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Impact of Shifting Cultivation in the Chittagong Hill Tracts of Bangladesh on the Growth of Microbial Organisms

Shafat Hosen, Ohidul Alam and S. M. Sirajul Haque*

Abstract

Deforestation is a major environmental problem in the Chittagong Hill Tracts (CHTs) of Bangladesh, triggered mostly by shifting cultivation. This study was conducted at Barkal Upazila in Rangamati District within the CHTs to explore the effect of shifting cultivation on biological soil properties. It revealed that both fungal and bacterial population were lower in the soil of shifting cultivation land (SCL) than in the soil of natural forest land (NFL). The highest fungal population was found in the subsurface soil at the hill bottoms in NFL, while the lowest fungal population was found in subsurface soil at the hill bottoms in SCL. While there were a variety of fungal genera present in both SCL and NFL soils (including *Rhizophus*, *Asperzillus*, *Trichoderna*, *Peniciliium*, *Colletrotrichum*, and *Fusarium*), the microbial genus of *Mucor* (which constitutes about 6 species of molds) was found only in NFL soil. It any case, the soil analysis shows that shifting cultivation has resulted in a great biological change in the soil.

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I. Introduction

There have been a number of studies in the Chittagong Hill Tracts (CHTs) to determine the changes of biological properties of soil due to shifting cultivation. However, little has been done to identify the impact of shifting cultivation on soil microbial organisms. This study was undertaken to identify the impact of shifting cultivation on soil microorganisms (bacterial and fungal population) as well to determine different soil biological properties in shifting cultivated land (SCL) and natural forest land (NFL). This paper is organized as follows. The next section provides some background information on shifting cultivation, especially in the CHTs. Section III then describes the methodology of this study, followed by the results of the study in section IV. The last section (Section V) provides some conclusions.

II. Background on Shifting Cultivation

II.1. Definition of Shifting Cultivation

Shifting cultivation is a form of agriculture, in which an area of ground is cleared of vegetation and cultivated for a few years and then abandoned for a new area until its fertility has been naturally restored. It can be defined as an agricultural system in which plots of land are cultivated temporarily, then abandoned and allowed to revert to their natural vegetation while the cultivator moves on to another plot. Generally, it involves clearing of a piece of land, followed by several years of wood harvesting or farming, during which the soil loses much of its fertility.

When land becomes inadequate for crop production, it is left to be reclaimed by natural vegetation. The ecological consequences are often deleterious, but can be partially mitigated if new forests are not invaded (Lal, 1975). Many cultivators use a practice of slash-and-burn as one element of their farming cycle while others employ land clearing without any burning (Serajuddin, 1971).

According to Forestal (1966), 73 percent of the land of CHTs is suitable only for forest, 15 percent for horticulture, and only three percent for intensive terraced agriculture. Shifting cultivation or jhum has been practiced in CHTs for many hundreds of years by the local people. Shifting cultivation was also practiced as a viable and stable form of agriculture in many parts of Europe and Asia at the end of the 19^{th} century, and in some places well into the 20^{th} century (Darby, 1956). Shifting cultivation has been almost entirely replaced by sedentary agriculture in Europe as well as in Nepal. It has also been replaced considerably in Thailand, and has been moderately replaced in Indonesia and Malaysia. However, shifting cultivation is still being widely practiced in Bangladesh, Laos, and northeastern India (Mohsin, 1997).

Shifting cultivation and its associated fires destroyed about 2/3 of the previously existing forests of CHTs (Farid and Husain, 1988), which has accelerated soil erosion (Shoaib et. al., 1998). While it was an environmentally suitable land use in the past when population pressure was low (Nye and Greenland, 1960), it has gradually become an environmentally incompatible land use system with the shortening of fallow period attributed to increasing population pressure, low investment in agriculture and poor management rights of forests in the CHTs (Knudsen and Khan, 2002). Shifting cultivation practice not only affects the soil of the cultivated land, but also surrounding environments of such cultivated land. Numerous scientists and the general public

consider shifting cultivation as primitive, backward, wasteful, unproductive, and exploitative as well as the cause of widespread environmental degradation (Thomas, 1956).

II.2. Phases of Shifting Cultivation

There are several phases of shifting cultivation, i.e., clearing (including slashing and felling), burning, cropping, and fallowing. The success of the burn depends on the thoroughness of cutting activities, the type of vegetation and weather (Barua, 2001). Ridges and mounds may be made if roots are planted as a first crop. Mixed cropping also provides more complete cover and controls weed growth, thus reducing the labor for weeding (Roy, 2002). Fallowing is defined as a period in which the land is prepared for the next shifting cultivation cycle by controlled natural reforestation and forest enrichment. This period is important for re-establishment of soil fertility. The long term success of a shifting cultivation system depends upon how well the fallow period restores soil fertility (Uddin et. al., 2000).

II.3. Causes of Shifting Cultivation in the CHT

Shifting cultivation is the premature, oldest and the standard system among the forest dwellers and nomadic people in different parts of the world including Bangladesh. There are many reasons for using shifting cultivation in the CHTs of Bangladesh. Firstly, jhumias have no fixed home and permanent settlement for agriculture and other practices for their survival which lead them to practice such destructive cultivation (Ali and Amin, 1987). During then Pakistan reign, a hydro-electric project was established at Kaptai for industrial growth and many people were displaced (Roy, 2002). Permanent cultivators, who were not given adequate compensation, were compelled to practice jhum fully or partly due to a lack of alternative livelihood sources. It is reported that 65 percent of the Reinkhyong reserve forest was destroyed by shifting cultivators (Ministry of Environment and Forest, 1993; Bartlett, 1956).

II.4. Impact of Shifting Cultivation on Soil

The characteristics of CHTs soils are coarse- to medium-textured, associated with well porous capacity and drainage system. Hills are mainly yellowish brown to reddish brown loams. High hill soils are shallow to moderately deep, well to excessively drained, mostly pale brown and sandy loam to clay (Richards and Hassan, 1988).

A large proportion of the mineral nutrients in the ecosystem are stored in the vegetation, not the soil. Shifting cultivation affects the soil quality seriously. The number of microorganism initially decreases after burning (Ahlgren and Ahlgren, 1965). Variability in soil temperature during burning depends on the intensity and duration of the burn, fuel quality and moisture content. The highest temperature (200°Celsius) was reached during an experimental burn in Costa Rica in dense litter, 1-2 centimeter (cm) above the soil surface (Ewel et. al., 1981; Zinke et. al., 1978). Burning causes partial sterilization of the soil, initially followed by a ‘flush’ of microbial population but eventually followed by a decline of microbial population which approaches new equilibrium levels (Laudelot, 1961).

The rapid mineralization of organic matter and additions of ash after clearing and burning provide a sharp increase of available nutrients to the first planted crops (Sanchez, 1976), but yields gradually decline with successive cropping. Moreover, there are several reasons for

declining yields (Nye and Greenland, 1960), including a) increases of pests, diseases, and weeds; b) topsoil erosion; c) deterioration in the physical condition of the soil; and d) changes in the numbers and composition of soil fauna and flora, which is influenced by humus (Ahn, 1974).

During the fallow period nutrient changes are closely linked with an increase in soil organic matter and soil humus, which helps to store important amounts of phosphorus and sulphur, as well acts as a nitrogen reservoir (Nye and Greenland, 1960). Under moist lowland evergreen or semi-deciduous forest, the maximum soil organic matter attained after very long periods of fallow averaged about 67 tons/ha of carbon and 6.15 tons/ha of nitrogen within the top 30 cm layer of the soil. Contrary, annual litter production in moist tropical forests is about 12 tons/ha (Kalpage, 1974). The initial rate of increase of humus carbon ranges between 280-670 kg/ha annually.

Bacteria are the smallest and most diverse soil microbes and some bacteria carry out special roles in soil, namely, *Rhizobia*, which is a nitrogen-fixing bacteria associated with legume roots. *Protozoa* are mobile organisms that feed on other microbes and soil organic matter (Frey et. al., 1999). *Algae*, like plants, photosynthesize and are found near the soil surface. *Fungi* and *Actinomycetes* are a diverse group of microbes, which are extremely important for the breakdown of soil organic matter (Tugel and Lewandowski, 1999).

The most numerous and varied type of Nematodes that live on decaying organic matter (saprophytes) are predatory on other nematodes, bacteria, algae, protozoa and the like (Brady, 1999). Mycorrhizae associations have been shown to increase plant-water relations and to reduce the severity of some plant diseases (Smith and Read, 1997), as-well-as to improve soil aggregate stability due to the binding actions of *Hyphae* and *Glomalin* (Nichols et. al, 2004). Other soil factors that promote activity are adequate levels of oxygen, near-neutral pH levels, temperatures between 85-95°Fahrenheit, and 50-60 percent moisture (Brady, 1999). Tillage typically accelerates short-term bacteria and protozoa activity by increasing aeration and breaking up residue into smaller particles (Vigil and Sparks, 2003).

II.5. Influencing Factors of Microbial Growth in Soil

The major external factors that influence microbial community in soil are moisture, pH, temperature, gases, organic and inorganic fertilizers, organic matter content, types of vegetation, ploughing and season (Griffin, 1972). Most of the animals make their habitat in the transition zone between the forest floor and mineral soil. Moisture affects microbial activity mostly for being a component of protoplasm and it is present in the form of film in soil spores (Dubey and Dwivedi, 1988). Besides, microbial population is also sensitive to the moisture condition and composition of soil (Alexander, 1997). Though temperature affects the activity of all soil organisms but the influence is not same for all. Most of the soil organisms grow best within the range of 25-35°Celsius, but they can also survive and develop in higher and lower temperature (Lutz and Chandler, 1946).

Contrary, high acidity in soil inhibits activity of common bacteria, fungi, algae and actinomycetes but most fungi can survive at low pH levels (Pritchett and Fisher, 1987). Gases, acids, micro and macro elements, clay elements etc. are chemical factors which provide nutrition for growth, activity and survival of microorganisms in ecologically different niches in soil (Alexander, 1997). Besides, the number and activity of microorganisms in soil governs the

quantity of plant available nutrients (Griffin, 1972). Incorporation of green manure, crop residues etc. in soil increases the amount of microbes, whilst at the same time, application of these materials in soil alters the composition of soil micro flora, macro fauna and relative dominance of antagonistic bacteria, actinomycetes, fungi, amoeba etc. (Baker and Cook, 1974).

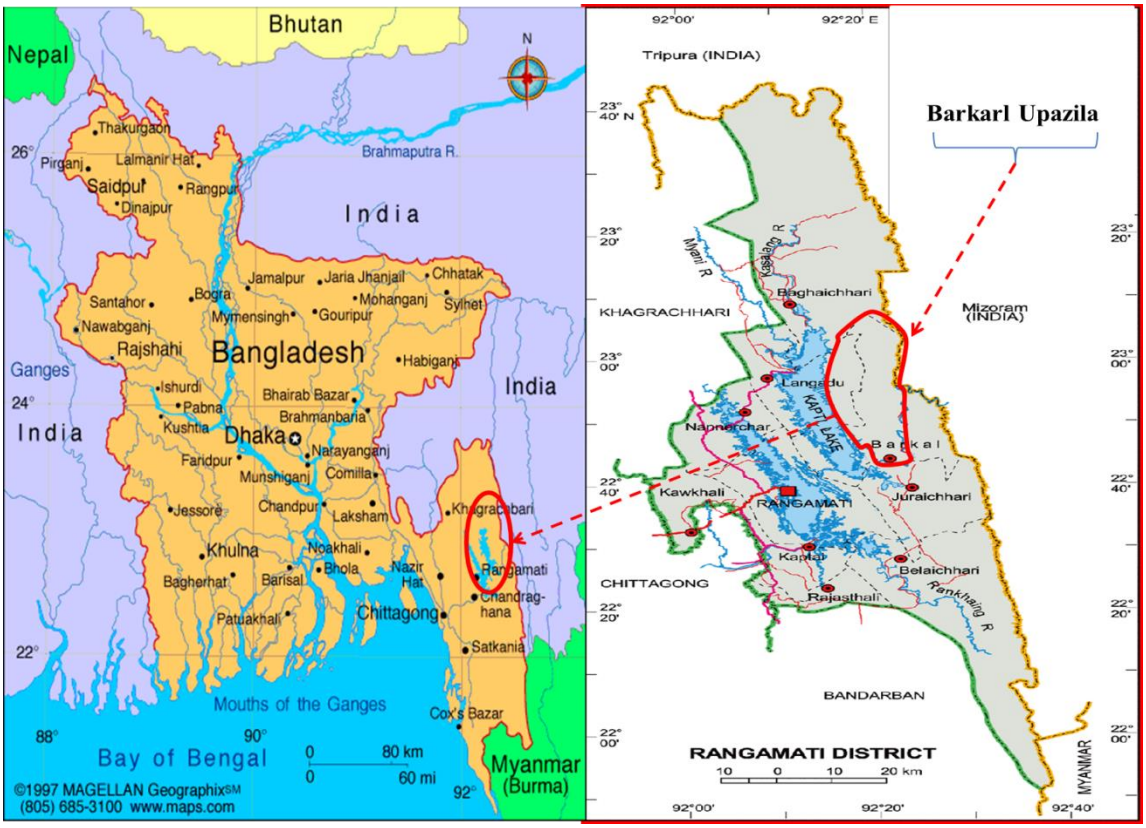
Dubey and Dewedi (1998) found an increased population of fungi in the non-rhizosphere and rhizosphere of soybean according to season and growth stages, respectively. Moreover, Mueller et al., (1985) determined the incidence of fungi and bacteria occurring in the rots of six soybean cultivators growing in the field cropped for three years either with corn or soybean. Soils from different long-term managed environments such as crop and pasture were subjected to stress and disturbance. It showed that microbial communities with lower population in crop fields were less resistance to stress and disturbance than the soil of higher population (Allison, 1973).

III. Methodology

III.1. Study Area

The study area is a one year old shifting cultivated area with a hill slope of 42 percent, located in Barkal upazila in Rangamati district (under Chittagong division), with a geographical position of 22°46.808´ North and 92°19.12´ East (see Figure 1).

Figure 1: Sketch of the Study Area (Red Circle) at Barkal Upazila in Rangamati District



Source: Created by authors based on maps provided by Banglapedia.

The site was kept unused (fallow) for one year during sampling and collection time. Very little ground coverage and litter was present on the land. Banana plantation, one-year old teak seedlings (with a 1.89m×1.83m spacing), naturally growing muli bamboo (of 2-3 meter of height), and gamar were present along with old paddy plants (of 0.75 meter of height). The adjacent natural forest land analyzed consisted of tree species like pitali, sada koroi, shimul, bel, kalojam, gamar, medha, jhumur, shorea, chatim etc. The tree canopy and ground coverage vegetation was 100 percent. The examined forest land is known as village common forest (VCF) since 1995, with an area of 80.94 hectare (Khisa, 1997). The sampling plot was 20 meter by 20 meter.

III.2. Soil Sampling

Soil samples at each site were collected from a depth of 0-10 cm (surface soil) and 10-20 cm (subsurface soil). From each site and depth, 5 soil samples were collected randomly covering each land use type and mixed together to give a composite sample. Each composite soil sample was put into labeled polybags, sterilized with 95 percent ethyl alcohol and brought to the laboratory. In the laboratory samples were kept in an incubator at 4°Celsius temperature, appropriate to determine biological properties.

III.3. Determination of Microbial Population

Microbes are single-cell organisms so tiny that millions can fit into the eye of a needle. Then, microbial is the study of microbes in the environment and their interactions with each other. Microbial population indicates a summation of all the organisms of the same group or species, which live in a particular geographical area, and have the capability of interbreeding. Determination of microbial population is very significant to identify specific types of microbes and their total number of population as well characteristics. Besides, microbial activities greatly influence soil fertility; therefore, several microbial population determination methods have been discovered by many researchers wherein we adopted sterilization method.

Sterilization method: After primary washing with water all the glassware such as petridish, conical flask, pipette, bend glass rod etc. were ringed with 95 percent ethyl alcohol and wrapped properly with brown paper. All prepared media in conical flask were cotton plucked properly and mouth was wrapped with enamel foil. All glassware and media were then placed carefully in an autoclave machine with proper pre-caution. Autoclave was then placed on gas stove at full flame and heated until the temperature reaches to 121°Celsius and continued for 15 minutes to unwanted microorganisms.

Soil dilution: The homogenized soil samples were passed through a 2 millimeter (mm) sieve. Exactly 1 gram sieved soil was dispersed in 99 milliliter (ml) sterile water in a 150 ml conical flask. The flask was covered with a rubber stopper and shaken vigorously for 10 minutes. For the determination of fungi, a similar procedure was followed, except that not shaking the flask vigorously. Thus, a 1:100 (10^{-2}) dilution was prepared, then 1 ml of this suspension was taken out and mixed thoroughly adding 9 ml sterile water in another conical flask and labeled as dilution 1:1000 (10^{-3}). Similarly, dilutions of 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8} and 10^{-9} solution were prepared. Dilutions 10^{-3}, 10^{-4} and 10^{-5} were used for culturing and isolation of fungi; while dilutions 10^{-7}, 10^{-8} and 10^{-9} were used for culturing and isolation of bacteria (Black et al., 1965).

Setting glassware for plating in lamina flow: Before plating, lamina flow bench was cleaned with absolute alcohol using cotton and autoclave run simultaneously. In the lamina flow bench, ultra-violate ray and fan were switched on for a period of 30 minutes, after which ultra-violate ray was switched off and fluorescent light was turned on. All the glassware such as petridish, conical flask, pipette, bend glass rod etc. in autoclave was then transferred to the lamina flow bench unwrapping each carefully to avoid any contamination. Each of the petridishes was then marked with glass marker specifying dilution state and sample used.

Plating media and incubation: Each of the potato dextrose agar (PDA) media and nutrient agar (NA) media in conical flask was carefully unwrapped and the cotton pluck was removed from the mouth of the conical flask. The lid of the plates was opened at an angle of 45° to avoid contamination. About 15 ml of sterilized PDA or NA media from conical flask was poured in petridishes, rotated clockwise and anticlockwise several times to spread the media evenly throughout petridishes. Thus replicated petridishes were prepared from each of the PDA and NA media. Before that, exactly 300 mg Streptomycin sulfate (0.30 mg/ml) was added in 1000 ml sterile distilled water to make a streptomycin suspension. This suspension is added in 1 liter sterile PDA media. Suspension is used in media for inhibiting bacterial growth and allowed to solidify. A nystate solution of 0.005 ml was used as antifungal for the bacterial culture. For fungi isolation, 1 ml soil suspension was pipetted out from each of 10^{-2} and 10^{-4} dilutions to the test tubes, each containing 9 ml sterile distilled water to give 10^{-3} and 10^{-5} dilutions, respectively. Similarly, 10^{-6}, 10^{-7}, 10^{-8}, and 10^{-9} dilutions were made for the isolation of bacteria.

Plate counting: After 24 hours of incubation for bacteria and 72 hours incubation for fungi, all petridishes were examined to see whether a particular dilution range plated. A plate prepared from a given dilution should have only one tenth of colonies of the plate prepared from the next lower dilution. Petridishes which had numerous (>300) or less numerous (< 300) of colonies on the plates and had no dilution effect were discarded. Plates with one or more large bacterial or fungal colonies (>2 cm in diameter), were also discarded. The total number of colonies on each suitable plate was counted using square grid (Black et al., 1965).

III.4. Fungi or Bacterial Population Calculation

According to Black et al. (1965), the microbial population is calculated by the colony forming unit (CFU). The CFU is defined at the average number of colonies per gram (g) of oven dry soil (ODS), multiplied by the dilution factor. That is:

CFU = average number of colonies per g of ODS, multiplied by the dilution factor.

For example, let's calculate the CFU of soil containing 25 percent moisture, which had 90, 120, 110, 100 and 85 colonies in 5 replicated plates in dilutions with a dilution factor of 10^7.

The first step is to calculate the average colony number, which in this case would be:

(90+120+110+100+85)/5 = 101

i.e.: 1 gram of moist soil contains on average 101 colonies.

The second step is to calculate the average colony number per gram of ODS, which for soil containing 25 percent moisture, would be:

$\frac{101}{0.75}$ = 134.6667

The third step is to multiply the average colony number per gram of ODS by the dilution factor.

Therefore, CFU = $\frac{101}{0.75}$ x 10^7 per gram of ODS (Note: 10^7 is the dilution factor.)

= 1.346667 x 10^9 per gram of ODS

III.5. Morphological Studies of Selected Fungal and Bacterial Strain

Non microscopic characteristics such as colony size, shape, edge color, opacity distribution of fungi and bacteria were determined. And some microscopic characteristics of these two organisms were also studied after 72 hours incubation periods for fungi and 24 hours for bacteria with a view to identify the species in a limited extent.

III.6. Microscopic Characteristics

The shapes of the vegetative cells were determined. The arrangements of the cells like present singly or in chain or in clusters were also observed in both 10X and 40X magnification and photographs were taken. Fungi were mounted in cotton blue for the morphological studies like shape and orientation of mycelium etc.

IV. Results and Discussions

IV.1. Characteristics of Soil Texture

Soil texture and soil structure are both unique properties of the soil that will have a profound effect on the behavior of soils, such as water holding capacity, nutrient retention and supply, drainage, and nutrient leaching. In soil fertility, coarser soils generally have a lower ability to hold and retain nutrients than finer soils.

However, this ability is reduced as finely-textured soils undergo intense leaching in moist environments. Further, soil texture is an important soil characteristic that influences storm water infiltration rates. Moreover, it is important to identify whether the soil is either suitable for microbial growth or not, because, microbial growth and population as well as their activities increase soil nutrient or fertility.

Soil texture of hill top and bottom position in SCL ranges between sandy loam to sandy clay loam. Inversely, in mixed NFL, soil was only sandy loam. In another words, we can say that both land uses possess mainly fine sand and sand textured soil. Further details on the textural characteristics of SCL and NFL soils are provided in Table 1.

Table 1: **Textural Characteristics of Soil in SCL and NFL on Two Different Hill Positions**

Land use	Hill position	Soil depth (cm)	Soil particles					Textural classes of loam
			Coarse sand	Fine sand	Sand	Silt	Clay	
SCL soil	Top	0-10	25.78	55.85	62.0	22.15	18.20	Sandy
		10- 20	23.45	60.55	65.0	18.00	22.50	Sandy Clay
	Bottom	0-10	35.00	45.80	57.3	26.78	22.50	Sandy Clay
		10-20	25.45	43.75	43.80	22.90	21.80	Sandy
NFL soil	Top	0-10	32.55	46.50	77.90	11.15	19.50	Sandy
		10- 20	27.50	44.05	68.50	20.15	16.70	Sandy
	Bottom	0-10	19.25	39.80	54.55	24.45	17.70	Sandy
		10-20	25.05	35.00	59.00	24.15	17.70	Sandy

Source: Based on sample collected for analysis in 2012 from Barkal Upazila.

IV.2. Moisture, Organic Matter, and Power of Hydrogen (pH)

Organic matter in soil increases its fertility but the rate of decomposition of organic matter depends on the soil's temperature, moisture, aeration, pH, and nutrient levels. The warmer and wetter the climate is, the faster the rate of organic matter breakdown. Inversely, waterlogged organic matter breaks down very slowly because microorganisms necessary for decomposition cannot exist where there is no oxygen. Furthermore, acid soils with low pH levels usually contain greater quantities of organic matter because microorganisms become less active as soil acidity increases. However, organic matter is the lifeblood of fertile, productive soil. Without it, agricultural production is not sustainable.

The main sources of organic matter in farms are plant litter (plant roots, stubble, leaves, mulch) and animal manures that are decomposed by earthworms and microorganisms. The process of decomposition releases nutrients, which can be taken up by plant roots. The end product of decomposition is humus that is resistant to further decomposition. Humus, a complex chemical substance, stores plant nutrients, holds moisture and improves soil structure. But the transformation and movement of materials within soil organic matter pools is a dynamic process influenced by climate, soil type, vegetation, and soil organisms. All these factors operate within a hierarchical, spatial scale. Besides, soil organisms are responsible for the decay and cycling of both macronutrients and micronutrients, and their activity affects the structure, tilth and productivity of the soil.

Table 2 shows that in both positions (top and bottom) of SCL soil, the moisture content and pH level is lower than at the two positions of NFL soil. On average, hill top position of SCL soil has 19.55 percent moisture, 1.88 percent organic content and a pH level of 4.9, while hill top position NFL soil has 25.55 percent moisture, 2.5 percent organic content and a pH level of 5.5.

On the contrary, in hill bottom position SCL soil has 22.11 percent moisture, 2.2 percent organic content and a pH level of 4.5, whereas hill bottom NFL soil has 25.55 percent moisture, 2.5 percent organic content and a pH level of 5.5. Comparatively, the pH level is lower in SCL soil but the organic matter content is higher in NFL soil.

Table 2: **Physic-Chemical Properties of Soil in SCL and NFL at Barkal Upazila**

Land use	Hill position	Soil depth (cm)	Moisture content (%)	Organic matter (%)	pH
SCL soil	Top	0-10	13.55	1.11	4.5
		10-20	15.55	0.95	4.3
	Bottom	0-10	12	1.55	4.3
		10-20	13	0.95	4.1
NFL soil	Top	0-10	18	2.91	4.8
		10-20	19	2.32	4.5
	Bottom	0-10	16	2.10	4.9
		10-20	19	2.00	4.7

Source: Based on sample collected for analysis in 2012 from Barkal Upazila.

IV.3. Microbial Population in SCL and NFL

As Table 3 shows, the fungal population at both soil depths (the 0-10 cm surface and 10-20 cm subsurface levels) on the hill top was significantly ($p \leq 0.05$) lower in SCL compared to NFL. Fungal population was also significantly lower in the hill bottom at soil depth of 10-20 cm. Its microbial population on the hill top at 0-10 cm soil depth in SCL was 121.25×10^4 cfu/g oven dry soil (ODS) versus 185×10^4 cfu/g ODS at 0-10 cm soil depth in NFL.

Table 3 also shows that the bacterial population at soil depth of 0-10 cm on the hill bottom was significantly lower in SCL compared to NFL. Moreover, bacterial population at other hill positions was lower in SCL than in NFL. Its population on the hill bottom at 0-10 cm soil depth in SCL was 262×10^7 cfu/g ODS, while it was 320×10^7 cfu/g ODS at the same soil depth in NFL. Fungal population in SCL ranged from 113.50×10^4 cfu/g ODS to 165×10^4 cfu/g ODS, while it ranged from 156.25×10^4 cfu/g ODS to 185×10^4 cfu/g ODS in NFL. Bacterial population ranged from 118×10^7 cfu/g ODS to 262×10^7 cfu/g ODS in SCL and 238×10^7 cfu/g ODS to 320×10 cfu/g ODS in NFL.

Table 3: **Fungal and Bacterial Population (cfu/g ODS) in SCL and NFL at Barkal Upazila**

Hill position	Soil depth (cm)	Fungal population (cfu/g ODS)		Bacterial population (cfu/g ODS)	
		SCL	NFL	SCL	NFL
Hill top	0-10	$121.25\times10^{4*}$	185.00×10^{4}	235.00×10^{7}	278.00×10^{7}
	10-20	$112.20\times10^{4**}$	156.25×10^{4}	118.00×10^{7}	238.00×10^{7}
Hill bottom	0-10	137.50×10^{4}	200.00×10^{4}	$262.00\times10^{7*}$	320.00×10^{7}
	10-20	$113.50\times10^{4**}$	165.00×10^{4}	218.00×10^{7}	268.00×10^{7}

Note: (*) indicates significant at $p\leq0.05$, and (**) indicates highly significant at $p\leq0.01$.

Source: Based on sample collected for analysis in 2012 from Barkal Upazila.

IV.4. Non-microscopic Characteristics of Fungus Colonies

Ocular observation of cultured fungal plates from NFL soil showed seven different types of fungus colonies: *Rhizophus, Asperzillus, Trichoderna, Penicillium, Colletrotrichum, Fusarium* and *Mucor*. The soil from SCL contained all the same types, except that *Mucor* was missing. The identifying characteristics of each genus are as follows and further detailed in Table 4.

- *Rhizophus* (Type A): Was whitish black in color both in SCL soil and NFL soil, but differed in colony diameter, 0.55 cm being in SCL soil and 0.85 cm in NFL soil.
- *Asperzillus* (Type B): Was whitish black color in SCL soil with colony diameter 0.65 cm and in NFL soil was light whitish black in color with colony diameter 0.70 cm.
- *Penicillium* (Type C): Was greenish light blue in color with 0.65 cm colony diameter in SCL soil, while greenish blue with 0.85 cm colony diameter in NFL soil.
- *Trichoderma* (Type D): The color was greenish white in both the SCL and NFL soils, but the colony diameter was 0.50 cm in SCL soil and 0.65 cm in NFL soil.
- *Colletrotrichum* (Type E): Was milky white in color among all sample soils, but differed in colony diameter size, 0.36 cm being SCL soil, and 0.58 cm in NFL soils.
- *Fusarium* (Type F): Both in NFL and SCL soils the color was yellowish white, but the colony diameter was 0.55 cm in NFL soil and 0.75 cm in SCL soil.
- *Mucor* (Type G): Found only in NFL soil, brownish white in color, and with a colony diameter of 0.80 cm.

IV.5. Non-microscopic Characteristics of Bacteria Colonies

Ocular observations of cultured bacterial plates from NFL and SCL soils provided each three different types of bacterial colonies, with the identifying characteristics of each genus as follows and further detailed in Table 5. Finally, Figures 2 and 3 show three replicated bacterial colonies in NFL and SCL, respectively.

- *Streptococcus* (type A): Was creamy white in color with a colony diameter of 0.15 cm in SCL soil and with colony diameter of 0.32 cm in NFL soil.
- *Coccus* (type B): Was pale creamy off white in color with a colony diameter of 0.35 cm in SCL soil and a colony diameter of 0.56 cm in NFL soil.

- *Bacillus* (type C): Was condensed off white in color with a colony diameter of 0.23 cm in SCL soil and a colony diameter of 0.36 cm in NFL soil.

Table 4: **Summary of Fungal Colonies Characteristics of NFL Soil and SCL Soil**

Colony type	Colony size (cm)	Colony shape	Colony color	Colony appearance	Colony opacity	Colony distribution	Colony edge
Natural Forest Land (NFL) Soil							
A	0.88	round	WB	glossy	opaque	periphery	Irregular
B	0.70	round	WB	velvety	opaque	periphery	regular
C	0.78	round	GLB	glossy	opaque	periphery	regular
D	0.65	deform	GW	velvety	opaque	periphery	regular
E	0.55	deform	MW	sporous	opaque	periphery	regular
F	0.80	deform	YW	hyphal	dense	periphery	irregular
G	0.81	deform	YW	sporous	dense	periphery	regular
Shifting Cultivated Land (SCL) Soil							
A	0.55	round	WB	deform	dense	periphery	irregular
B	0.62	round	WB	deform	dense	periphery	irregular
C	0.72	deform	GLB	deform	dense	periphery	irregular
D	0.50	deform	GW	deform	dense	periphery	regular
E	0.36	round	MW	sporous	opaque	periphery	irregular
F	0.55	deform	YW	sporous	dense	-	irregular
G	-	-	-	-	-	-	-

Note: WB=whitish black, GLB=greenish light blue, GW=greenish white, MW=milkish white, YW=yellowish white.

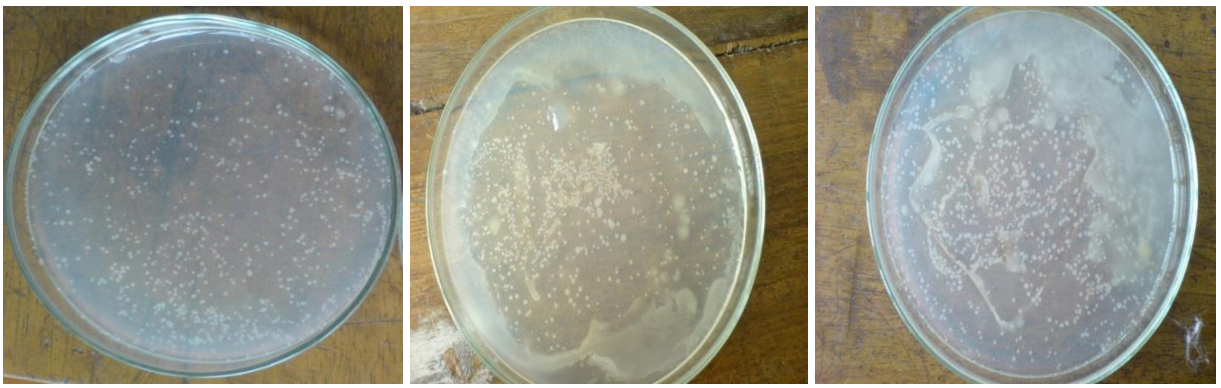
Source: Based on sample collected for analysis in 2012 from Barkal Upazila.

Table 5: **Summary of Bacterial Colonies Characteristics of Soil at NFL and SCL**

Colony type	Colony size (cm)	Colony shape	Colony appearance	Colony opacity	Colony distribution	Colony edge
Natural Forest Land (NFL) Soil						
A	0.32	deform	regular	opaque	scattered	regular
B	0.55	round	regular	opaque	scattered	round
C	0.46	deform	irregular	opaque	periphery	irregular
Shifting Cultivated Land (SCL) Soil						
A	0.12	deform	regular	opaque	periphery	regular
B	0.35	round	regular	-	-	irregular
C	0.22	deform	irregular	dense	-	regular

Source: Based on sample collected for analysis in 2012 from Barkal Upazila.

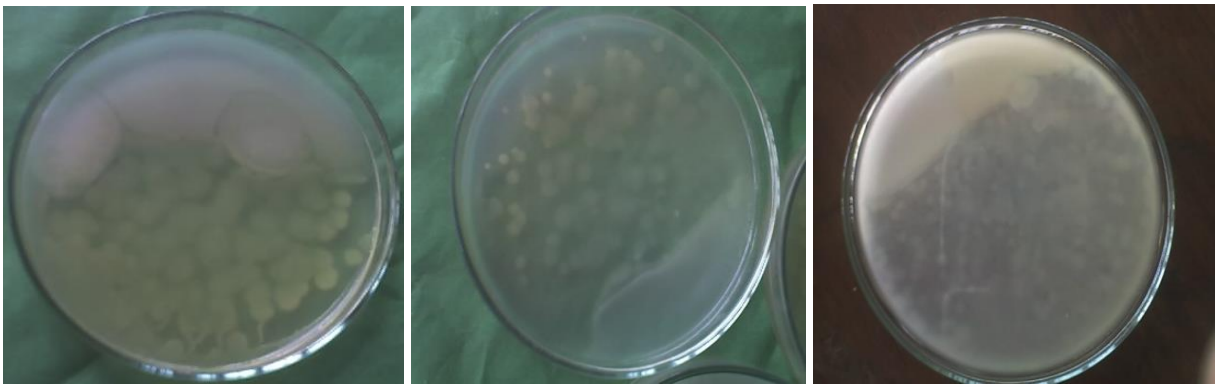
Figure 2: Three Replicated Bacterial Colonies in NFL (NFL_1, NFL_2 and NFL_3) at Barkal



NFL_1 NFL_2 NFL_3

Source: Pictures taken by the authors.

Figure 3: Three Replicated Bacterial Colonies in SCL (SCL_1, SCL_2 and SCL_3) at Barkal



SCL_1 SCL_2 SCL_3

Source: Pictures taken by the authors.

V. Conclusion

This study was conducted to determine the differences in biological properties of soils at two different land uses in the Chittagong Hill Tracts (CHTs): shifting cultivation lands and natural forest lands. It showed that shifting cultivation has definite effects on soil biological properties. The significant changes that occurred due to shifting cultivation are that i) the soil of shifting cultivated land showed significantly lower fungal population than natural forest land soil, and ii) the soil of natural forest land showed significantly higher bacterial population than shifting cultivated land soil. Shifting cultivation is reducing availability of microbes in soils along with creating a crisis of nutrients. Based on these results as well as the literature review provided in section II, we suggest to stop shifting cultivation practices in the CHTs and to conserve the remaining natural forests. Still, there is scope for further research, which could focus on individual species identification of soil as well as on the identification of shifting cultivation effects on soil biological properties with respect to seasonal variations.

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