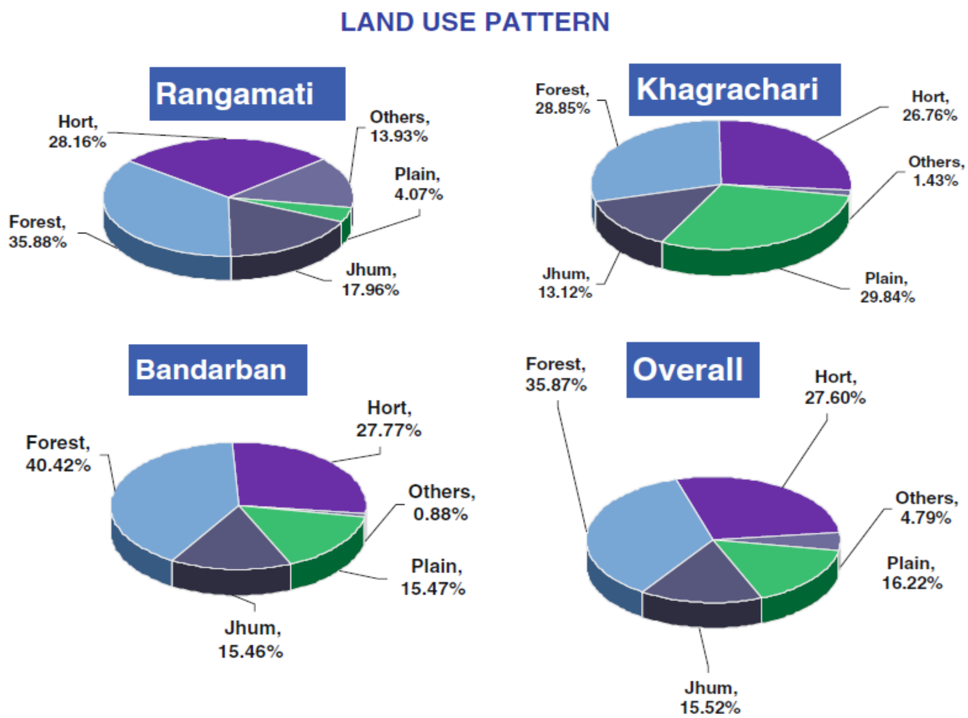

Fig. 1. Land use patterns of the Chittagong Hill Tracts (CHT). Source: Bala *et al.*, 2013.

3.2.1 Cropping Patterns in Hilly Areas

The top cropping pattern in the Chittagong Hill Tracts was Boro-Fallow-T. Aman which accounts 15.07% NCA of CHT followed by Fallow-Fallow-T. Aman (13.68% of NCA), Fallow-Aus+Non-rice (shifting cultivation 9.24% of NCA) and others (Table 2). In Lalmai hill farmer practices fallow-country bean cropping pattern on the top of hillock and in gentle slope, the most practiced cropping patterns were fallow-bitter gourd-country bean, fallow-cucumber-country bean, long bean-fallow-country bean, fallow-cucumber-country bean, and others (Sarker *et al.*, 2014).

Table 2. Major cropping patterns in CHT

SL.	Cropping pattern	Practicing site	Area (ha)	% of NCA of CHT
1	Boro-Fallow-T. Aman	valley	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.

3.3 Plain land Plough Agriculture

Plain land basically occupies valley bottoms which is suitable for Plough Agriculture, river bank and lower slopes in the CTH. Valleys and floodplains suitable for plough agriculture cover only 3.2% (270812 ha) of the total land in CHT. 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 CHT is much higher (3.4 t ha^{-1}) than jhum (1.5 t ha^{-1}); rice cultivation in the valleys of the CHT can yield higher profits than cultivated on the plains land of the country (Nathan *et al.*, 2013).

3.3.1 Spiny Coriander

Spiny coriander (*Eryngium foetidum*) 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 CHT as the net benefit of this farming is very high (4022680 Tk/ha). A Study in two village of CHT found that the majority of farmers (86%) preferred to cultivate spiny coriander (Hossain *et al.*, 2017a). It is an annual crop with a cropping cycle of 8-10 months and the cycle starts in January and continues until October (Fig. 2). Field study on Spiny coriander reported that the average yield was 59.22 t ha^{-1} in CHT and on average spiny coriander cultivation per household earned 472345 Tk. in every year (Table 3).

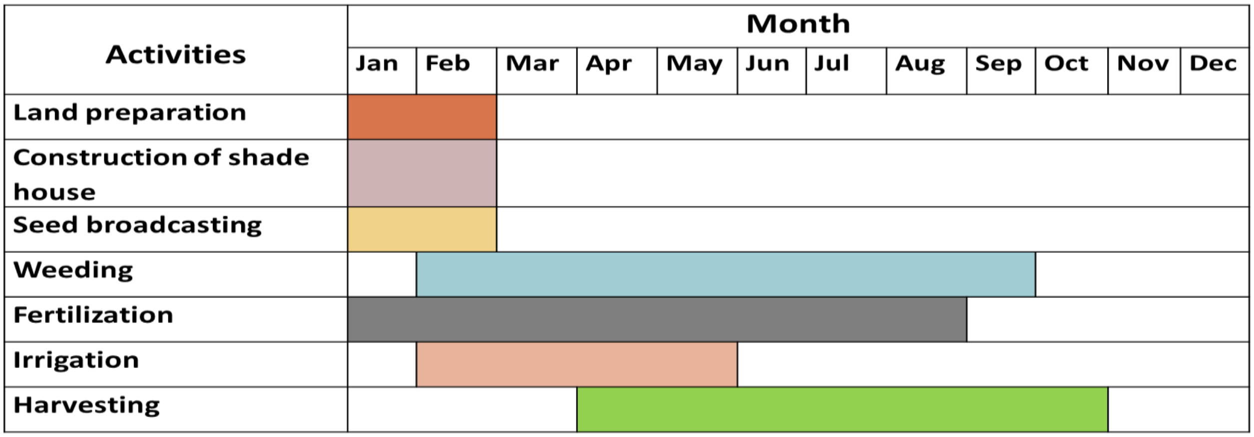

Fig. 2. Spiny coriander production cycle in CHT. Source: Hossain *et al.*, 2017a.

Table 3. Spiny coriander yield, production cost and benefit from unit land cultivation in CTH

Farm size (ha)	Fresh Yield (t ha^{-1})	Net benefit per household (BDT)	Cost per ha (BDT)	Net benefit per ha (BDT)
Small farm (0.004-0.081)	54.93	227543	1354959	3758743
Medium farm (0.082-0.161)	61.95	574269	1386567	4189533
Large farm (0.162-0.242)	62.86	1033850	1400262	4257825
Mean (0.12)	59.23	472345	1375019	4022680

Source: Hossain *et al.*, 2017a.

3.3.2 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 CHT. 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 CHT 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 CHT 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.

3.4 Slope Agriculture

3.4.1 Shifting Cultivation (Jhum) in CHT

Jhum cultivation is a special kind of subsistence farming on sloppy hills of the indigenous hilly people in CHT. This method of cultivation is also known as “Slash and Burn” or “Swidden” cultivation. About 60,000 families engaged in shifting cultivation in CHT (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 (Fig. 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.

Jum cultivation process	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Land selection		■										
Land clear/ Preparation			■	■								
Sowing and planting					■	■						
Weeding						■	■	■				
Pest and management								■	■	■		
Vegetables, marpha harvesting						■	■	■				
Melon harvesting							■					
Cucumber, gourd harvesting							■	■	■			
Maize, rice harvesting									■	■		
Chilli harvesting									■	■	■	■
Pumkin, cheena harvesting										■	■	
Brinjal harvesting										■	■	■
Cassava harvesting											■	■
Cotton, turmeric, ginger, arum harvesting												■
Drying											■	■

Fig. 3. Jhum cropping calendar in CHT. Source: Chakma and Ando, 2008.

3.4.1.1 Jhum Cycle Practices in 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 4). 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 4. 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.

3.4.1.2 Area of Jhum Plots

A study on jhum cultivation in Bandarban hill district found that most of the farmers (48%) 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 (Table 5). In a similar study in Rangamati, it was also found that about 60% of the respondents have only 1-2 acres of land for jhum cultivation and 25% of the respondents have 2.1-3 acres of land (Chakma and Nahar, 2012).

Table 5. Frequency distribution of Jhum area under CHT

Jhum farm size (decimal)	Number of Jhumias	% of respondent
up to 100	32	27
101-200	58	48
201-400	23	19
above 400	7	6
Total	120	100

Source: Hossain and Ahmed, 2017.

3.4.1.3 Crops of Shifting Cultivation

Jhum farmers produce cultivate crops whatever they need including cereals, vegetable, pulse, oilseed, spices, fruits and fiber. 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 6). Previously, 15-20 crops used to be grown together, now 5-8 crops were usually grown in a Jhum field (Chakma and Ando, 2008). 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 6. Basic sloping-land farming practices in jhum plots of CHT, Bangladesh

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.

3.4.1.4 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 7). About 40% higher Rice Equivalent Yield (REY) was recorded in improved jhum

(6786.8kg/ha) than local jhum (4339.8 kg/ha). Rate of return of improved jhum was higher (2.15) than traditional jhum (1.56).

Table 7. Yields of different component crops and total REY of improved and local 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 of REY 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.

3.4.1.5 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 are the key benefits of jhum cultivation. In contrast soil erosion, biodiversity loss, deforestation, very high dependency on nature, lower yield, negative response from government authority etc. are some disadvantages of jhum farming. A study on farmer's opinion on jhum farming in terms of costs and benefits are shown in Fig. 4.

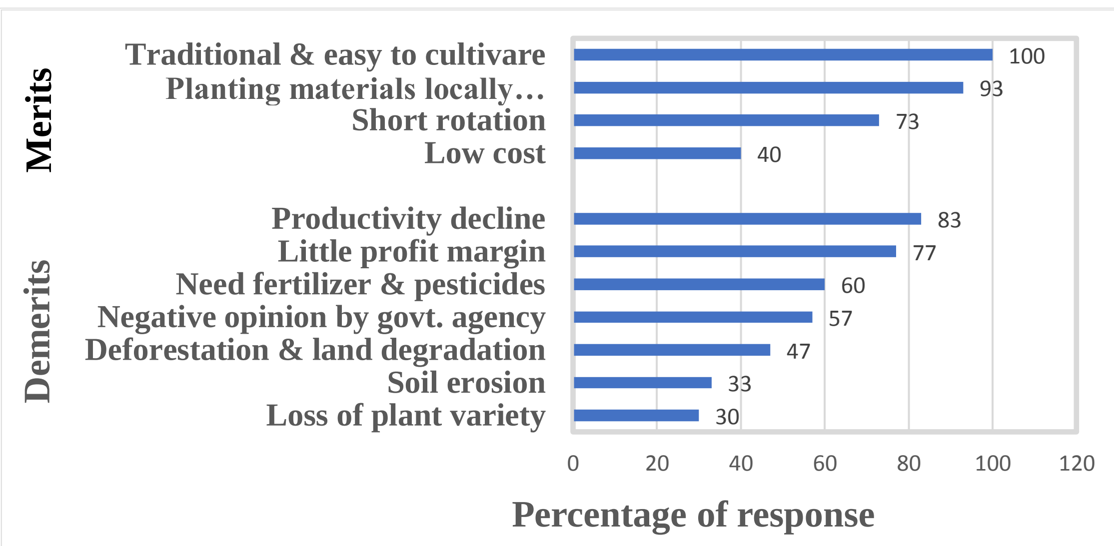

Fig. 4. Participant's opinion on merits and demerits of jhum. Source: Nath *et al.*, 2016a.

3.4.2 Alternate Land use in CHT

There are many alternate modern farming systems in the CHT 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. Efforts were made to control shifting cultivation and promote alternative land-use systems since 1860 in CHT. Over last couple of decades, alternative land uses with perennial horticultural species with or without timber trees have increased in CHT.
A pair-wise comparison of three factors of sustainability (social, economic and environmental) study to evaluate farmer's preference for land uses in CHT revealed that participants emphasized most on the economic (75%) aspect over social (17%) and environmental (8%) aspects (Table 8). In respect to social and economic aspects, the priority vector were 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 8). Bala *et al.*, (2013) reported that at least 30% of total land uses cover different types of fruit plantation in the CHT. Fruits production is increasing day by day in CHT. Many commercial fruit gardens of mango, sweet orange, litchi, pineapple, dragon fruit etc. has been established in these areas. An increasing trend of fruit growing area and production were observed in hilly areas of Chittagong and Sylhet (Hossain *et al.*, 2017b).

Table 8. Land use priority 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.

3.4.2.1 Multi-storey Fruit Garden (MSFG)

Multi-storey fruit gardening is getting popularity in the CHT. 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 9. 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 10). 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 9. Performance of different fruits in multi-storey fruit garden and sole cropping system in CHT

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 10. 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.

3.4.2.2 Agroforestry System (AFs)

Jhum land has been gradually replaced by agroforestry and tree-based land uses in CHT. Farmers moved toward market-oriented horticultural crop-based agroforestry system for cash income generation. In CHT, different crops, fruits and timber species are grown under different slope of agroforestry systems (Table 11). Uses and planting of medicinal plants in CHT are the old-age practices over there.

Table 11. Agroforestry based farming practices in different slopes of Chittagong Hill Tracts

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.

3.4.2.2.1 Multi-strata Agroforestry System (MAFS)

Mostly multi-storey agroforestry systems in CHT 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 12). 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 (Fig. 5a). In studied multistorey agroforestry system, under-storied crops provided 77% net-benefits and the overall BCR of the system was 3.03 (Table 12).

Table 12. Benefit-cost analysis of multi-storey agroforestry plots in CHT

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.

The income from multistorey agroforestry gradually increases because from 2-3 year onwards the fruit species has start to provide yields (Fig. 5a). Comparative calculation among three land use system in hilly area at 10 % annual discount rate yearly cash flow, it indicates that multistorey agroforestry system provides more income than shifting cultivation and a ten years rotational conservation horti-silvicultural agroforest (Fig. 5b).

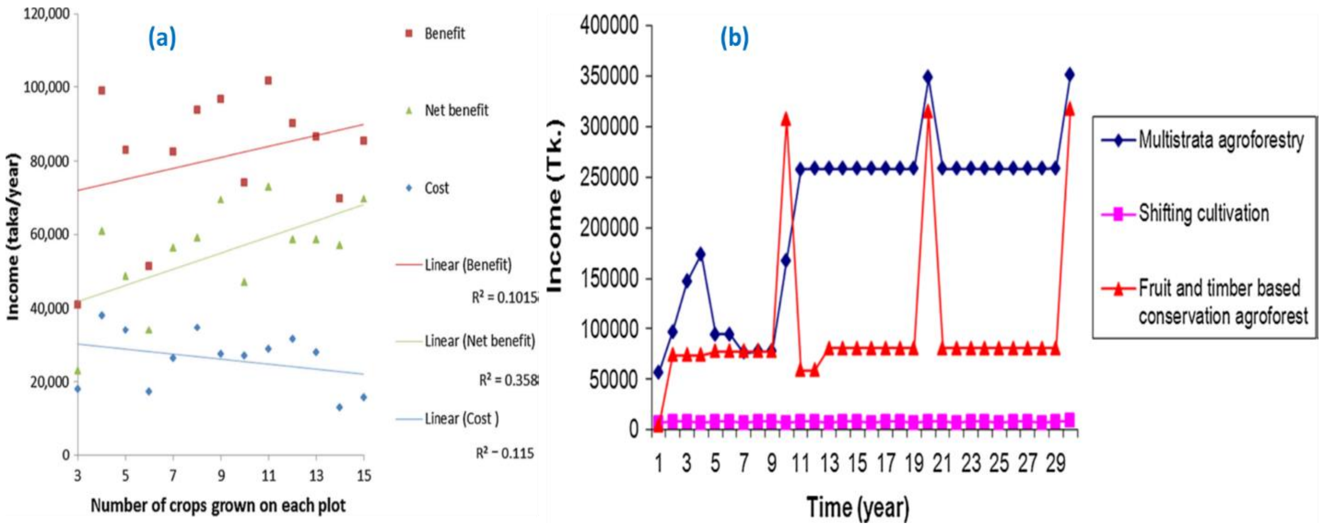

Fig. 5. (a) Benefit and costs of the multistrata agroforestry system according to number of species; **(b)** Yearly discounted cash flow of the multistrata agroforestry system in compared to other traditional land uses (taka/acre). Source: Nath *et al.*, 2016b; Rahman *et al.*, 2014.

3.4.2.3 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 CHT (Khan and Alam, 2015). The SALT increases soil fertility status, decreases erosion and slows the flow of rainfall down the slope.

3.4.3 Farming Systems of Northeastern Hill

The physical and historical characters of the studied hill farming systems greatly varied in the northeastern hilly areas of greater Sylhet (Table 13). Averaged highest elevation was 34.1 m in case of betel vine agroforestry systems whereas pineapple agroforestry plots were located in steeper slope (39.5). Both attributes the total number of trees per hectare and canopy coverage were highest (1670 and 40.5%) in of betel vine agroforestry system among all systems. Amongst the all plots, betel vine-based agroforestry plots were under such kind of land-uses for about 39 years followed by Lemon agroforestry plots was 20 years (Table 13).

Table 13. Physical and historical attributes of agroforestry land use in northeastern hill of Bangladesh

Variable	Betel-vine agroforestry	Lemon agroforestry	Pineapple agroforestry	Shifting cultivation
Elevation (m)	34.1 (±17.97)	26.8 (±11.93)	24.6 (±7.30)	27.9 (±9.50)
Slope (in degree)	28.5 (±16.51)	17.0 (±8.56)	39.5 (±13.01)	28.0 (±15.31)
Canopy cover (%)	40.5 (±12.35)	17.2 (±6.49)	4.2 (±2.53)	7.1 (±4.48)
Year under land use	39.0 (±15.6)	20 (±8.22)	17.5 (±6.84)	1.0 (0.0)
Number of trees /ha	1670	740	330	680

Values in the parenthesis indicate the ±SD Source: Mukul, 2014.

3.4.3.1 Betel Leaf based agroforestry in northeastern hill

Betel leaf and betel nut cultivation are the major sources of income among Khasia people a forest dwelling indigenous community. Khasia economy and livelihoods are almost entirely dependent on betel leaf agroforestry also known as Khasia agroforestry system. Tree based betel leaf production is a productive and sustainable agroforestry system, and the average farm size is 1.21 ha per Khasia household (Haider *et al.*, 2013). Betel leaf and betel nut production provide 82% of the income of poor farmers, 76% of medium and 63% of rich farmers in Moulavibazar district (Islam and Nath, 2014). The productivity of betel leaf is high during in-season (May to August) but the profitability remains high during off-season (September to February) due to high market price and demand (Table 14).

Table 14. Mean annual betel leaf production costs, outputs and income from betel leaf in North-eastern Hill Forests of Bangladesh

Season	Betel leaf productivity (kuri)*	Sale value (Tk.)	Mean annual sale value (Tk. $ha^{-1}yr.^{-1}$)	Mean input costs (Tk. $ha^{-1}yr.^{-1}$)	Net mean annual income (Tk. $ha^{-1}yr.^{-1}$)
In-season	132	39683	124014	12806	111208
Off-season	118	84331			

*1 kuri = 2880 individual betel leaves; 300 Tk per kuri in season and 650-700 Tk in off season; even more than Tk 1000 in February and March. Source: Nath and Inoue, 2009.

Farmers of Jaintapur upazila of Sylhet district cultivate some annual crops in betel leaf agroforestry system. Betel leaf, betel nut, black pepper, ginger, pineapple, and other fruits, are the components making up the total agroforestry income where betel leaf contributes 79.73% of the total agroforestry income (Rahman *et al*, 2009). Profitability of betel leaf AFs increases from second year as plucking of betel leaf starts from second year. Profitability of this agroforestry system reaches peak at fifth year after then profit starts to decline and sustains up to eighth year (Fig. 6). From nineth year the production decreases drastically as the farmers follow rotation at eighth year.

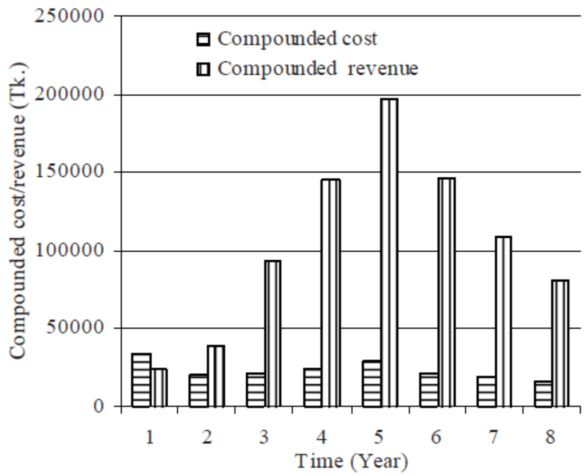

Fig. 6. A year wise cost benefit comparison of betel leaf plantation up to rotation age under agroforestry system in Jaintapur upazila of Sylhet district. Source: Rahman *et al*, 2009.

3.5. 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, 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 impacts of jhum cultivation on environment which are displayed 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. 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 CHT 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 CHT, the maximum soil loss was recorded in annual crops cultivation without mulching (99.15 t $ha^{-1}yr.^{-1}$) followed by shifting cultivation (41.23 ton/ha/yr.) where least (10 t $ha^{-1}yr.^{-1}$) soil loss occurs for agroforestry and orcharding (Table 15). The factors influencing soil loss are rainfall, land slope, slope length, land management practices, vegetation cover density etc.

Table 15. Soil erosion in Chittagong Hill Tracts under different agricultural land use system

Land use		Average soil Loss (t $ha^{-1}yr.^{-1}$)	Natural rate of soil formation (t $ha^{-1}yr.^{-1}$)	Net soil loss (t $ha^{-1}yr.^{-1}$)
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.

3.6 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-2) are identified and suggested for hilly areas to maintain agricultural production and environmental gradient.

CHAPTER IV
CONCLUSIONS

- In hilly areas 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 hilly areas of the country. 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 cultivation 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.

- Tree based land use through agroforestry and fruit farming in hilly areas 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. Tobacco cultivation in valley and floodplain should be replaced by high value annual crops.

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