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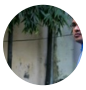
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ORIGINAL PAPER

Study on soils under shifting cultivation and other land use categories in Chittagong Hill Tracts, Bangladesh

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Abstract: Soil samples were collected and analyzed from 25 sites of three hilly regions (Rangamati, Banderban and Khagrachari) for an understanding of the impact of denudation and land use on soils in Chittagong Hill Tracts, Bangladesh. There were natural forests, bushy land, slashed sites, slashed and burnt sites, and the sites prepared for shifting cultivation, one year after shifting cultivation and two years after shifting cultivation. The soils were generally yellowish brown to reddish brown, sandy to sandy clay loam, strongly acid, and well to excessively drained on steep slopes with considerable variation among the sites and land use categories. Bulk density was the highest in sites of one year after shifting cultivation (1.52 $g \cdot cm^{-3}$) and the lowest in forested sites (1.38 $g \cdot cm^{-3}$). Water holding capacities were, however, statistically similar in all sites. Organic carbon varied from 0.54% (slashed and burnt sites) to 1.55% (forested sites) and total N ranged from 0.05% (shifting cultivation for one year) to 0.13% (forested sites). Available phosphorus (Bray & Kurtz-2 P) was the maximum in forested sites (12.32 $mg \cdot kg^{-1}$), and it did not differ significantly in other sites. Contents of available Ca, Mg and K were also higher in the bushy lands and forested sites than cleared and shifting cultivated sites.

Keywords: Chittagong Hill Tracts; Bangladesh; denudation; shifting cultivation; soil degradation

Introduction

Shifting cultivation, locally known as *jhum*, is a dominant land use in Chittagong Hill Tracts of Bangladesh by indigenous people. Clearing a patch of vegetation by slash and burn, growing assorted varieties of crops in the cleared land for one or two seasons, then, moving to another plot are the major characteristic of this land use. It is a kind of cropping and land use system that has little or no commitment to long-term sustainable use (van Noordwijk et al. 2008). Traditional shifting cultivation in the humid zone involves clearance of primary forests followed by cropping for one or two seasons, and then fallowing for a decade or so. As demographic pressure has increased and more and more people have been forced to seek land in the forested areas, traditional systems have been replaced by crude slash-and-burn, in which the cultivation period is prolonged, fallow period is shortened, secondary forests are also cleared, forest regeneration is endangered and soil fertility is threatened (Ickowitz 2004). The practice of slash-and-burn farming under reduced fallow cycle is a threat to biodiversity and soil conservation. It is no longer sustainable (Duguma et al. 2001).

Effects of shifting cultivation on forest, land and soil in CHT were not earlier sufficiently studied. However, some investigators reported that growing annual crops by slash and burn on steep slopes has adversely affected the forest, land and environment (Gafur 2001, DANIDA 2000, Knudsen and Khan 2002). Forest fires along with shifting cultivation destroyed about two-thirds of forest of CHT (Farid and Hossain 1988). Declining forest cover has accelerated soil erosion (BDGCHT 1971) Razzaque and Roy 1998; Shoaib et al. 1998). The continuous soil loss reduced soil fertility (Gafur 2001).

On the above background, the present work was undertaken to observe the effects of shifting cultivation and other land uses on soil in Chittagong Hill Tracts, Bangladesh.

Materials and methods

Ecology and physiography of Chittagong Hill Tracts (CHT)

Chittagong Hill Tracts, the only extensive hilly area in Bangladesh, lies in the southeastern part of the country (21°25′ N to 23°45′ N latitude and 91°54′ E to 92°50′ E longitude)

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bordering Myanmar on the south-east, the Indian state of Tripura on the north, Mizoram on the east and Chittagong district on the west.

Of the two kinds of topography, a) Low Hill Ranges (Dupi Tila and Dihing Formations) and b) High Hill Ranges (Surma and Tipam Formations), Chittagong Hill Tracts comprise mainly of the high hills. It is an almost parallel ridge running approximately north-south with summits reaching 300–1,000 m above msl. and on steep slopes generally >40%, and are often subject to landslide erosion. They mainly underlie consolidated shales, siltstones and sandstones. There are extensive stretches of low hills and hillocks within the high hill ranges (Anon 1996). The soils in the area develop from semi-consolidated to consolidated shales and sandstones on very undulating relief in a tropical climate with heavy rainfall concentrated in the monsoon. The parent materials are low in weatherable minerals. The area was earlier covered by dense tropical rainforests that suffered extensive deforestation during the recent past.

Sampling sites

Twenty five sites in eight locations of Chittagong Hill Tracts were selected in the study. These locations were Betchara, Kemlong Uddonti, Tarasa of Banderban District; Kutukchari, Mulari Para of Rangamati District; Kark Mohajon Para, Simina Para and Milan Karbari Para of Khagrachari District (Fig. 1). The land use categories were natural forest (4 sites), bushy land (secondary vegetation – 3 sites), slashed (3 three sites), slashed and burnt (3 sites), prepared for shifting cultivation (3 sites), one year after shifting cultivation (3 sites), and two years after shifting cultivation (4 sites).

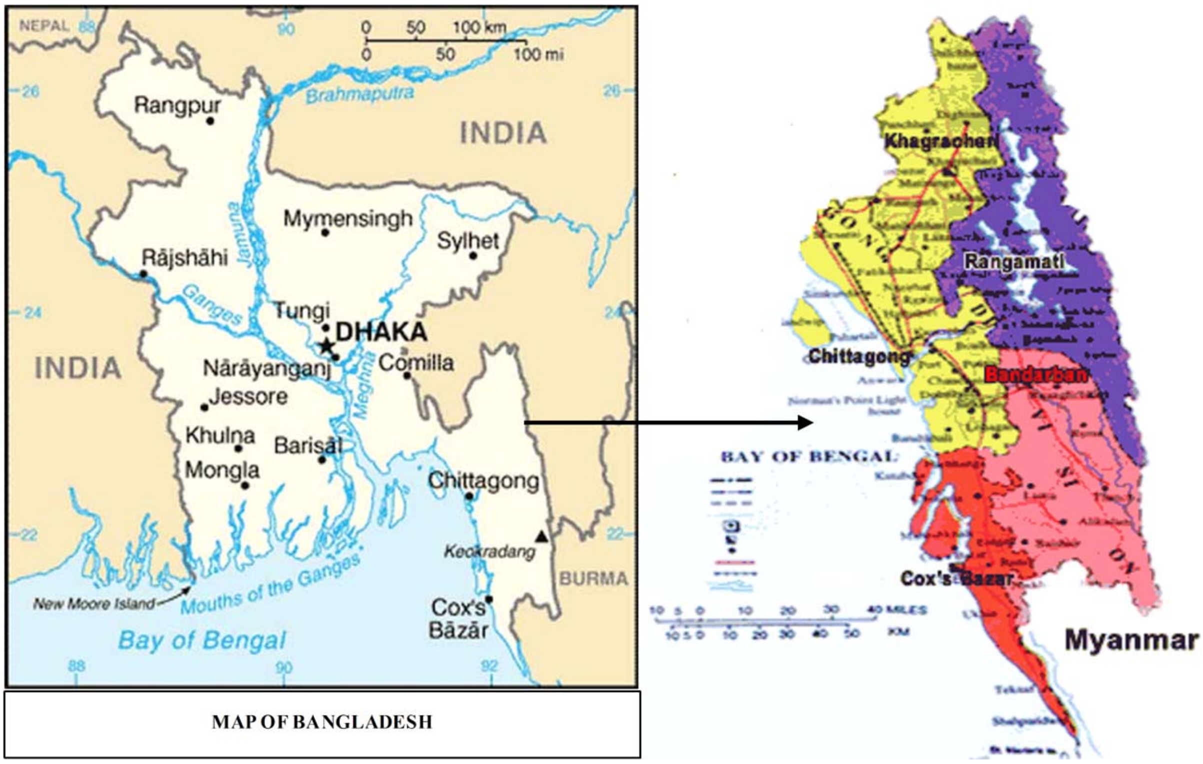

Fig. 1 Location of the study area

Soil sampling

Soil pits of 1 m × 1 m size were excavated down to the parent material from selected sites of the locations. The horizons were marked and morphological characteristics were noted. Soil samples were taken from each horizon and processed for analysis.

Soil Analysis

Soil color was measured by Munsell soil color chart at moist condition of soil. Bulk density, maximum water holding capacity and field capacity were determined from cores. Soil texture was determined by hydrometer method (Piper 2005). Soil pH was measured by an electronic pH meter from a 1:2.5 soil-water suspension. Organic carbon was determined by wet oxidation method of Walkley and Black (1934). Total nitrogen was determined by micro-Kjeldahl digestion and distillation method (Jackson 1973). Available phosphorus of field moist soil was extracted by ammonium fluoride - hydrochloric acid (Bray & Kurtz-2) and determined according to the $SnCl_2$ reduced molybdophosphoric blue color method (Jackson 1973). Available calcium, magnesium and potassium were extracted with 1N NH_4OAC and determined by an atomic absorption spectrophotometer.

Results and discussion

Physico-chemical and nutritional properties of soils of individual sites were separately determined and the mean values of surface soils (0–15 cm) of different land use categories are presented in Table 1 and 2, respectively. These soils on steeply sloping lands were generally from yellowish brown to reddish brown, sandy to sandy clay loam, strongly acid and well to excessively drained. Soil profiles were very deep, being often more than 1 m and well differentiated. Surface horizons were, however, generally thin with signs of moderate to severe erosion. Surface soils of forested, bushy and slashed sites were comparatively darker and thicker.

Table 1. Physico-chemical properties of soils under different land use categories

Land-use categories	Texture*	Bulk density ($g·cm^{-3}$)	Max. water holding capacity (w/w)	Field capacity (w/w %)	pH	Org. carbon (%)	C/N
Forested sites	SL	1.38c**	35.82a	19.80a	4.56c	1.55a	14.36a
Bushy land	SC	1.44b	35.61a	20.34a	4.70a	1.12b	9.94c
Slashed	SCL to C	1.48a	36.48a	20.97a	4.67b	1.28b	12.40b
Slashed and burnt	L to CL	1.43b	36.36a	20.49a	4.58b	0.54d	9.54c
Prepared for jhuming	SL to SCL	1.42bc	35.91a	20.10a	4.62b	0.75c	11.87b
One year shifting cultivation	SCL	1.52a	36.70a	21.05a	4.59c	0.69c	10.36b
Two years shifting cultivation	SL to C	1.43b	35.94a	20.32a	4.77a	0.69c	12.54b

*SL = sandy loam, SC= sandy clay, SCL= sandy clay loam, C =clay, L= loam.
** Figures followed by the same letter(s) in the same column do not differ significantly according to DMRT.

Table 2. Organic carbon and nutrients in soils under different land use categories.

Land-use categories	Total N (%)	Av. P ($mg·kg^{-1}$)	Av. Ca ($mg·kg^{-1}$)	Av. Mg ($mg·kg^{-1}$)	Av. K ($mg·kg^{-1}$)
Forested site	0.13a*	12.32a	6.66a	4.93a	4.53a
Bushy land	0.11a	10.56b	6.94a	3.70b	4.80a
Slashed	0.10a	9.51b	4.56b	2.73c	3.90b
Slashed and burnt	0.06b	9.51b	4.85b	2.95c	3.17c
Prepared for jhuming	0.06b	9.08b	3.41c	3.12c	3.61b
One-year shifting cultivation	0.06b	8.13b	4.35b	2.47c	4.52a
Two years shifting cultivation	0.05b	9.84b	4.18bc	2.87c	4.34b

* Figures followed by the same letter(s) in the same column do not differ significantly according to DMRT.

Data in Table 1 illustrated that bulk density, maximum water holding capacity and field capacity of soils ranged from 1.38 $g·cm^{-3}$ (forested) to 1.52 $g·cm^{-3}$ (one year after shifting cultivation), 35.61% (bushy land) to 36.70% (one year after shifting cultivation) and 19.80% (forested) to 21.05% (one year after shifting cultivation), respectively. Although the mean bulk density value of the forested sites was significantly lower than the others, the land use categories did not differ much in water holding capacities of soil. Probably the higher organic matter content in forested sites caused relatively low bulk density. Textural differences did not apparently cause significant variation in water holding capacities which did not vary significantly among different land use categories.

The soils of the present study belong to the general soil type - Brown Hill Soils (Ultisols and some Alfisols) derived from highly weathered parent materials (tertiary semi-consolidated to consolidated sediments) on precipitous steep slopes. They are severely surface-drained and leached. The resulting soils are, therefore, naturally moderate to strongly acid (SRDI 1976). Soil pH in the present sites varied within a narrow range from 4.56 (forested sites) to 4.77 (two years after shifting cultivation). Earlier reports showed a significant increase in pH of shifting cultivated soils by base rich ashes produced during burning (Armando et al. 1996). In burnt sites of the present study such an effect could not be noticed. In the locality heavy rainfall generally follows burning. In shifting cultivated and fallow sites, probably bases produced by burning were removed by run-off water. Leaching and crop removal of bases may take place during cropping cycles, and the burnt soils are acidified again with subsequent lowering of pH. Such pH reversion may also take place during the fallow phase when a major portion of the exchangeable bases are taken up by the fallow vegetation (Juo and Manu 1996).

Soils of Bangladesh are particularly low in organic matter content with most values below 1% (BARC 1985). However, organic carbon varied from 0.54% in slashed and burnt sites to 1.55% in forested sites, followed by the bushy land (1.12%) and slashed sites (1.28%) in the present study. Slashing, burning and replanting caused significant reduction in soil organic matter, as was also reported by other investigators (Ewel et al. 1981; Andriesse and Schelhaas 1987; Hölscher et al. 1997; Brand and Pfund 1998).

A narrow C/N ratio with little variation among the sites (Table 1) justifies a trend of variation of total nitrogen (Table 2) similar to that of organic carbon of soils. Total N was also low, ranging between 0.05% (two years after shifting cultivation) and 0.13%

(forested sites) with 0.06% in most shifting cultivated and fallow sites. Burning for shifting cultivation not only destroys organic matter, ground flora, and the major source of nitrogen in unfertilized soils, but also causes loss of native nitrogen. In an experiment with burning rice straw, Nagarajah and Amarisiri (1977) found that 700°C temperature was reached at the surface and 300°C–400°C in the centre of the heap, resulting in 93% of N loss. With increased temperatures, C disappeared faster than N (Andriesse and Schelhaas 1987). Brand and Pfund (1998) recorded a loss of 98% C and 95% N through slash and burn of a five-year old fallow.

There was a considerably higher content of available P, K, Ca and Mg in the present forested sites and bushy land. Burning followed by shifting cultivation considerably decreased the base contents. Keeping lands fallow for short period like one or two years after shifting cultivation did not improve the situation. An increase in available bases of soil particularly after burning was reported earlier (Armando et al. 1996; Salacedo et al. 1997). Brand and Pfund (1998) observed approximately 234, 55 and 20 $kg·ha^{-1}$ increase in Ca, Mg and K respectively after burning. Shifting cultivators get the benefit of this increase of nutrients for crop production (Nye and Greenland 1960; Seubert et al. 1977; Stromgaard 1984; Andriesse and Schelhaas 1987), and this is one reason why they burn the ground vegetation. However, such an effect is extremely temporary, because subsequent rainfall washes and leaches the soluble bases. Gafur et al. (2000) studied nutrient losses due to burning prior to shifting cultivation in nearby comparable sites of the present study. They observed annual losses per ha of 61 kg Ca, 13 kg Mg, 13 kg K, 0.14 kg P, 0.20 kg S, 0.05 kg Cu, 6.7 kg Fe, 6.1 kg Mn and 0.065 kg Zn corresponding to 8% Ca, 3% Mg, 17% K, 11 %P, 27% S, 4% Cu, 8% Fe, 14% Mn and 5% Zn of the nutrient content before burning.

Soils tend to remain in equilibrium with their environmental components and drastic changes such as removal of the vegetation and burning the organic debris, and must exert short and long term effects on their physical and chemical characteristics. Within one or two years of slashing, burning and cropping, considerable combustion, erosion, leaching and crop removal may take place with a negative net effect on soil.

Results of the present study indicate that the soils were mostly poorly fertile in agricultural standard, although they supported dense lush green rainforests in the recent past. Continuous human interference on vegetation and soil might cause poor soil fertility. Further observations showed that all sorts of denudation along with shifting cultivation exerted a negative impact on the soils. Soil fertility and productivity are threatened in future. Further use of these lands for crop production would be difficult, and regeneration of the secondary forests would be unsatisfactory.

Conclusion

Shifting cultivation is primarily practiced by indigenous people in the hilly forested areas of Bangladesh. Results of the present study suggest that shifting cultivation and associated operations enhance soil erosion and fertility depletion. Since it is difficult to prevent indigenous people from shifting cultivation, an act related to their heritage, they may be motivated to extend the fallow period and to include perennial crops and retaining sufficient vegetative cover. Therefore, the choice of crops, methods of cultivation and associated impacts on soil and vegetation are necessary in the further systematic research.

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