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SOIL PROPERTIES AND CARBON STOCK ALONG THE TOPOSEQUENCE OF LALMAI HILL ECOSYSTEM OF BANGLADESH

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Key words: Lalmai hill ecosystem, Toposequence, Soil properties, Carbon stock

Abstract

A study was carried out in the Lalmai hill ecosystem of Bangladesh regarding their soil properties and soil organic carbon (SOC) stocks. The Lalmai hill ecosystem consists of three toposequence arrangements as hills, piedmonts, and floodplains. Forty-five soil samples covering nine soil profiles were selected to conduct the present study. Soil samples were collected at five different depths of 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm and 80-100 cm intervals from each pit of the study sites. Soil pH, percent SOC, percent total nitrogen (TN), bulk density, cation exchange capacity (CEC), particle size distribution, and SOC storage (kg/m^2) dataset indicates that piedmont deposits and floodplain soils are more enriched than the upper hill soils. Regarding SOC storage, the post hoc test indicates that hill soils are significantly different from the other two physiographic units, but there is no significant difference between piedmont deposits and floodplain soils. The soil property varies differently depending on their depth level at different physiographic units. Estimation on SOC stock revealed that 2.01Tg, 21.75Tg, 12.68Tg carbon remains in the hill soils, piedmont soils, and estuarine floodplain soils, respectively. The total SOC stock was estimated at 36.44 Tg in the Lalmai hill ecosystem of Bangladesh, where piedmont deposits contained the highest level of SOC stock. It is assumed that more clay-organic substances are washed in at the foot of piedmont units due to the well-drained nature of upper Pleistocene hill soils. Thus, fine soil textural nature, diverse land and land cover accelerates to sequester more carbon in piedmont zone rather than hill or floodplain zones.

Introduction

Topography is an important driver of the biogeochemical cycling of essential elements in sloping landscapes and is highly important to SOC stocks[1,2]. With the variations in hydrological parameters and other biophysical variables, sloping transects cause differences in soil morphology, genesis, and nature of vegetation[3] and the spatial variability of SOC and their dynamics [4]. In most sloping landscapes with visible erosion

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and deposition, soils in foot slopes or valleys were usually enriched in SOC, and carbon accumulation in these topographically lower areas was mainly induced by carbon redistribution[5,6], and higher carbon input from vegetation[7]. SOC is largely concentrated at the top 30 cm of the surface layer. Still, there is growing evidence that deeper soil horizons can sequester high amounts of SOC[8], which is considered for SOC storage analysis. The role of SOC sequestration in sub-soils in mitigating the greenhouse effect and thus subsoil SOC becomes fairly stable and highly recalcitrant forms to biodegradation[9]. Other soil properties like soil pH govern C: N ratio by regulating microbial activities and where higher pH value has a negative effect probably because of accelerated decomposition of SOC[10]. Soil textural class accelerates the biomass productivity via water availability and soil fertility[11], where the clay protects SOC from decomposition [12] by adsorption and aggregation, slowing turnover and effectively increasing SOC[2].

It is reported that higher SOC and TN are found in finer textured soils, and clay content has been recognized as a key factor controlling soil C and N dynamics[13]. The present study area received very diverse and complex geomorphology where three major topographic units, e.g., Dupi Tila hills, piedmonts and floodplains prevail. There are very few studies on the soil properties and carbon stock in the Lalmai hill ecosystem of Bangladesh. Understanding SOC stocks in a topographic gradient is very vital for assessing land quality and its management. The study aimed at estimating SOC stocks within one meter depth in relation to toposequence of the landscape and some other soil properties. This study might help provide diverse datasets regarding Dupi Tila hills, piedmont deposits and even floodplains to understand the factors on SOC stocks at different depth levels.

Materials and Methods

The Lalmai hills lie between 23°20' to 23°30' North latitude and 91°05' E to 91°10' East longitudes. This area is bordered on the east by the Tripura hills of India, particularly the Raghunandan hill; on the west by the Meghna River; on the north by the Gumti River; and on the south-southeast by the Dakatia River[14]. The land use and the land cover are very diverse in the study sites. It was reported[15] the predominant flora species include Sal (Shorea robusta), Jackfruit (Artocarpus heterophyllus), Taal (Borassus flabellifer), and Kadam tree (Neolamarckia cadamba), etc. On the other hand, a variety of shrubs and herbs were also reported, *viz.* Bhant (Clerodendrum viscosum), Assam lata (Mikania scandens), Sothi (Curcuma zeodaria), Motkila (Glycosmis arborea) etc. The topography of the Lalmai hills consists of hillocks, floodplains, rivers, etc., and are located along with the central arcuate bulge of the westernmost part of the Chittagong-Tripura Fold Belt (CTFB) of the Bengal fore deep[14]. It is reported that CTFB formed due to the still-ongoing collision between the Indian plate and the Burmese plate and exposing the

Miocene to Recent deposits[16,17]. The nature of the parent material is unconsolidated to semi-consolidated clay, silty clay, silt, and sands[14]. Forty-five soil samples covering nine soil profiles (Fig. 1) were selected to conduct the present study. Four soil profiles, e.g., *Lalmai series* (Typic Endoaquepts), *Khadimnagar series* (Typic Endoaquents), *Shalbon series* (Aeric Endoaquepts), and *Kharera soil series* belongs to hill formation. It is reported that the Lalmai series, Khadimnagar series, Shalbon series belongs to Dupi Tila hill formation and whereas Kharera series (Typic Endoaquepts) belongs to Pleistocene piedmont deposits over Dihing formation; *Pritimpasha series* (Aeric Dystrudepts), *Mano series* (Aeric Dystrudepts) and *Chakla series* (Vertic Endoaquepts) belongs to North-eastern piedmont alluvium; *Chandina series* (Typic Dystrudepts/ Typic Endoaquepts) and *Debidwar series* (Typic Dystrudepts) belongs to Meghna estuarine alluvium[18]. During field visit and sampling, Global positioning systems (GPS) was used to identify the geo-coordinates and elevation of the sampling sites (Table 1). Soil drainage and soil textural class was assessed using appropriate field guides. The elevation of the sampling points was also verified from the raster data of the digital elevation model (DEM) using ArcGIS 10.3.

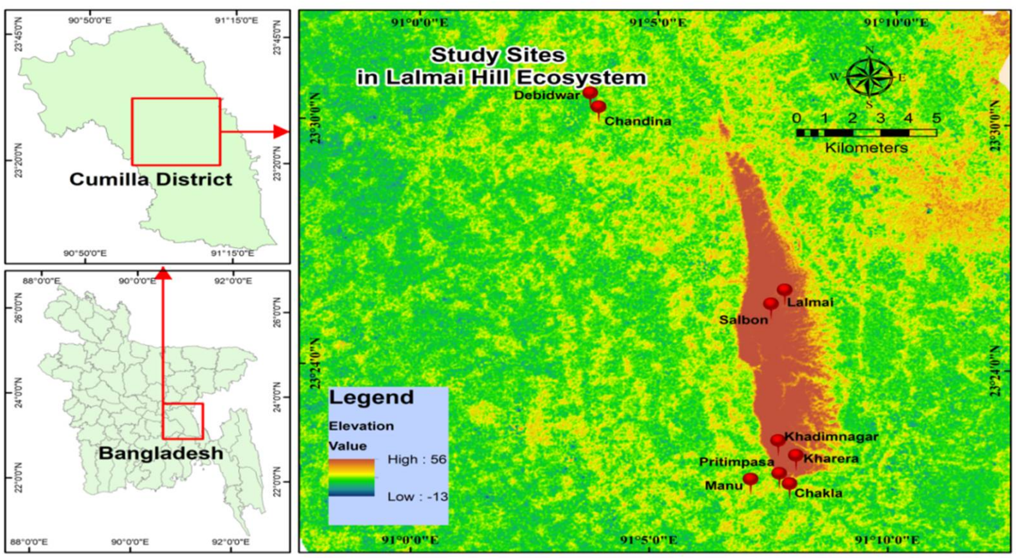

Fig 1. Soil sampling locations in the Lalmai hill ecosystem of Bangladesh.

Soil samples were collected at five different depths of 0-20, 20-40, 40-60, 60-80, and 80-100 cm intervals from each pit of the study sites. Using fixed depth (1 meter) of the soil profile, the sampling was performed in toposequence arrangements. Soil samples from each pit/profile were collected in thick polythene bags. The samples were air-dried, ground, and sieved through 2 mm and 0.5 mm sieve, respectively, and mixed thoroughly. The samples were then preserved in plastic containers for laboratory analysis. Soil pH was determined in soil-water suspension using a precalibrated pH meter[19]. SOC was determined by following the method of Walkley and Black[20] and the Kjeldahl method[21] was used for total soil nitrogen (TSN) determination. The particle size analysis of soils was carried out by the hydrometer method[22]. Soil bulk density was determined by using the core method[23]. The cation exchange capacity of soils was determined by 1N ammonium acetate [24]. It may be noted that the bulk density and SOC concentration (%) are the two prerequisites for estimating SOC stock or storage. SOC storage was calculated using the following equations[9,25,26]. Total soil organic carbon (TSOC) = $SOC_i \times BD_i \times D_i$; Where SOC_i is the SOC content in the i^{th} layer (g/kg soil), BD_i is the bulk density in the i^{th} layer (g/cc), and D_i represents the thickness of the i^{th} layer (cm).

Table 1. Soil series, sampling location, elevation, drainage, and textural conditions of the Lalmai hill ecosystem.

Soil series	Geo-coordinates	Elevation (in m)	Soil drainage and texture
Lalmai	23°25'29.6"North to 91°07'28.4"East	38	Well drained with coarse textured soils
Khadimnagar	23°21'34.8"North to 91°07'40.3"East	34	Well drained with coarse to moderately coarse textured soils
Shalbaon	23°25'50.4"North to 91°07'45.4"East	32	Well drained with moderately coarse textured soils
Kharera	23°21'18.3"North to 91°07'52.6"East	28	Moderately well drained with fine textured formation
Pritimpasha	23°21'21.3" North to 91°07'42.1"East	14	Imperfectly to poorly drained with moderately fine textured soils
Manu	23°21'12.3" North to 91°07'06.3"East	13	Imperfectly to poorly drained with fine textured soils
Chakla	23°21'16.2"North to 91°07'47.5"East	12	Poorly drained with very fine textured soils
Chandina	23°30'16.2"North to 91°03'47.3"East	12	Poorly drained with moderate textured soils
Debidwar	23°30'36.7"North to 91°03'36.4"East	10	Poorly drained with fine textured soils

Results and Discussion

Soil pH: The soil reaction of Dupi Tila hill soils, varied from 4.10 to 5.89 with higher pH in the deeper soil layers. Similar pH values were also reported for the Lalmai and Shalban hill soils[27]. In the piedmont alluvial soils pH varied from 4.10 to 6.81, and in the lower toposequence floodplain soils, soil pH varied from 6.71 to 7.12 (Table 2). There is a sharp synchronous elevated value of pH with the increase in depth (Fig 2). The mean pH values of hills, piedmont alluvium and estuarine floodplain soils were recorded at 5.03, 6.32, and 6.96, respectively. The acidity in hill soils might be developed due to the continuous washing out of base cations as influenced by drainage facilitated along the sloping of the landform[2].

Percent SOC: The percent SOC of Dupi Tila hill soils varied from 0.12 to 1.16, with lower SOC values in the deeper soil layers. Similar SOC values were also reported for the Lalmai and Shalban hill soils[27]. In the piedmont alluvial soils, SOC varied from 0.18 to 3.16, and in the lower toposequence- floodplain soils, SOC varied from 0.21 to 1.39 (Table 2). SOC values decreased with depth (Fig 2) indicating that downward movement of SOC due to the well-drained nature of the soil system. The mean percent SOC values of hills, piedmont alluvium, and estuarine floodplain soils were recorded at 0.26, 1.08, and 0.81 respectively. The organic carbon content in the soils was observed to be distributed with the varying level at different depths showing a consistent decreasing trend with depth. However, a significant portion of organic carbon content was found at the top 20 cm of surface soils. It is assumed that hill soils are covered by natural mixed forests where the litter inputs supply SOC and are thus concentrated in the surface layer. The relatively higher carbon content in piedmont soils than hilly regions could be explained in terms of carbon loss through water erosion and run-off and subsequently accumulated in those soils.

Percent total nitrogen: The percent total nitrogen of Dupi Tila hill soils varied from 0.01 to 0.08, which denotes very low total nitrogen contents. Similar total nitrogen values were also reported for the Lalmai and Shalban hill soils[27]. In the piedmont alluvial soils, percent nitrogen varied from 0.04 to 0.22, and in the lower floodplain alluvial soils, it varied from 0.03 to 0.12 (Table 2). The mean percent nitrogen values of Dupi Tila hills, piedmont alluvium, and estuarine floodplain soils were recorded at 0.053, 0.133, and 0.085, respectively. Nitrogen followed a decreasing pattern with depth in all soils (Fig. 2). It may be assumed that wash out of SOC with the drainage water accelerates in transporting nitrogen from the upper topography to the lower sequence. A similar observation was also reported for the variation SOC and TN stock along a toposequence[28]. A positive with significant correlation was found between SOC and TN contents in the soils of piedmont deposits ($r = 0.657$ at $p<0.01$) and floodplain alluvial soils ($r = 0.943$ at $p<0.01$) but in case of Dupi Tila hills, it showed only positive ($r = 0.423$ at $p<0.01$).

Bulk density: The bulk density of Dupi Tila hill soils varied from 0.98 to 1.78 g/cc with its mean value of 1.49 g/cc. In the piedmont alluvial soils, bulk density varied from 1.08 to 1.48 g/cc with the mean value of 1.26 g/cc, and in the lower toposequence floodplain soils, bulk density varied from 1.13 to 1.38 g/cc with its mean value of 1.26 g/cc (Table 2).

Table 2. Soil Properties of Lalmai Hill Ecosystem covering Hills, Piedmont deposits and Floodplains.

Physio-graphic units	Soil series	Depth (cm)	%Clay	%Silt	%Sand	Tex-tural class	BD (g/cc)	pH	%OC	CEC meq/ 100g	%N	SOC storage (kg/m²)
Hill soils	Lalmai	0-20	49.30	20.54	30.16	C	1.52	4.85	0.328	20.21	0.055	1.00
		20-40	44.15	20.54	35.31	C	1.47	4.81	0.292	19.40	0.048	0.86
		40-60	41.51	17.94	40.55	C	1.33	5.01	0.255	20.67	0.047	0.68
		60-80	34.96	19.14	45.90	Scl	1.65	5.35	0.200	15.84	0.055	0.66
		80-100	33.70	17.87	48.43	Scl	1.75	5.83	0.200	13.65	0.049	0.70
	Shalbon	0-20	44.02	17.92	38.06	C	1.69	4.23	0.390	20.09	0.072	1.32
		20-40	26.16	17.95	55.88	Scl	1.28	4.19	0.273	16.41	0.069	0.70
		40-60	26.13	15.37	58.50	Scl	1.71	4.12	0.200	13.42	0.068	0.69
		60-80	33.73	15.33	50.93	Scl	1.66	4.10	0.146	12.16	0.078	0.48
		80-100	37.84	16.73	45.43	Scl	1.62	4.29	0.073	10.89	0.082	0.24
	Khadimnagar	0-20	13.13	20.19	66.68	Sl	1.78	5.17	0.355	9.40	0.048	1.26
		20-40	7.00	9.07	83.93	Ls	1.72	5.05	0.266	8.94	0.029	0.91
		40-60	5.56	7.54	86.90	Ls	1.62	5.62	0.195	9.74	0.015	0.63
		60-80	5.55	5.04	89.41	S	1.85	5.79	0.142	10.09	0.012	0.52
		80-100	10.73	22.99	66.28	SL	1.77	5.98	0.195	11.24	0.006	0.69
	Kharera	0-20	32.15	30.38	37.48	CL	1.16	4.79	1.161	13.86	0.097	2.69
		20-40	54.76	32.29	12.95	C	1.14	4.82	0.142	9.71	0.068	0.32
		40-60	56.07	23.26	20.67	C	1.11	5.32	0.160	10.00	0.070	0.35
		60-80	61.37	28.49	10.14	C	1.06	5.44	0.140	6.43	0.045	0.30
		80-100	66.35	28.40	5.25	C	0.98	5.89	0.124	5.43	0.038	0.24
	Mean	-	34.21	19.35	46.44	-	1.49	5.03	0.262	12.88	0.053	0.76
Piedmont deposits	Pritimpasa	0-20	37.53	54.89	7.58	Sicl	1.19	5.86	1.315	17.68	0.152	3.13
		20-40	36.17	48.40	15.42	Sicl	1.24	6.38	1.173	21.59	0.121	2.91
		40-60	20.70	38.33	40.97	l	1.29	4.10	0.837	11.24	0.096	2.16
		60-80	19.56	39.37	41.08	L	1.15	6.77	0.301	19.98	0.068	0.69
		80-100	12.97	43.06	43.97	L	1.09	6.56	0.213	15.38	0.036	0.46
	Chakla	0-20	22.28	37.97	39.75	L	1.48	6.46	1.180	21.00	0.147	3.49
		20-40	53.31	42.06	4.63	Sic	1.42	6.58	1.670	21.86	0.153	4.74
		40-60	36.86	61.15	2.00	Sicl	1.37	6.62	1.600	18.71	0.131	4.38
		60-80	27.55	45.91	26.54	Cl	1.26	6.78	1.180	15.00	0.105	2.97
		80-100	25.34	36.20	38.46	L	1.08	6.81	0.820	14.00	0.098	1.77
	Manu	0-20	27.37	43.08	29.55	Cl	1.25	6.35	1.230	16.64	0.187	3.08
		20-40	23.68	36.91	39.41	L	1.39	6.28	1.210	15.26	0.196	3.36
		40-60	19.21	72.36	8.43	Sil	1.08	5.89	3.160	12.73	0.215	6.83
		60-80	35.18	61.18	3.64	Sicl	1.27	6.54	0.220	14.46	0.153	0.56
		80-100	30.02	58.51	11.48	Sicl	1.36	6.75	0.180	16.07	0.137	0.49
	Mean	-	28.51	48.09	23.39	-	1.26	6.32	1.086	16.77	0.133	2.74

(Contd.)

Table 2 contd.

Floodplain soils	Chandina	0-20	22.31	73.53	4.16	Sil	1.13	7.08	1.226	22.28	0.115	2.77
		20-40	19.83	73.71	6.46	Sil	1.29	7.05	1.048	21.93	0.102	2.70
		40-60	21.02	72.19	6.78	Sil	1.18	7.01	0.355	20.32	0.051	0.84
		60-80	22.36	73.68	3.96	Sil	1.13	6.71	0.248	15.84	0.042	0.56
		80-100	22.16	76.71	1.13	Sil	1.22	6.75	0.213	18.71	0.033	0.52
	Debidwar	0-20	24.91	68.63	6.46	Sil	1.38	7.12	1.386	16.14	0.113	3.83
		20-40	23.64	67.37	8.99	Sil	1.33	7.09	1.279	15.14	0.106	3.40
		40-60	21.12	72.52	6.36	Sil	1.28	6.93	0.871	14.00	0.098	2.23
		60-80	24.90	71.16	3.94	Sil	1.34	6.82	0.888	14.43	0.101	2.38
		80-100	26.12	72.95	0.93	Sil	1.36	7.03	0.640	12.71	0.089	1.74
	Mean	-	22.84	77.24	4.92	-	1.26	6.96	0.815	17.15	0.085	2.10
Grand Mean			29.70	41.05	29.24	-	1.36	5.90	0.663	15.15	0.087	1.73

Bulk density varied sharply with depth in all soils (Fig. 2). Kharera soil of the Dupi Tila hill has the lowest bulk density, and the decreasing trend with depth was almost uniform. It is reported that high bulk densities in deeper soils are due to the weight of the overlying horizons[29]. However, the textural class has significantly influences bulk density as the coarse textures develop with less porosity and more compaction result in high bulk density[30]. Strong negative correlation ($r = -0.75$ at $p < 0.01$) between bulk density and clay content in the Dupi Tila hill soils signifies the fact very well. On the other hand, piedmont deposits ($r = 0.446$ at $p < 0.01$) and estuarine floodplain soil (($r = 0.579$ at $p < 0.01$) possess positive correlation between bulk density and clay contents of the soils.

Particle size distribution: The percent clay in the Dupi Tila hill soil varies from 5.55 to 66.35, with mean values of 34.21. The percent silt varies from 5.04 to 30.38, with mean values of 19.35. The percent sand varies from 5.25 to 89.41, with mean values of 46.44. The textural class in the Dupi Tila hill soil varies from silty clay loam to clay. The percent clay in the piedmont soil varies from 12.97 to 53.31, with a mean value of 28.51. The percent silt varies from 36.20 to 72.36, with a mean value of 48.09. The percent sand varies from 2.00 to 43.97, with a mean value of 23.39. The textural class in the piedmont soil varies from silty clay loam to loam. The percent clay in the floodplain soil varies from 19.83 to 26.12 with a mean value of 22.84. The percent silt varies from 71.16 to 76.71, with a mean value of 77.24. The percent sand varies from 0.93 to 8.99, with a mean value of 4.92 (Table 2). The textural class in the estuarine floodplain soil is predominantly silt loam. It may be noted that there is a variation of percent sand, silt, and clay with depths in all soils (Fig. 2) where sand is dominant in hill soil; silt is dominant in piedmont and floodplain soils. It is reported[9,31] that clay has the stabilizing effect where SOC can be trapped in their small spaces between clay particles, making them inaccessible to micro-organisms and thereby slowing decomposition, which is applicable in the case of piedmont deposits.

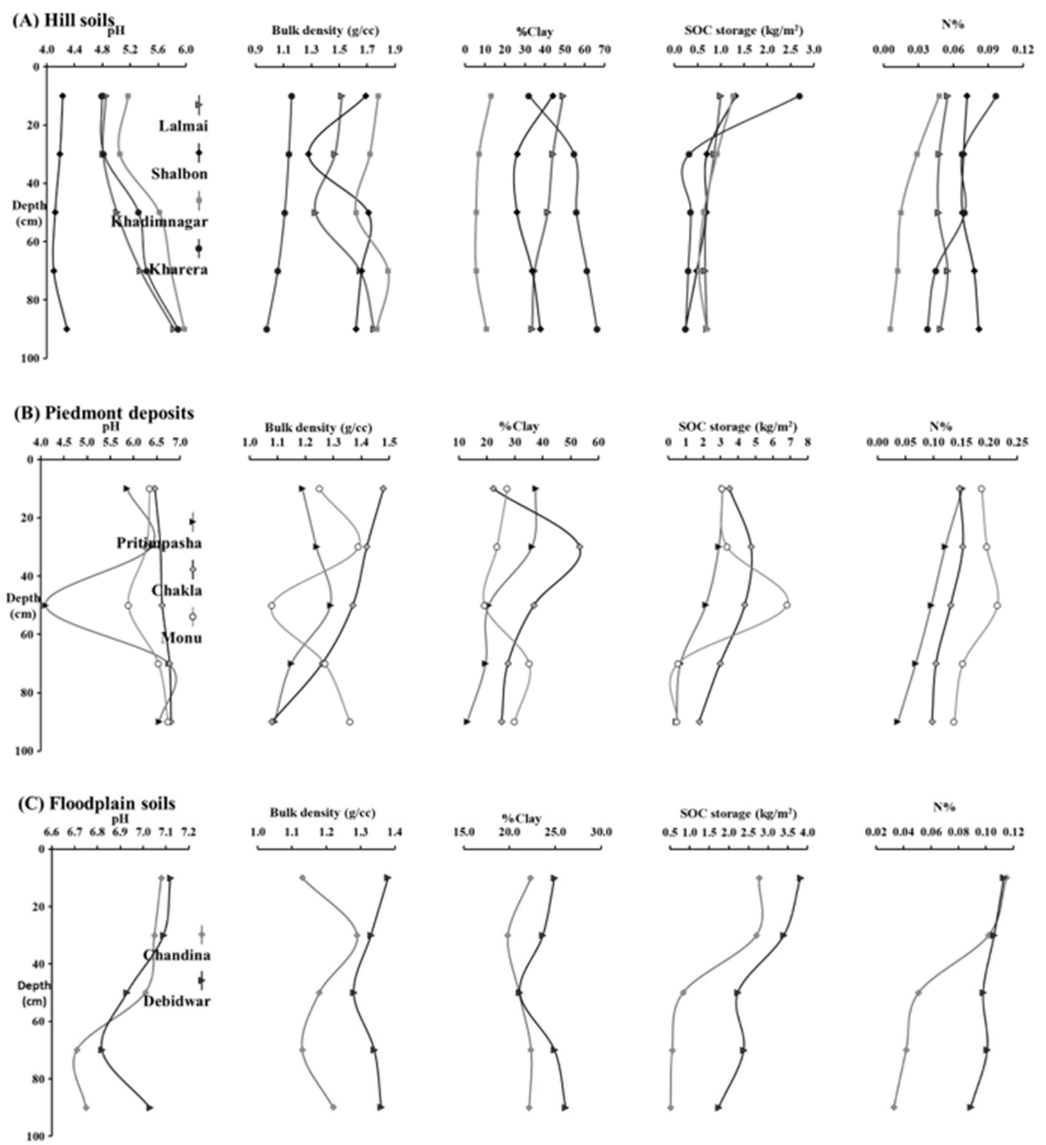

Fig. 2 Vertical distribution of soil pH, bulk density (g/cc), percent clay, percent nitrogen and SOC storage kgm^{-2} with depths in hills, piedmont and floodplain soils of Lalmai hill ecosystem.

Cation Exchange Capacity (CEC): CEC (meq/100g) of the Dupi Tilla hill soils varied from 5.43 to 20.67 with a mean CEC of 12.88. CEC of piedmont deposits varied from 12.73 to 21.86, with a mean CEC of 16.77. CEC of Meghna estuarine alluvial soils ranged from 14.00 to 22.28, with a mean CEC of 17.15 (Table 2). A significant correlation was found between CEC and percent clay contents in the soils of piedmont deposits ($r = 0.513$ at p <

0.01) and floodplain alluvial soils ($r = 0.676$ at $p < 0.01$) but in case of Dupi Tila hills, it showed insignificant ($r = 0.067$ at $p < 0.01$). All the soils exhibited an almost uniform decrease in CEC with depths (Fig. 2).

SOC Storage: SOC storage is higher in topsoil (0-20 cm) in all the soil series across the studied sites. In Dupi Tila hill soils, SOC storage ranged from 0.24 to1.32 kgm^{-2} with mean value of 0.76 kgm^{-2} (Table 2). In piedmont deposits, SOC storage varied from 0.46 to 3.13 kgm^{-2} with mean values 2.74 kgm^{-2}. In the estuarine floodplain soils, SOC varied from 0.52 to 2.7713 kgm^{-2} with mean value of 2.10 kgm^{-2}. The highest values of SOC storage were observed through the layers of piedmont deposits. In the present study, the SOC content decreased more or less with the increase of soil depth, consistent with many studies[32,33]. However, SOC storage was observed to have a sharp decrease after topsoil, i.e., 2.69 kg/m^2 to 0.32 kg/m^2 in the Kharera soil profile, and a fairly close distribution of very low organic carbons in the deeper layers. A significant portion of SOC storage in this toposequence occurred at a depth of 40 cm (Fig. 2). Topographic variability is vital to affect SOC storage by influencing environmental factors, parent material and land use pattern as well[31]. The upper slope of organic matter is transported and deposited downward, resulting from higher SOC storage in downslope soil ecosystems[34-36] due to unsustainable management in the upper catchment. It is assumed that the occurrence of relatively higher SOC storage in piedmont deposits than Dupi Tila hills is consistent with the existing facts that the higher rate of transportation and accumulation of SOC in piedmont soils. Elevation with geomorphology could influence soil erosion and deposition, and subsequently, SOC levels[37,38]. A significant negative correlation ($r = -0.786$ at $p < 0.01$) was found between SOC storage and elevation.

ANOVA Test: A two-way ANOVA test of SOC storage indicates that physiographic units and sampling depths significant influence SOC storage ($p < 0.05$, $F = 2.678$). SOC storage level are significantly different in the 3 topographic units ($p < 0.001$, $F = 21.908$). SOC storage levels are also significantly vary ($p < 0.001$, $F = 7.198$) at different soil depths. Regarding SOC storage, the post hoc test indicates that hill soils are significantly different from the other two physiographic units, but there is no significant difference between piedmont deposits and floodplain soils.

Assessment of SOC Stock: SOC storage was 2.01Tg in the upper hill soils, where the lowest stock amounts to 0.03 Tg in the Lalmai soil series (Fig. 3). SOC stock was estimated at 0.71, 1.22 and 0.05 Tg in Shalbon, Khadimnagar, and Kharera soil. SOC stock was 21.75 Tg in piedmont deposits, where the lowest stock amounts to 5.77 Tg in the Pritimpasha soil series. The SOC stock was estimated for Pritimpasa, Chakla, and Manu soil series to 5.77, 8.77, and 7.71 Tg, respectively. SOC stock was 12.68 Tg in the estuarine floodplain system covering Chandina and Debidwar soil series. The highest SOC stock is estimated in the Debidwar soil series, which amounts to 12.03 Tg, where, the Chandina soil series holds the lowest SOC stock, 0.65 Tg. It may be reported that about 36.44 Tg

SOC stock was estimated in the Lalmai hill ecosystem of Bangladesh, where piedmont deposits contained the highest level of SOC stock despite hill and floodplain soils. It was found that the upper catenary hill belongs to well-drained conditions with coarse-textured soils. The middle catenary piedmont belongs to imperfectly to poorly drained with fine-textured soils. The lower catenary floodplain belongs to poorly drained soils with moderately fine textured soils. It is important to note that continuous biomass removal by deforestation and other unwise land management in the upper catchment hill accelerates erosion. Thus, over-washed materials deposited in the piedmonts and probably infiltration take place slowly in piedmont zones. Possibly an impervious layer

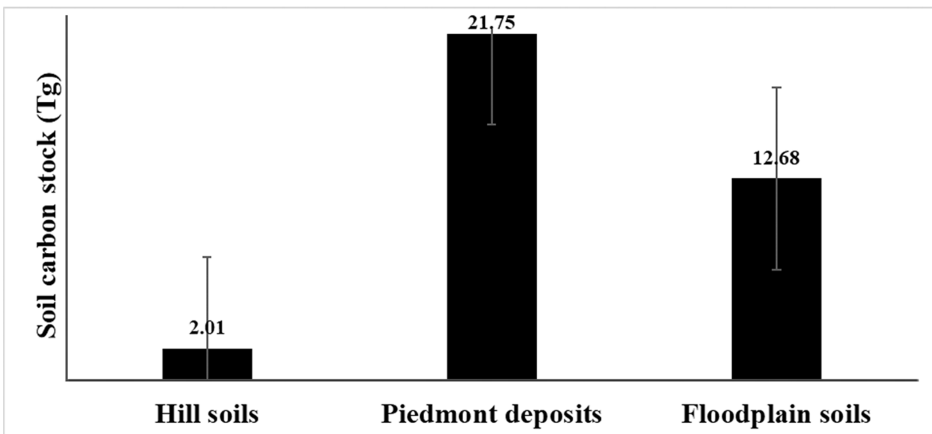

Fig. 3 Soil carbon stock (Tg) in the Lalmai hill ecosystem of Bangladesh.

creates in the piedmont zone due to its finer textural nature. The over-washed materials are washed in and remain in piedmonts and subsequently the emerging processes of carbon sequestration. On the other hand, the piedmont ecosystem occupies a large volume of shrubs and herbs despite the hill and floodplain ecosystem. It was reported[39] that carbon concentrations in plant tissues were 51.6, 39.0, and 42.2% in the trees, shrubs, and herbs, respectively The above finding confirms that carbon concentration is much higher in the herbs and shrubs habitats of the piedmont ecosystem. Thus, the soil textural nature and land use or land cover signify the highest stocks of SOC in the piedmont eco-zone than the other ecosystems.

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