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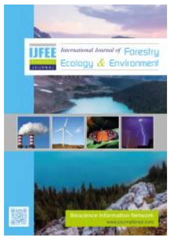
Vol. 05, Issue 01: 202-214

International Journal of Forestry, Ecology and Environment

Journal Home: https://www.journalbinet.com/ijfee-journal.html



Soil properties under eight different land uses in Bandarban hill district of Bangladesh

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Article received: 14.11.20; Revised: 09.05.21; First published online: 15 September, 2021.

ABSTRACT

The Hill Tracts of Bangladesh has been exploited beyond its sustainable limits in the last century. Research for restoration and sustainable practices are now emphasized in this region. Studies on present soil conditions are essential as these will determine the type and intensity of inputs needed to restore and achieve sustainability. This study was conducted to assess the physical and chemical properties of soil in the Bandarban hill district under eight different land uses. Convenience sampling was done in the Ruma upazila of the district, and eight different land uses were selected as- 1. Jhum (shifting cultivation) land, 2. Turmeric cultivated area, 3. Papaya orchard, 4. Tectona grandis (Teak) plantation, 5. Banana orchard, 6. Orange orchard, 7. Natural forest and 8. Fallow land- for the collection of soil. Most of the nutrient values (Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sulfur, organic carbon) and physical soil factors (maximum water holding capacity, bulk density, porosity) were significantly ($p \leq 0.05$) better in some land uses, as shown in the hierarchy of natural forest > fallow land >Banana orchard >Papaya orchard. A monoculture of Tectona grandis plantation was found significantly ($p \leq 0.05$) poor in topsoil conditions. In all cases, mostly used soil showed less tendency toward sustainable production although higher nutrient availability can be found in those soils (such as application of inorganic fertilizer) but the presence of the lower amount of organic deposits implies that there is a lack of natural source of nutrients in the long run. This research can benefit both policymakers and practitioners to implement sustainable land use practices in Bandarban and the Hill Tracts of Bangladesh.

Key Words: *Chittagong Hill Tracts, Land use, Soil physical properties, Soil chemical properties, Nitrogen and Organic carbon.*

Cite Article: Mamun, M. M. A. A., Emon, S. B. T. A. and Alam, M. S. (2021). Soil properties under eight different land uses in Bandarban hill district of Bangladesh. International Journal of Forestry, Ecology and Environment, 05(01), 202-214.
Crossref: https://doi.org/10.18801/ijfee.050121.23

I. Introduction

The complex integration of the primary natural resources such as soil, water and vegetation are vital for maintaining terrestrial ecosystem functions and productivity. Destruction of agricultural land and increase poverty causes careless misuse of natural resources in developing countries of the world

EISSN: 2708-5430,

(Mahtab and Karim, 1992). Particularly, forests in tropical areas are transformed at a very high rate to other types of land uses such as agriculture or settlement due to the growing demand for various daily necessaries such as fuelwood, food, timber, etc. (Johansson et al. 1993). In recent times, practitioners became more interested in finding out the soil properties of particular land use for better land management, enhancing sustainable benefits from a specific ecosystem such as forest (Alam, 2008). The choice of a standard set of properties as indicators of soil quality can be complex and will vary among forest systems and management objectives (Belsky et al., 1989). Alam (2008) states that all types of soil properties such as physical, chemical and biological of forest are closely related to the management aspects. In addition, soil properties of a forest largely depend on many aspects such as altitude, available water, state of temperature, etc. (Huq and Shoaib, 2013). For example, soil compaction increases soil strength, affected not only by many factors including soil structure, soil water content, soil texture, and cementing agents (Mirreh and Ketcheson, 1972; Chanasyk and Naeth, 1998) but also by management variables including trampling intensity (Bryant et al., 1972), the season of use (Chanasyk and Naeth, 1995) and grazing regime (Donkor et al., 2002).

Land use is one of the main factors that impact physical, chemical and biological processes of soils (García-Oliva et al., 1994), leading to losses in soil organic carbon and nutrients, amount of groundwater reduction, changes in soil structure and less amount of biological elements. Changes in the structure of microbial communities, which is one of the principal factors of ecosystem productivity, may lead to changes in important functions such as organic matter decomposition and pollutant degradation (Macalady et al., 1998). With a rapid increase in population and limited land resources, Bangladesh faces acute land problems for food production and settlement, which instigate to convert the hills and forest lands into agriculture, horticulture, and many other uses (Hassan, 1994). Particularly in Chittagong Hill Tracts (CHTs), due to various practices such as jhum (shifting) cultivation, the soil degraded considerably (Biswas et al., 2012). Most of the studies in the CHTs considered the soil properties of forested sites (Hossain et al., 2014) rather than different land uses. However, both agricultural lands and natural forests are being rapidly depleted. So, it is high time for planners and policymakers to frame rules/laws to protect arable soils from ruination based on soil properties. Therefore, the objectives of this study are to determine the physical and chemical characteristics of soil from eight different land uses in the Bandarban hill district and to discuss the effects of land uses on soil properties.

II. Materials and Methods

The study was based on primary data obtained by physical and chemical analysis of soil samples collected from Ruma Upazila (an administrative unit under the district administration in Bangladesh) of Bandarban district in Bangladesh. Besides, some valuable information on previous studies has also been presented from secondary sources.

Description of the study area

Bandarban, one of the important districts in the Chittagong Hill Tracts, has seven Upazilas (BBS, 2011). The district is located in between 21°11' N and 22°22' N latitudes and 92°04' E 92°41' E longitudes. The total area covered by the district is 4,479 $km^{2,}$ of which 2653.54 km^2 is under forest (Banglapedia, 2015). The area lies 26m above sea level, has significant rainfall in most of the months, with a short dry season. The Köppen-Geiger climate classification is Am (Tropical monsoon). The average temperature in the region is 25.9 °C and about 2528 mm of precipitation falls annually (Climate-data.Org, n.d.). The area falls under the tropical evergreen and semi-evergreen bio-geographic zone. The area is characterized by steep to very steep hill ranges with a good amount of mineral contents in the sedimentary rocks at the bottom of the hill. By the weathering process, soils are developed from these mineral contents (Alam, 2008).

Description of selected eight land uses

Many land uses were practiced in this hilly region. Eight land uses were selected to determine the variation in soil properties and other features.

Jhum land (Since 2015): The sample site of Jhum (shifting cultivation) land is situated on the West of Turmeric cultivated area. The soil was hardened due to the loss of moisture. It enjoys adequate

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sunlight. The soil with a pH of 6.07 was whitish to light yellowish. The site was moderately well-drained to well-drained with severe to very severe erosion hazards, friable consistency and severe aridity in the dry season (November to February). However, soil erosion was occurred unevenly at varied rates depending on the downward sloping features of the site.

Turmeric cultivated area: This area is on the lower end of the hill. The area enjoys partial shade all the round. The soil with a pH of 6.23 was blackish-brown to yellowish-brown. There is severe to severe erosion hazard, friable consistency, and severe aridity in the dry season. However, during the field study, soil erosion was found uneven. No undergrowth was observed on the site.

Papaya orchard (2-years-old): Selling papaya to the local market is an important source of revenue for the locals. Fresh, partially and entirely degraded leaf litter coated the orchard. The soil was reddish-brown to yellowish-brown. The site was well-drained with pH 6.17. There exist severe to very severe erosion hazards, friable consistency, and severe water scarcity in the dry months (November to February). However, during the reconnaissance field visit, soil erosion was found uneven. Grassy undergrowth was observed on the site.

Tectona grandis (Teak) plantation (9-years-old): *Tectona grandis* was planted in a moderately sloping plot of 3m×3m spacing. Surface soil in this garden was covered by fresh, partially decomposed leaf litter. The soil with a pH of 5.73 was dark brown to dark yellowish-brown. The site was moderately well-drained to well-drained with severe to very severe erosion hazard, friable consistency, and severe water scarcity in the dry season. However, soil erosion was occurred unevenly at varied rates depending on the downward sloping features of the site. No undergrowth was observed in the area.

Banana orchard: Selling banana to the local market is another important source of income for local folks. The orchard was covered by fresh, partially and completely decomposed leaf litter. Soil erosion was found least in this site with moist and humid conditions. The soil with a pH of 5.87 was dark brown to dark yellowish-brown. The place was moderately well-drained to well-drained.

Orange orchard (Since 2010): Orange was not found to be abundant in the hills. There were only a few Orange orchards in the area. The soil with a pH of 6.07 was dark brown to dark yellowish-brown. The site was moderately well-drained to well-drained with severe to very severe erosion hazards, friable consistency, and severe water scarcity in the dry season. However, soil erosion was occurred unevenly at varied rates depending on the downward sloping features of the site. Bushy undergrowth was observed in the area.

Natural forest: There was declared or officially recognized Village Common Forest (VCF) in the study location however, the local people managed a patch of woods. They can cut trees only with permission from the head of the tribe. Their drinking water source- a permanent spring is in the area. The forest was covered by fresh, partially, and completely decomposed leaf litter and was well-drained. The soil with a pH of 6.17 was blackish-brown to reddish-brown. Severe to very severe erosion hazards, friable consistency, and severe water scarcity in the dry season exist. Soil erosion occurred unevenly at varied rates was found. Undergrowth vegetation was observed with many herbs, shrubs, and climbers.

Fallow land (Since 2015): Jhum was previously practiced in the area and kept the land fallow for five years. A small number of saplings of neighbouring tree species were found in the area. Paddy was grown on the hill slope without disturbances like levelling of land, cutting of earth, etc. The soil was yellowish-brown to dark yellowish-brown with a pH of 5.53. This site was moderately well-drained to well-drained. Severe erosion hazards, firm consistency, and severe water scarcity were experienced in the dry season and heavy moistness during the rainy season. There was bushy undergrowth in the area.

Site selection and sample collection

After a vigorous reconnaissance survey, convenience sampling was used to select the sample plots (Figure 01). Three samples were considered from each land use type (total 24 samples) for the laboratory analysis. Samples were collected in tagged, double-layered sample collection bags. Before bagging, straw, root, seed, leaf, or other unwanted materials were handpicked and gotten rid of.

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Sample preparation

Samples were first sieved through a 10 mm mesh sieve to remove gravel, coarse roots, small stones and other unwanted materials. Then they were sieved through a 2 mm mesh sieve and dried at room temperature. Finally, the samples were oven-dried for 24 hours at 105^{0}C (O'Kelly, 2005). Some dry samples were used for determining pH and oven-dry samples to determine other parameters.

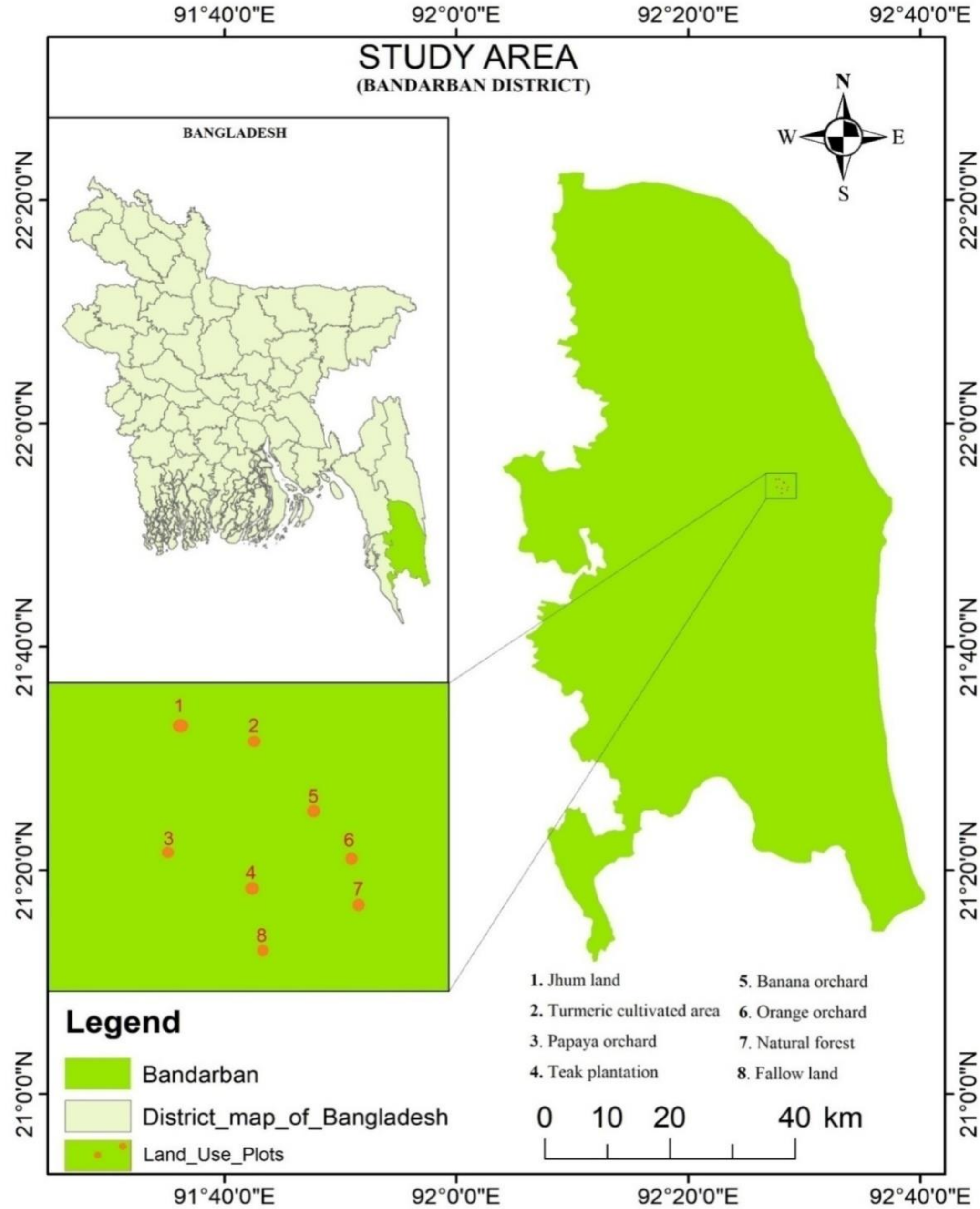

Figure 01. Study area map indicating sampling locations

Determination of physical properties of soil

The core samples were collected for determining the maximum water holding capacity, bulk density and porosity. At first, field moist soil cores were accurately weighed, and then they were allowed to saturate with water by diving two-thirds of the cores in a tray. When a thin film of water developed on the upper surface of the cores, they were withdrawn from water and weighed. The cores were then allowed to drain water on a tray filled with sand for 24 hours and then reweighed. The cores were then dried in an oven at 105^{0}C for 8 hours, cooled in desiccators and weighed. From these values, field moist and oven-dry weight of the soils in the scores were calculated and dividing separately by the core volumes (100 cm3), dry bulk density was determined. Soil color was determined with the help of the Munsell Soil Color Chart (Sanchez-Maranon, 2005). The texture was determined by hand feeling. Soil structure was determined immediately after digging the soil on the field.

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Maximum water holding capacity (%)	$= \frac{W_3 - W_4}{W_4 - W_1} \times 100$	
Bulk density (g cm^{-3})	$= \frac{W_4 - W_1}{V} \times 100$	
Porosity (%)	$= (1 - \frac{\text{Bulk density}}{\text{Particle density}}) \times 100$	Where,
Water (%);	$= \frac{W_2 - W_1}{W_4 - W_1} \times 100$	W_1 = Weight of core, W_2 = Weight of core + Field moist soil, W_3 = Weight of core + Saturated soil,
Air (%)	= Porosity (%) – Water (%)	W_4 = Weight of core + Dry soil and
Solids (%)	= 100 – [Water (%) + Air (%)]	V = Volume of core
Particle density (gcm^{-3})	= weight of soil sample/ volume of soil sample	

Determination of chemical properties

The pH of the suspension was measured with a digital pH meter (TOA, Japan). The filtered water was then measured with a digital conductivity meter (TOA, Japan). Before taking the conductivity reading of filtered water, the meter was standardized. Percentage of carbon and organic matter was calculated from the following relationship % C = 0.476 X (% LOI – 1.87). Nitrogen was determined by the micro-Kjeldahl digestion process (Jackson, 1973). Available Phosphorous was extracted by ammonium fluoride-hydrochloric acid and measured by Bray and Kurtz (1945). Available Potassium was determined from the extraction with 1N NH_4O Ac using a flame photometer. Available Ca and Mg were extracted with1N NH_4OAc and determined by atomic absorption spectroscopy (AAS). Sulfur was measured according to Johnson and Nishita (1952).

Statistical analysis

Data were analyzed using IBM SPSS version 24.0 for Window (Li et al., 2004). One way analysis of variance (ANOVA) was done to compare the differences among the land uses (Sokal and Rohlf, 1995). Duncan Multiple Range Test (DMRT) was performed to determine whether treatment means were significantly different at $p \leq 0.05$ (Su and Zhao, 2003).

III. Results and Discussion

Physical properties of soil

Maximum water holding capacity: The water holding capacity of soil indicates the number of pore spaces in the soil and the channeling of water through the pores. The maximum water holding capacity showed significant ($p \leq 0.05$) differences between different land uses (Table 01). The maximum water holding capacity was highest in natural forests and lowest in *Tectona grandis* plantation. Banana and Orange gardens also showed significantly higher values. Papaya, Turmeric and Jhum land followed *Tectona grandis* plantation in the hierarchy. It is as follows:
Tectona grandis<Papaya<Turmeric<Jhum<Fallow <Orange<Banana<Natural

Chowdhury et al. (2007) found higher water holding capacity in the forest than orange orchards in the Chittagong Hill Tracts. The higher maximum water holding capacity of the natural forest may occur due to higher organic matter and effective weathering of parent materials by micro-organisms. On the other hand, the lower maximum water holding capacity of *Tectona grandis* plantation or in the orchard may be due to a lack of forest floor vegetation and excessive erosion.

Bulk density: The bulk density of soil under different land uses was highly significant ($p \leq 0.05$) (Table 01). Bulk density was highest in *Tectona grandis* plantation and lowest in natural forest. Fallow land and Turmeric cultivation area also showed significantly higher values. Jhum land, Papaya and Orange garden followed *Tectona grandis* plantation in the hierarchy. It is as follows:
Natural< Fallow <Turmeric<Banana<Papaya<Orange<Jhum<*Tectona grandis*

Highly erosion-prone deforested areas significantly increased bulk density, increased surface soil compaction and reduced the water holding capacity and porosity. Due to a lack of adequate aeration

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and resistance to root penetration in the subsurface horizons, porosity decreased. Severe erosion, trampling by grazing animals and use of agricultural tools are the primary reason for high bulk density in Jhum land and *Tectona grandis* plantation. This trend was also found by many other researchers (Mongya and Bandyopadhyay, 1994; Singh et al., 1989). Higher organic matter in the natural forest may be the reason for low bulk density (Rolfe and Boggess, 1973).

Particle density: The soil particle density under different land uses was highly significant ($p \leq 0.05$) (Table 01). Maximum particle density was highest in natural forests and lowest in fallow land. Turmeric cultivation, banana and papaya orchard also showed significantly higher values. Orange garden, *Tectona grandis* plantation and jhum land were followed by fallow land in the hierarchy. It is as follows:
Fallow <Orange<*Tectona grandis*<Jhum<Papaya<Banana<Turmeric<Natural

This trend is supported by Alam (2008). A higher value was found by Mongya and Bandopadhyay (1994) as they conducted a study on a large number of diverse samples. The main reason may be the fineness of the particles in the more weathered soil rather than in the less weathered and eroded soil.

Table 01. Maximum water holding capacity (MWHC %), bulk density (gcm^{-3}) and particle density ($g\ cm^{-3}$) of soils collected from different land uses

Land use	MWHC (%)	Bulk density ($g\ cm^{-3}$)	Particle density ($g\ cm^{-3}$)
Jhum	30.12 a (0.90)	1.22 b (0.01)	2.33 c (0.02)
Tectona grandis	27.37 a (0.53)	1.23 c (0.06)	2.24 b (0.02)
Papaya	29.23 a (0.75)	1.19 b (0.01)	2.48 d (0.02)
Fallow	32.09 a (1.33)	1.14 a (0.01)	1.88 a (0.02)
Turmeric	30.06 a (1.39)	1.17 a (0.00)	2.68 e (0.03)
Orange	34.78 b (2.54)	1.19 b (0.01)	2.19 b (0.03)
Banana	35.95 c (1.88)	1.18 b (0.01)	2.55 d (0.01)
Natural	37.14 c (1.18)	1.09 a (0.01)	2.92 f (0.02)

Each value represents the mean of three replications. Values in the same column by different letters (a-e) indicate significant ($p \leq 0.05$) difference. Numbers in the parentheses are standard errors of mean.

Porosity: Soil porosity under different land uses in Bandarban is presented in Table 02. There were highly significant ($p \leq 0.05$) differences in the porosity of the soil in most of the land uses. Maximum porosity was highest in natural forests and lowest in fallow land. Turmeric cultivation, banana and papaya orchard also showed significantly higher values. *Tectona grandis* plantation, orange garden and jhum land were followed by fallow land in the hierarchy. It is as follows:
Fallow <*Tectona grandis*<Orange<Jhum<Papaya<Banana<Turmeric<Natural.

Soils of fallow land and *Tectona grandis* plantation showed low porosity because of compactness due to grazing and erosion. This finding is supported by other researchers (Mongya and Bandyopadhyay, 1994; Singh et al., 1989).

Water: The difference in volume distribution of water in soil was highly significant ($p \leq 0.05$) at most land uses (Table 02). Water was highest in natural forests and lowest in fallow land. *Tectona grandis* plantation, jhum land and turmeric cultivation area also showed significantly higher values. Papaya orchard, banana orchard and orange orchard were followed by fallow land in the hierarchy. It is as follows:
Fallow <Papaya<Banana<Orange<Turmeric<Jhum<*Tectona grandis* <Natural

Water was higher in the natural forest because of high organic matter and finer particles in the soils. On the other hand, fallow land may be managed too extensively previously to have less water. The result is supported by Alam (2008) and Singh et al. (1989).

Air: The difference in air volume distribution in soil was highly significant ($p \leq 0.05$) at most land uses (Table 02). Air was highest in papaya orchards and lowest in *Tectona grandis* plantation. Natural forest, turmeric cultivation area and banana orchard also showed significantly higher values. Fallow land, jhum land and orange orchard were followed by *Tectona grandis* plantation in the hierarchy. It is as follows:
Tectona grandis<Orange<Jhum< Fallow <Banana<Turmeric<Natural<Papaya

The air was higher in the papaya garden maybe because of more micro-organism activity in the soil. The parent material and the root system of papaya also play a vital role. On the other hand, *Tectona grandis* plantation may have fewer pores and microbial activity to hold air. Similarly, Alam (2008) and Singh et al. (1989) found a similar conclusion.

Table 02. Porosity (%), water (%) and air (%) of soils collected from different land use

Land use	Porosity (%)	Water (%)	Air (%)
Jhum	47.70 b (0.16)	38.36 c (0.96)	9.34 b (0.83)
Tectona grandis	45.27 b (2.43)	40.35 d (0.49)	4.92 a (2.40)
Papaya	52.01 c (0.21)	30.81 b (0.97)	21.20 d (1.18)
Fallow	39.18 a (0.22)	24.38 a (0.84)	14.80 c (1.05)
Turmeric	56.40 d (0.57)	37.89 d (0.99)	18.51 d (1.56)
Orange	45.73 b (0.76)	37.08 c (0.67)	8.65 a (1.18)
Banana	53.79 c (0.42)	36.02 c (0.63)	17.77 c (0.52)
Natural	62.51 e (0.01)	42.81 e (1.25)	19.70 d (1.24)

Soil color and structure: Soil color and structure of different land uses in the study area are shown in Table 03. The color of most soil ranged from grey to dark brown. The color variation was apparent from one land use to another. The whitish brown color of the jhum land may be the cause of hardened dry topsoil. The reddish-yellow color of the soil in the *Tectona grandis* plantation may be caused by a lack of ground vegetation. Heavy erosion may be another fact for this. The solid brown color of natural forest soil may be due to partially decomposed leafy and non-leafy litters and micro-organisms in the soil. Soil structure also indicates the health of the soil. Soil with high organic matter tends to aggregate and low organic matter soils are loose. The soil in the region is mostly granular. The type of soil structure also indicates the level and intensity of weathering to the soil.

Table 03. Structure and color of soils collected from different land uses

Land use	Soil structure	Soil color		Soil condition
		Value	Description	
Jhum	Platy	10 YR 8/2	Whitish brown	Moist
Turmeric	Granular	10 YR 3/3	Dark brown	Moist
Papaya	Granular	10 YR 4/5	Dark yellowish brown	Moist
Tectona grandis	Crumb	7.5 YR 7/7	Reddish yellow	Moist
Banana	Sub-angular blocky	10 YR 3/2	Very dark grayish brown	Moist
Orange	Granular	10 YR 4/1	Dark gray	Moist
Natural	Granular	7.5 YR 5/5	Strong brown	Moist
Fallow	Granular	10 YR 4/1	Dark gray	Moist

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Chemical properties of soil

Loss on ignition: The loss on ignition (%) of soil indicates the amount of flamed organic matter in the soil. Loss on ignition (%) showed highly significant ($p \leq 0.05$) differences among different land uses (Table 04). Loss on ignition (%) was highest in natural forest and lowest in *Tectona grandis* plantation. Banana orchards, fallow land and papaya garden also showed significantly higher values. Orange garden, turmeric cultivation area and jhum land were followed by *Tectona grandis* plantation in the hierarchy. It is as follows:

Tectona grandis<Jhum<Turmeric<Orange<Papaya< Fallow <Banana<Natural

These findings correspond mostly to Lal (1989). The higher loss on ignition (%) of the natural forest may occur due to higher organic matter and effective weathering of parent materials by micro-organisms. On the other hand, lower loss on ignition (%) of *Tectona grandis* plantation may be due to a lack of forest floor vegetation and excessive erosion.

Organic Carbon: The organic carbon (%) showed highly significant ($p \leq 0.05$) differences among different land uses (Table 04). Organic carbon (%) was highest in natural forest and lowest in *Tectona grandis* plantation. Banana orchards, fallow land and papaya garden also showed significantly higher values. Orange garden, turmeric cultivation area and jhum land were followed by *Tectona grandis* plantation in the hierarchy. It is as follows:

Tectona grandis<Jhum<Turmeric<Orange<Papaya< Fallow <Banana<Natural

The higher organic carbon (%) of the natural forest may occur due to higher organic matter and effective weathering of parent materials by micro-organisms. On the other hand, lower organic carbon (%) of *Tectona grandis* plantation may be due to a lack of forest floor vegetation and excessive erosion. Similar findings have been concluded by Biswas et al. (2012) where they found more organic carbon (%) in forest sites than shifting cultivated land in the Chittagong Hill Tracts.

Table 04. The loss on ignition (%) and organic carbon (%) of soils collected from different land uses

Land use	LOI (%)	OC (%)
Jhum	6.55 a (0.22)	2.23 a (0.11)
Tectona grandis	6.11 a (0.11)	2.02 a (0.05)
Papaya	8.11 b (0.11)	2.97 b (0.05)
Fallow	9.22 c (0.22)	3.50 c (0.11)
Turmeric	6.78 d (0.11)	2.33 d (0.05)
Orange	7.33 e (0.19)	2.60 e (0.09)
Banana	10.67 f (0.19)	4.19 f (0.09)
Natural	11.22 g (0.11)	4.45 g (0.05)

Soil pH (1:2 water): Soil pH showed highly significant ($p \leq 0.05$) differences among different land uses (Table 05). Soil pH was highest in banana orchards and lowest in *Tectona grandis* plantation. Orange gardens, fallow land and natural forests also showed significantly higher values. Turmeric cultivation area, papaya garden and jhum land were followed by *Tectona grandis* plantation in the hierarchy. It is as follows:

Tectona grandis<Jhum<Papaya<Turmeric<Natural< Fallow <Orange<Banana

The study shows classic data on the hilly soil of Bangladesh. This trend has coincided with Singh et al. (1989). Besides, Osman et al. (2013) found higher pH in slashed areas of Bandarban.

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Electrical conductivity: The electrical conductivity of soil indicates the capacity of soil to regulate different salt ions needed for the growth and development of the plant. Electrical conductivity showed significant ($p \leq 0.05$) differences among different land uses (Table 05). Electrical conductivity was highest in the turmeric cultivation area and lowest in jhum land. Orange garden, papaya garden and *Tectona grandis* plantation also showed higher values. Banana orchard, fallow land and natural forest were followed by jhum land in the hierarchy. It is as follows:
Jhum<Natural< Fallow <Banana<*Tectona grandis*<Papaya<Orange<Turmeric

The value of electrical conductivity is not significant as there is a scarce source of salt minerals in the hilly region.

Table 05. The pH and electrical conductivity (µS/cm) of soils collected from different land uses

Land use	pH	EC (µS/cm)
Jhum	5.07 b (0.03)	62.00 a (1.53)
Tectona grandis	4.67 a (0.03)	103.67 c (4.41)
Papaya	5.17 b (0.03)	124.00 d (2.65)
Fallow	5.53 d (0.03)	90.67 b (2.73)
Turmeric	5.23 c (0.03)	172.00 e (4.58)
Orange	5.83 e (0.09)	130.67 d (2.96)
Banana	5.87 e (0.03)	91.00 b (2.08)
Natural	5.30 c (0.06)	88.67 b (1.86)

Total Nitrogen (N): The total N (%) did not show significant ($p \leq 0.05$) differences among different land uses (Table 06). Total N (%) was highest in fallow land and lowest in jhum land. *Tectona grandis* plantation, turmeric cultivation area and orange garden also showed high values. Natural forest, banana orchard and papaya orchard were followed by jhum land in the hierarchy. It is as follows:
Jhum<Papaya<Banana<Natural<Orange<Turmeric<*Tectona grandis*<Fallow

Nitrogen is one of the basic components to get sufficient production. Erosion can remove nitrogen-rich soil in steep hilly areas. These findings correspond mostly with Alam (2008) and Lal (1989). However, Osman et al. (2013) found significant N differences between jhum land and forest sites.

C/N ratio: The C/N ratio showed significant ($p \leq 0.05$) differences between different land uses (Table 06). The C/N ratio was highest in natural forests and lowest in *Tectona grandis* plantation. Banana orchards, fallow land and papaya garden also showed significantly higher values. Orange garden, turmeric cultivation area and jhum land were followed by *Tectona grandis* plantation in the hierarchy. It is as follows:
Tectona grandis<Jhum<Turmeric<Orange<Papaya< Fallow <Banana<Natural

The C/N ratio gives a valuable indication of the degree of decomposition of organic matter in soils. Well decomposed humus in soils of temperate regions has a C/N ratio of around 10, whereas less decomposed organic layers give values ranging up to 50 (Avery, 1990). C/N ratios of about 8-13 indicate that organic matter is undergoing relatively rapid humification, while high C/N ratios of 15-25 indicate the decomposition rate is much slower (Heslop and Bown, 1969). C/N ratios in the present study represent medium litter decomposition. The higher value of the C/N ratio for the natural forest is reasonable, as plant residues in the natural forest soils are rich in carbon content and comparatively poor in total N.

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Table 06. The total N (%) and C/N ratio of soils collected from different land uses

Land use	Total N (%)	C/N ratio
Jhum	0.090 a (0.006)	25.13 b (2.78)
Tectona grandis	0.100 a (0.006)	20.38 a (1.69)
Papaya	0.093 a (0.003)	31.93 c (1.47)
Fallow	0.100 a (0.006)	35.34 c (3.08)
Turmeric	0.100 a (0.006)	23.51 a (1.41)
Orange	0.097 a (0.009)	27.56 b (3.63)
Banana	0.093 a (0.007)	45.23 d (2.60)
Natural	0.093 a (0.003)	47.79 d (1.47)

Phosphorus (P): The Phosphorus ($mg.kg^{-1}$) showed highly significant ($p \leq 0.05$) differences among different land use (Table 07). Phosphorus ($mg.kg^{-1}$) was highest in natural forests and lowest in fallow land. Orange garden, jhum land and papaya garden also showed significantly higher values. Turmeric cultivation area, banana orchard and *Tectona grandis* plantation were followed by fallow land in the hierarchy. It is as follows:
Fallow <*Tectona grandis*<Banana<Turmeric<Papaya<Jhum<Orange<Natural

These findings correspond mostly with Biswas et al. (2012), where they found more available Phosphorus in forest sites in the Chittagong Hill Tracts. The higher Phosphorus ($mg.kg^{-1}$) of the natural forest may occur due to the presence of fully and partially decomposed ground litter and effective weathering of parent materials by micro-organisms. High values on the orange and jhum land may indicate the application of inorganic fertilizers. On the other hand, lower Phosphorus ($mg.kg^{-1}$) of fallow land may be due to a lack of organic Phosphorus minerals and excessive erosion.

Table 07. Phosphorus ($mg.kg^{-1}$) and Potassium ($cmol(+).kg^{-1}soil$) of soils collected from different land uses

Land use	Phosphorus ($mg.kg^{-1}$)	Potassium ($cmol(+).kg^{-1}$ soil)
Jhum	8.67 b (2.19)	0.26 a (0.03)
Tectona grandis	4.00 a (1.15)	0.24 a (0.01)
Papaya	8.00 b (5.00)	0.63 d (0.01)
Fallow	1.00a (0.00)	0.26 a (0.00)
Turmeric	7.00 a (1.00)	0.72 e (0.03)
Orange	8.67 b (0.33)	0.59 d (0.03)
Banana	5.00 b (0.58)	0.46 c (0.04)
Natural	13.67 c (0.33)	0.38 b (0.01)

Potassium (K): The Potassium (cmol(+).kg-1soil) showed highly significant ($p \leq 0.05$) differences among different land uses (**Table 07**). Potassium was highest in the turmeric cultivation area and lowest in *Tectona grandis* plantation. Papaya garden, orange garden and banana orchard also showed significantly higher values. Natural forest, fallow land and jhum land were followed by *Tectona grandis* plantation in the hierarchy. It is as follows:

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Tectona grandis<Jhum<Fallow <Natural<Banana<Orange<Papaya<Turmeric

Biswas et al. (2012) found more Potassium in bushy lands and forest sites than shifting cultivated land in Chittagong Hill Tracts. The higher Potassium of the turmeric cultivation area may due to the application of inorganic fertilizers. High values on the orange and papaya may also indicate the same as these are horticultural practices. On the other hand, lower potassium (cmol(+).kg^{-1}soil) of *Tectona grandis* plantation may be due to a lack of organic potassium minerals and excessive erosion.

Calcium (Ca): The Calcium (cmol(+).kg^{-1}soil) did not show significant ($p \leq 0.05$) differences among different land uses (Table 08). Calcium (cmol(+).kg^{-1}soil) was highest in *Tectona grandis* plantation and lowest in the turmeric cultivation area. Orange gardens, natural forests and jhum land also showed higher values. The turmeric cultivation area followed fallow land, papaya garden and banana orchard in the hierarchy. It is as follows:
Turmeric<Banana<Papaya< Fallow <Jhum<Natural<Orange<*Tectona grandis*.

Biswas et al. (2012) researched the Chittagong Hill Tracts, where they found more Calcium in bushy lands and forest sites.

Magnesium (Mg): The Magnesium (cmol(+).kg^{-1}soil) did not show significant ($p \leq 0.05$) differences among different land uses (Table 08). Magnesium (cmol(+).kg^{-1} soil) was highest in *Tectona grandis* plantation and lowest in jhum land. Orange garden, turmeric cultivation area and banana orchard also showed higher values. Fallow land, natural forest and papaya garden were followed by in hierarchy. It is as follows:
Jhum<Papaya<Natural< Fallow <Banana<Turmeric<Orange<*Tectona grandis*

Similarly, other researchers drew the same conclusion (Alam, 2008 and Lal, 1989). Osman et al. (2013) studied the impacts of shifting cultivation on different soil properties and found significant differences in Mg between jhum land and forest sites.

Sulfur (S): The Sulfur (mg.kg^{-1}) showed significant ($p \leq 0.05$) differences among different land uses and the turmeric cultivation area (Table 08). It is evident that Sulfur (mg.kg^{-1}) was highest in the turmeric cultivation area and lowest in the banana orchard. Papaya garden, jhum land and *Tectona grandis* plantation showed higher values. Fallow land, natural forest and orange garden were followed by banana orchards in the hierarchy. It is as follows:
Banana<Orange<Natural<Fallow <*Tectona grandis*<Jhum<Papaya<Turmeric

These findings correspond mostly to Lal (1989). The recent application of Sulfate may be the reason for a high amount in the Turmeric cultivation area.

Table 08. The Calcium (cmol(+).kg^{-1} soil), Magnesium (cmol(+).kg^{-1} soil), and Sulfur (mg.kg^{-1}) of soils collected from different land uses

Land use	Calcium (cmol(+).kg^{-1} soil)	Magnesium (cmol(+).kg^{-1} soil)	Sulfur (mg.kg^{-1})
Jhum	3.80 a (0.33)	0.47 a (0.09)	4.67 b (0.67)
Tectona grandis	4.66 a (1.11)	0.85 a (0.09)	4.33 b (0.67)
Papaya	2.97 a (0.81)	0.47 a (0.10)	5.33 b (0.88)
Fallow	3.05 a (0.38)	0.53 a (0.06)	3.67 (1.20)
Turmeric	2.69 a (0.16)	0.78 a (0.16)	6.67 b (0.88)
Orange	4.37 a (0.32)	0.83 a (0.28)	3.67 a (0.67)
Banana	2.70 a (0.87)	0.60 a (0.09)	3.33 a (0.88)
Natural	4.20 a (0.64)	0.53 a (0.21)	3.67 a (0.67)

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IV. Conclusion

The land use of the Bandarban hill district is diverse and the soil properties are varied widely. Due to disturbance by human activities, the forest and floor cover are now declining. Intensive soil working for farming practices plays a vital role in topsoil erosion. Subsequently, the nutrient quality has been declined. The result found in this research concludes that the natural forest holds the upper hand in all the criteria of soil health. On the other hand, the more disturbed the soil is, the less they can support healthy vegetation. In most cases, erosion prone land use such as jhum cultivated land or *Tectona grandis* land use showed poor soil characteristics. Some agricultural plots showed higher values of nutrients in the present context, but the externally applied inorganic fertilizers in the field will leach or erode in the long run. An interesting question can be arising here for further investigation that how much nutrients are leached or washed out from these plots and what amount of soil are eroded due to various land use practices?

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HOW TO CITE THIS ARTICLE?

MLA
Mamun, M. M. A. A. et al., “Soil properties under eight different land uses in Bandarban hill district of Bangladesh”. International Journal of Forestry, Ecology and Environment, 05(01) (2021): 202-214.

APA
Mamun, M. M. A. A., Emon, S. B. T. A. and Alam, M. S. (2021). Soil properties under eight different land uses in Bandarban hill district of Bangladesh. *International Journal of Forestry, Ecology and Environment*, 05(01), 202-214.

Chicago
Mamun, M. M. A. A., Emon, S. B. T. A. and Alam, M. S. “Soil properties under eight different land uses in Bandarban hill district of Bangladesh”. International Journal of Forestry, Ecology and Environment, 05(01) (2021): 202-214.

Harvard
Mamun, M. M. A. A., Emon, S. B. T. A. and Alam, M. S. 2021. Soil properties under eight different land uses in Bandarban hill district of Bangladesh. International Journal of Forestry, Ecology and Environment, 05(01), pp. 202-214.

Vancouver
Mamun, MMAA, Emon, SBTA and Alam, MS. Soil properties under eight different land uses in Bandarban hill district of Bangladesh. International Journal of Forestry, Ecology and Environment, 2021 September 05(01): 202-214.

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EISSN: 2708-5430,