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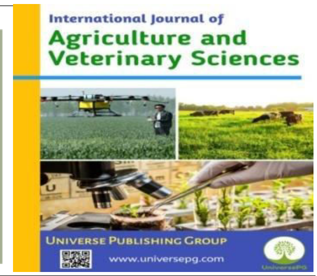

Variations of Soil Organic Matter and Nutrients in Diverse Hilly Soils of Bandarban, Bangladesh

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ABSTRACT

Functioning and positive interactions in an ecosystem depend on physical and chemical features of soil, along with nutrient status. These soil nutrients are vital for the growth and development of plants, playing a crucial role in various essential functions. The current study investigates the dynamic changes in soil nutrient patterns across different land use scenarios and soil depths at Bandarban Sadar Upazila, Chittagong Hill Tracts, Bangladesh. The research focuses on how soil nutrient levels are distributed in two soil depths (0-15 cm and 15-30 cm) among three different land use practices, such as forest land, agricultural land and barren land. About 90 soil samples from the study area were collected using a stratified random sampling design. The analysis reveals significant variations in soil pH, organic matter (OM), total nitrogen (TN), phosphorus (P), potassium (K), and sulfur (S) levels among these land use types and soil depths. The findings revealed that agricultural land typically exhibited higher levels of soil S content and pH, in contrast to forested areas where OM, TN, P, and K levels were comparatively more abundant. Again, barren land showed a relatively higher pH and S content than agricultural land and forest land. Additionally, the topsoil (0-15 cm) generally showed higher nutrient content than the deeper soil layer (15-30 cm). The investigation uncovered significant positive correlations of OM with soil nutrients such as TN, P, K & S, indicating mutual influences on their availability. Overall, the research outcomes emphasize the importance of sustainable land management practices to maintain soil fertility and optimize soil productivity in this ecologically significant region.

Keywords: Functioning, Development, Land use, Depths, Significant, Land management, and Hill tracts.

INTRODUCTION:

Plants, like all other living things, require a variety of nutrients for their growth and development (Silva *et al.,* 2000). Nutrients along with carbon dioxide (CO_2), water (H_2O) and sunlight collectively enable plants to convert light energy into chemical energy by the photo-synthesis, facilitating their growth and the providing oxygen to the environment. Plants require 17 essential elements where Carbon, Hydrogen and Oxygen are derived from the atmosphere, the soil and water; the remaining 13 vital components (Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sulphur, Iron, Zinc, Manganese, Copper, Boron, Molybdenum, Nickel, and Chlorine) are sourced from either soil minerals and organic matter or through the application of organic or the inorganic fertilizers (Sridhara *et al.,* 2022). Soil nutrients are divided into two categories: macronutrients such as nitrogen, potassium and phosphorus etc. are required by plants in large quantities and micronutrients such as iron, zinc and copper etc. are needed in smaller amounts but are still essential for plant growth (Food, 2022). Every nutrient has its distinct function on plants. Among all nutrients, Nitro-gen (N), potassium (K), phosphorus (P), and sulfur (S) are four of the most crucial nutrients required by plants in large quantities (Silva *et al.,* 2000; IPNI, 1999). Nitrogen is largely responsible for the growth of plant leaves; it is a component of chlorophyll, which is essential for photosynthesis, and is also a building block of amino acids, proteins, and nucleic acids (Gebreslassie, 2016; Plunkett *et al.,* 2022). Phosphorus plays a pivotal role in root growth, flower and fruit development, seed production, as well as energy transfer and storage within plants (IPNI, 1999). Potassium aids in water balance regulation, the stress tolerance improvement, disease resistance enhancement, enzyme activation, and protein synthesis (Silva *et al.,* 2000; Ekhlas *et al*., 2014; Asmare *et al.,* 2023).

Sulfur is important for the synthesis of amino acids, proteins, and enzymes which also involved in chlorophyll formation and helps improve the efficiency of nitrogen utilization (*Plunkett et al.,* 2022). The levels of soil nutrients may fluctuate based on the various factors, including soil composition, depth, prevailing climate conditions, and land management practices (Jiaying *et al.,* 2022 and Leghari *et al.,* 2016). For example, land use like intensive agriculture can deplete soil nutrients over time, while urban development can result in soil compaction and reduced water infiltration (Yousaf *et al.,* 2021; Islam *et al.,* 2021). Soil nutrient status in hilly agricultural land can vary depending on factors such as slope and elevation of land, soil texture, management techniques, and weather conditions (Leul *et al.,* 2023). Steep slopes can make the land vulnerable to erosion, leading to the loss of topsoil, organic matter, and nutrients and leaching of nutrients can also occur during periods of high rainfall (Siswanto and Sule, 2019). Also, Soil depth has a substantial effect on organic matter, nutrient availability and plant growth. Nutrients tend to accumulate near the surface due to the decomposition of organic matters, root activity and, mineralization of nutrients (Eldin and Ibrahim, 2006). The upper layer of soil, known as the topsoil, usually contains the highest concentration of organic matters and nutrients. Soil pH can change with soil depth also. Changes in pH with depth can affect organic matter and the nutrient availability patterns (Grandgirard *et al.,* 2002). Hilly soils have distinctive qualities because of terrain, climate, and geological formations among other things and these soils have particular physical, chemical, and biological characteristics that affect the availability and cycling of nutrients (Grandgirard *et al.,* 2002). For efficient land management and sustainable forestry practices, it is critical to understand the status of the soil nutrients in hilly forest land. The variations in soil nutrient content (fertility) and the variables affecting their distribution in Chittagong Hill Tracts are highlighted in numerous researches (Rasul and Thapa, 2005; Hassan et al., 2017; Chowdhury *et al.,* 2007; Uddin *et al*., 2017; and Al-Mamun *et al.,* 2021).

Therefore, the objectives of this study were; (i) to evaluate the dynamic changes of soil organic matter (OM) and nutrients with the land use changes; and (ii) to investigate the dynamic changes of soil OM and nutrients (TN, P, K and S) in different soil depths in Bandarban Sadar Upazila.

MATERIALS AND METHODS:

Study area

The study was conducted in 2023 in Bandarban Sadar Upazila which lie in the heart of Bandarban district, the south-eastern part of Bangladesh. Bandarban Sadar Upazila covers an approximate area of 501.99 square kilometers, situated between 21°55' and 22°22' north latitudes and 92°08' and 92°20' east longitudes. This Upazila is bordered to the north by Rajasthali Upazila, to the south by Lama Upazila, to the east by Rowangchhari and Ruma Upazilas, and to the west it is bounded by the upazilas of Rangunia, Satkania, and Lohagara and is adjacent to Cox's Bazar, Chittagong, Rangamati, and Khagrachari districts (Mumnun and Hossen, 2020). Predominant soil texture of this area is a mix of the sandy loam, clay and silt; providing a balanced medium for plant growth whereas the color of the soil ranges from light brown to dark brown, reflecting its rich organic content (Das *et al.,* 2014). This research also added that the average soil pH of this area is ranges from 5.1 to 5.7, indicated that this area is slightly acidic, supporting various crops and vegetation. In regards to the temperature, the annual average temperature of this region is about 26.5º C varies from maximum 37º C to minimum 12.5º C. The region is blessed with abundant rainfall, ranging from 3,000 to 4,000 millimeters annually, which contributes to soil moisture availability and nutrient cycling (IWMD, 2022; Adnan and Malek, 2004). Also, the organic content is generally high, fostering soil fertility and promoting nutrient cycling. The presence of sufficient nutrients, along with favorable soil conditions, makes Bandarban Sadar an agriculturally productive area in the Chittagong Hill Tracts. The whole landscape is covered with the zigzag courses of hills. The land use pattern varies for the different areas Bandarban Sadar Upazila.

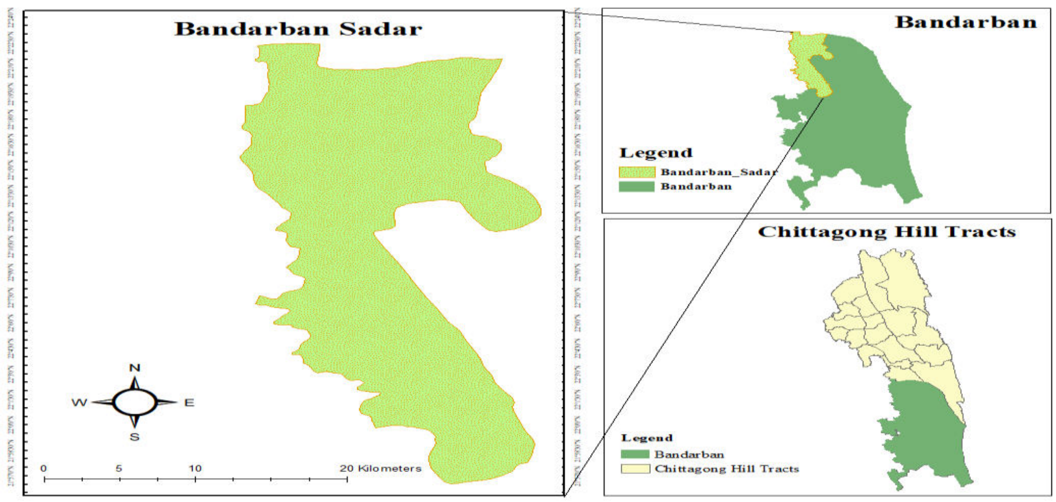

Fig. 1: Map of the study area.

Experimental Design

The experiment consists of 5 variables viz., Organic Matter (OM), Total Nitrogen (TN), Phosphorus (P), Potassium (K), and Sulfur (S); 3 Land uses are Forest land, Agriculture land and Barren land; and 2 soil depths (0-15 cm and 15-30 cm). Samples will be collected randomly from Bandarban Sadar Upazila. The experiment was laid out in a stratified random sampling design (SRSD) with three replications. Forest land and Agriculture land will be divided into 5 plots according to the distribution area and every plot had 6 soil samples (soil depth × replication). Forest land = plot × soil depth × replications (5×2×3) = 30 soil samples; Agriculture land = plot × soil depth × replications (5×2×3) = 30 soil samples and Barren land = plot × soil depth × replications (5×2×3) = 30 soil samples. Overall, 30+30+30 = 90 soil samples were collected to accomplish the objectives of this study.

Field sampling and measurements

Field surveys took place between 15th December 2022 to 25th December 2022. According to the distribution of different land uses in Bandarban Sadar Upazila, 15 representative plots (20m × 20m) were selected for sampling. Characteristics within a plot, such as slope, aspect, altitude, and soil type, were very similar; but varied plot by plot. 6 Soil samples were collected from the top right corner, bottom left corner, and center of each plot using a soil auger. At each sample point, the litter on the ground was removed before sampling. From each sampling point we were collected 2 soil samples, one from topsoil (0-15 cm) and another from deep soil (15-30 cm). Since we had 3 replications, 6 soil sample were obtained from each plot. 3 of these were represented topsoil and the other three represented deep soils. Each 3 sample of topsoil and deep soil mixed separately to make a representative sample for laboratory analysis. The collected soil samples were tightly sealed in a polyethylene bag as soon as possible to avoid air exposure. GPS soil sampling technology is used for soil sampling to navigate to accurate sampling locations. Clearly labeled bags were used for onsite sampling from the field. Labels were included field name or ID and sampling date. As soon as the samples arrived at laboratory, the samples were first air-dried at room temperature, then prepared appropriately for laboratory analysis.

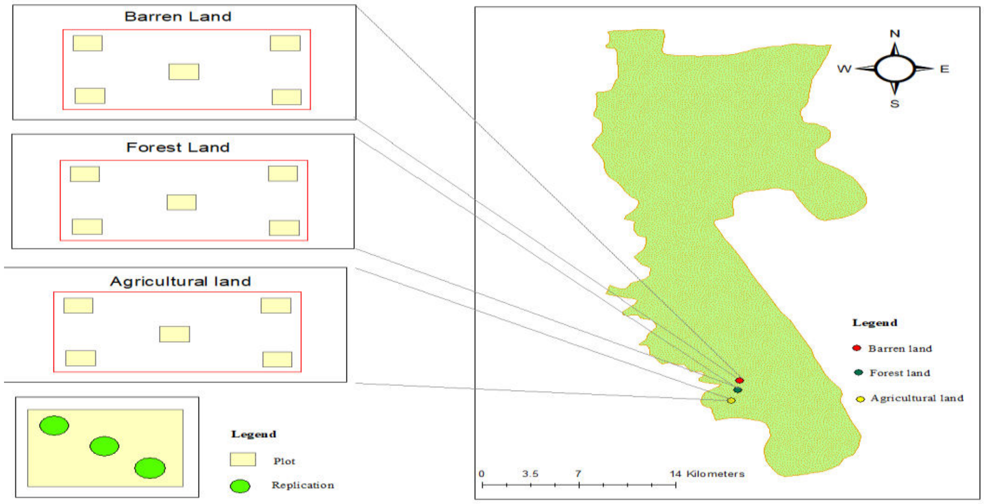

Fig. 2: Sample collection from three different land use types.

Determination of soil chemical parameters and nutrients

All soil parameters were determined in Soil Research Development Institute (SRDI), a laboratory in Cumilla, Bangladesh. pH was measured by a glass electrode pH meter (model: HI1131b, Manufactured in Romania). Soil organic matter (OM) were calculated from soil organic carbon (SOC) and SOC were determined by the Walkley-Black chromic acid wet oxidation method. The Kjeldahl method were applied to determine percentage total nitrogen (TN) in the samples. Since the amounts of soil phosphorus depends on soil pH, we used two different methods for phosphorus determination. When soil pH was <7.0, we were applied the method of Bray and Kurtz; and when soil was pH >7.0, we were applied the Olsen method for phosphorus determination. Atomic Absorption (AA) was applied to measure potassium ions, which were initially extracted from soil samples with a 1 mol/L solution of ammonium acetate (CH_3COONH_4). Soil sulfur was determined by turbidimetry method. We used a spectrophotometer set to a wavelength of 535 nm to gauge the level of turbidity, aiding us in assessing the sulfur content in the soil.

Statistical analysis

First, the study area was defined by 'ArcGIS'. Then, we used Microsoft Excel to arrange the data for statistical analysis, and then we used 2-way and 3-way analysis of variance (ANOVA) to examine the significance differences on the variable among the factors considered in this study. Finally, Tukey's HSD post-hoc was used to the examine multiple comparisons among the groups. ANOVA and Tukey's HSD post-hoc analyses were done using the R programming environment (R core team 2013).

RESULTS:

Table 1 shows the summary statistics for the soil variables between two soil depths of different land uses (barren, agriculture and forest land) in the present study area. **Fig. 4**, **5**, **6**, and **7** show the graphical representation of soil pH, OM, TN, P, K & S pattern. To compare the significance differences among the land uses (barren vs agriculture vs forest), soil depth, plot numbers in terms of soil variables, three-way ANOVA was conducted and represented in **Table 2**, **3**, **4**, and **5** where significant differences are marked in bold. Residuals of the model were normally distributed according to the Shapiro-Wilk test and variances among the groups were homogeneous according to the Bartlett's test. **Fig. 3** also represent the correlation matrix among the soil variables.

Summary statistics for the soil variables

Table 1 provides a comprehensive overview of key soil properties across three different land cover types: agricultural (A), forested (F), and barren (B) land. For pH, agricultural land (A) has the highest mean value (6.8), while barren land (B) has the lowest (6.4), with forested land (F) falling in between (6.6). The mean values of pH in each land type indicate that it is relatively acidic. Organic matter (OM) percentage is highest in forested land (9.9%) and lowest in barren land (4.3%). Total nitrogen (TN) percentage shows similar trends, with the highest mean value in forested land (0.4%) and the lowest in barren land (0.1%). Phosphorus (P) content is highest in agricultural land (9.5µg/g) and lowest in barren land (6.2µg/g). Potassium (K) content is relatively consistent across all land types, with small variations. Sulfur (S) content is highest in agricultural land (5.80µg/g) and lowest in barren land (4.1µg/g).

Table 1: Summary statistics of the soil variables. (A = Agriculture land, F = Forest land and B = Barren land).

Variables	Maximum			Minimum			Mean			Variance			Standard Deviation		
	A	F	B	A	F	B	A	F	B	A	F	B	A	F	B
pH	6.70	6.1	6.8	4.8	4.4	6.4	5.8	5.44	6.6	0.26	0.19	0.02	0.51	0.44	0.14
OM (%)	8.32	9.9	4.3	0.52	1	0.52	4.04	4.44	2.09	5.43	7.53	2.50	2.33	2.74	1.58
TN (%)	0.35	0.4	0.1	0.02	0.03	0.02	0.16	0.17	0.09	0.01	0.01	0.01	0.08	0.11	0.06
P (µg/g)	8.20	9.5	6.2	1.5	2.5	3.1	3.82	5.74	4.51	4.19	5.28	1.53	2.04	2.29	1.23
K(meq/100)	0.44	0.5	0.5	0.1	0.2	0.1	0.29	0.33	0.35	0.01	0.01	0.02	0.07	0.07	0.15
S (µg/g)	5.80	3.8	4.1	0.9	0.8	1.2	2.6	1.81	2.72	2.35	0.71	1.64	1.53	0.84	1.28

Correlation among soil variables

Overall, a significant positive correlation is observed between TN and OM, suggesting that when the TN content increases, the OM content also tends to rise. This association underscores the mutual influence of nitrogen (N) and OM dynamics in the soil. Moreover, a strong positive correlation is evident between TN and K, indicating that an increase in TN levels is typically accompanied by an increase in K content. This positive correlation highlights the interconnecttedness of N and K in soil nutrient availability. In contrast, a weak negative correlation is found between P and S, implying that when P levels increase, there is a slight decrease in S content. Though relatively weak, this negative correlation suggests that P and S might influence each other to some extent.

Soil pH

In **Table 2**, factors such as Land use (A) and depth (C) showed significant effects, as indicated by the high F-values and very low P-values. Plot (B) also had a significant effect, although with a slightly higher P-value. The interactions among these factors (A × B, A × C, B × C, and A × B × C) also showed very significant effects on soil pH. These findings suggested that age, plot, and depth individually influence the soil pH, as well as their interactions have a substantial impact.

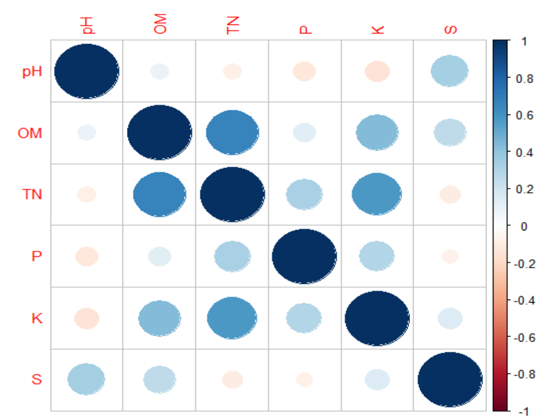

Fig. 3: Correlation among all of the recorded soil variables

Table 2: Three-way analysis of variance of soil pH at different soil depths (0-15 cm and 15-30 cm) under different land uses (agriculture, forest, and barren land) in different plots (1, 2, 3, 4, and 5) of the study area.

Factors	Df	Sum Sq.	Mean Sq.	F-value	P-value
Land use (A)	2	7.183	3.591	103.958	**$< 2e^{-16}$**
Plot (B)	4	1.011	0.253	7.316	**0.000131**
Soil depth (C)	1	1.969	1.969	57.000	**$1.80e^{-09}$**
A × B	4	3.021	0.755	21.863	**$5.46e^{-10}$**
A× C	2	0.875	0.437	12.663	**$4.53e^{-05}$**
B × C	4	2.445	0.611	17.694	**$1.01e^{-08}$**
A× B × C	4	2.811	0.703	20.343	**$1.51e^{-09}$**
Residuals	44	1.520	0.035		

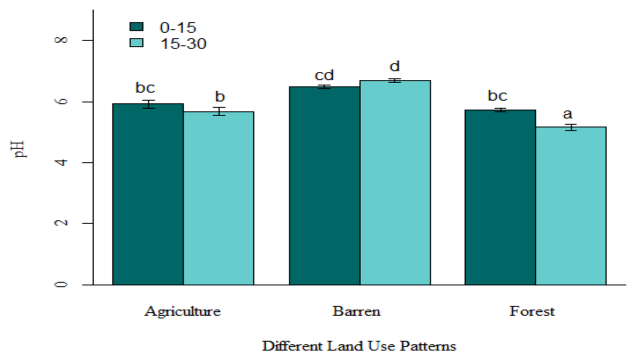

Fig. 4: Bar graph showing soil pH differences in 2 different (0-15 cm and 15-30 cm) at each land use type: agricultural, forest, and barren land; different letters indicate the significant differences in the same layer of different stand ages at the 0.05 level.

According to this bar graph represented in **Fig. 4**, the highest pH value is observed in the barren land for a 15-30 cm soil depth, while the lowest pH value is observed in the forest land for a 15-30 cm soil depth. Forest and agricultural land appeared to have a higher pH level in the upper soil layer (0-15 cm) than the lower soil layer (15-30 cm), but barren land showed a high pH in the lower soil level. Additionally, the pH values indicated that all land use types in our study area contain slightly acidic soils.

Soil Organic Matter (OM)

All the factors, as well as the interaction among these factors, showed highly significant and substantial impacts in determining soil organic matter as indicated by high F-values and very low P-values (**Table 3**).

Table 3: Three-way analysis of variance of soil organic matter (OM) at different soil depths (0-15 cm and 15-30 cm) under different land uses (agriculture, forest, and barren land) in different plots (1, 2, 3, 4, and 5) of the study area.

Factors	Df	Sum Sq.	Mean Sq.	F-value	P-value
Land use (A)	2	27.58	13.79	406.7	**< 2e^{-16}**
Plot (B)	4	96.64	24.16	712.5	**< 2e^{-16}**
Soil depth (C)	1	134.11	134.11	3954.9	**< 2e^{-16}**
A × B	4	18.51	4.63	136.5	**< 2e^{-16}**
A× C	2	15.07	7.53	222.2	**< 2e^{-16}**
B × C	4	49.79	12.45	367.1	**< 2e^{-16}**
A× B × C	4	68.99	17.25	508.7	**< 2e^{-16}**
Residuals	44	1.49	0.03		

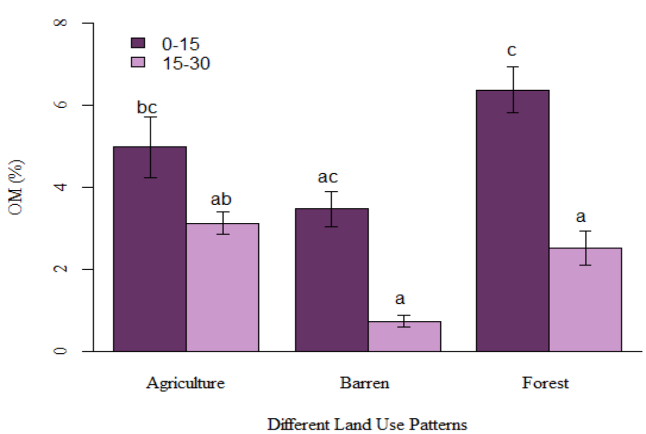

Fig. 5: Bar graph showing soil organic matter (OM) differences in 2 different (0-15 cm and 15-30 cm) soil depths at each land use type: agricultural, forest, and barren land; and different letters indicate the significant differences in the same layer of different stand ages at the 0.05 level.

According to **Fig. 5**, the upper soil layer (0-15 cm) appears to be more enriched with organic matter than the lower soil layer (15-30 cm), and the upper soil layer (0-15 cm) of forested areas is enriched with more organic matter than both agricultural and barren land. In contrast, barren land showed the lowest value of organic matter in both soil layers. The upper layer of agricultural land showed a moderate value, while the lower layer showed the highest value among the three land use systems.

Soil Total nitrogen (TN) and Phosphorus (P)

Table 4 shows all the factors, as well as their inter-actions showed highly significant & substantial impacts in determining soil TN and P, as indicated by high F-values and very low P-values. But the only inter-actions between land use and soil depth do not have a substantial impact because of high P-value (0.18113 and 0.0409) for soil TN and P respectively (**Table 4**).

Table 4: Three-way analysis of variance of TN & P at different soil depths (0-15 cm and 15-30 cm) under different land uses (agriculture, forest, and barren land) in different plots (1, 2, 3, 4, and 5) of the study area.

	Total Nitrogen (TN)					Phosphorus (P)			
Factors	**Df**	**SS**	**MS**	**F val.**	**P val.**	**SS**	**MS**	**F val.**	**P val.**
Land use (A)	2	0.234	0.1171	24.869	**$5.94e^{-08}$**	55.68	27.84	407.028	**$<2e^{-16}$**
Plot (B)	4	0.337	0.084	17.909	**$8.57e^{-09}$**	78.59	19.65	287.235	**$<2e^{-16}$**
Soil depth (C)	1	0.146	0.146	30.930	**$1.48e^{-06}$**	84.82	84.82	1239.98	**$<2e^{-16}$**
A × B	4	0.288	0.072	15.266	**$6.66e^{-08}$**	62.17	15.54	227.216	**$<2e^{-16}$**
A× C	2	0.017	0.009	1.777	0.18113	0.47	0.24	3.441	0.0409
B × C	4	0.077	0.019	4.110	**0.00647**	38.42	9.60	140.399	**$<2e^{-16}$**
A× B × C	4	0.077	0.019	4.116	**0.00642**	15.08	3.77	55.118	**$<2e^{-16}$**
Residuals	44	0.207	0.005			3.01	0.07		

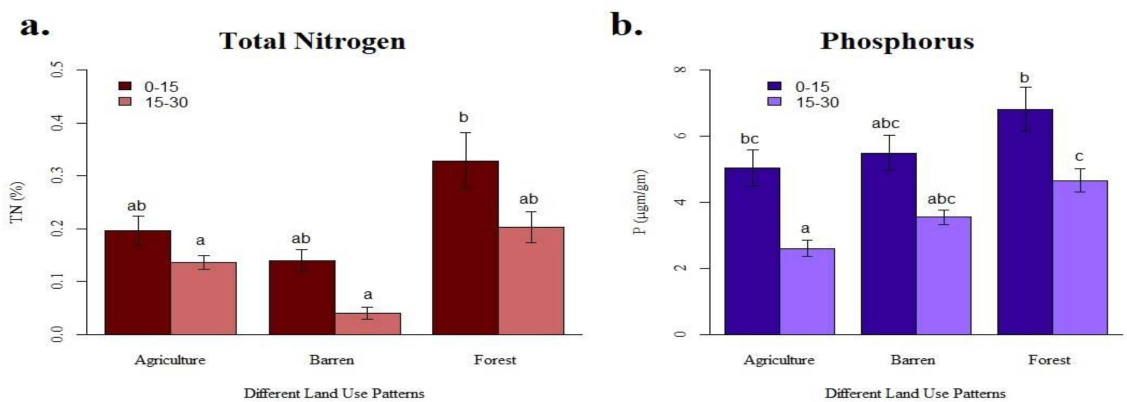

Fig. 6: Bar graph showing TN (a) & P (b) differences in 2 different (0-15 cm and 15-30 cm) soil depths at each land use type: agricultural, forest, and barren land; different letters indicate the significant differences in the same layer of different stand ages at the 0.05 level.

Fig. 6 shows the upper soil layer (0-15 cm) is enriched with a higher TN & P than the lower layer (15-30 cm). Additionally, forest land showed a higher percentage of total TN & P compared to agricultural land and barren land in both soil layers.

Soil Potassium (K) & Sulfur (S)

Table 5 shows all the factors showed highly significant and substantial impacts in determining soil K & S, as indicated by high F-values and very low P-values. The interactions of these factors (A×B, A×C, B×C, and A×B×C) also had a significant effect, although with a slightly higher P-value respectively (**Table 5**).

Table 5: Three-way analysis of variance of soil K & S at different soil depths (0-15cm and 15-30cm) under different land uses (Agriculture, forest and barren land) in different plots (1, 2, 3, 4 and 5) of the study area.

	Potassium (K)					Sulfur (S)			
Factors	**Df**	**SS**	**MS**	**F val.**	**P val.**	**SS**	**MS**	**F val.**	**P val.**
Land use (A)	2	0.1002	0.0501	66.58	**$4.92e^{-14}$**	21.818	10.91	255.77	**$< 2e^{-16}$**
Plot (B)	4	0.1623	0.0406	53.88	**$< 2e^{-16}$**	14.577	3.644	85.44	**$< 2e^{-16}$**
Soil depth (C)	1	0.0767	0.0768	101.86	**$5.02e^{-13}$**	26.195	26.19	614.17	**$< 2e^{-16}$**
A × B	4	0.0112	0.0028	3.70	**0.01102**	13.676	3.42	80.16	**$< 2e^{-16}$**
A× C	2	0.0081	0.0040	5.34	**0.00838**	5.266	2.63	61.73	**$1.7e^{-13}$**
B × C	4	0.0151	0.0038	5.00	**0.00207**	18.089	4.52	106.03	**$< 2e^{-16}$**
A× B × C	4	0.0099	0.0025	3.27	**0.01978**	11.833	2.96	69.36	**$< 2e^{-16}$**
Residuals	44	0.0331	0.0008			1.877	0.04		

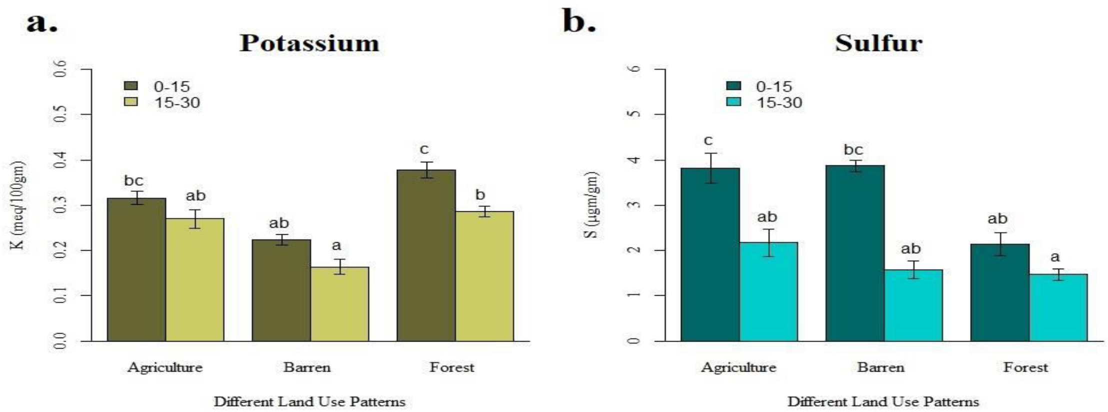

Fig. 7: Bar graph showing soil K (a) & S (b) differences in 2 different (0-15 cm and 15-30 cm) soil depths at each land use type: agricultural, forest, and barren land; different letters indicate the significant differences in the same layer of different stand ages at the 0.05 level.

Fig. 7 shows the upper soil layer (0-15 cm) is enriched with higher soil K (a) & S (b) than the lower layer (15-30 cm). Additionally, forest land showed a higher percentage of soil K & S than agricultural land and barren land in both soil layers.

DISCUSSION:

According to the results, it is clear that the value of soil pH is higher in agricultural land compared to forest land; as shown in Figure 4. Agricultural land typically has a higher soil pH due to the use of lime and other soil amendments to neutralize acidity and improve crop growth (Al-Mamun *et al.,* 2021). In contrast, the forest land tends to have a lower soil pH due to the accumulation of organic matter and the presence of microorganisms that produce acidic compounds and this observation (Hossain *et al.,* 2014; Wang *et al.,* 2022; Yuan *et al.,* 2023). Overall, these findings align with previous researches (Zhou *et al.,* 2019; Filippi *et al.,* 2019) and provide valuable insights into the relationship between land use patterns, soil depths, and soil pH. In terms of soil organic matter (OM), forest land exhibits significantly higher levels of OM compared to agricultural land and barren land in hilly regions. A notable study conducted by Hossain *et al.* (2014), in hilly landscapes found that forested areas exhibited substantial accumulations of organic matter due to the continuous input of plant residues, leaf litter, and decaying organic material (Fang *et al.,* 2015; Cardinael *et al.,* 2020). This organic matter enrichment is a result of the diverse and abundant vegetation in forest ecosystems, promoting the accumulation of biomass and organic debris on the forest floor. Agricultural land practices such as tillage, harvesting, and removal of crop residues lead to reduced organic matter input and accelerated decomposition, limiting the buildup of organic matter in the soil. In contrast, Barren land has low organic matter because it lacks vegetation and organic material, which are essential sources for the accumulation of organic matter in both lair of soil. These findings highlight the vital role of forests in carbon sequestration and the preservation of soil organic matter, emphasizing the importance of sustainable land management practices to maintain soil fertility and ecosystem health in hilly regions. Our findings indicate that the values of soil total nitrogen (TN), phosphorous (P) and potassium (K) is higher in forest land compared to agricultural land and barren land. Lowest TN and K values showed by barren land because it lacks vegetation and moisture content; and lowest P values showed by agricultural land. The dense and diverse vegetation in forests promotes nitrogen fixation and assimilation by plants and microorganisms, leading to increased nitrogen content in the soil (Sardar *et al.,* 2023). Also, Forest vegetation efficiently capture and recycle phosphorus and potassium, contributing to its enrichment in the forest soil. Agricultural practices, such as intensive fertilization and nitrogen-demanding crops, often result in higher nitrogen losses through leaching and runoff, leading to reduced nitrogen retention in agricultural soils in Chittagong Hill Tract. Surprisingly, among all land use types, barren land and forest land showed maximum and minimum S content respectively. Limited nutrient cycling in barren land may cause maximum S content in barren land. Without thriving ecosystems to efficiently cycle nutrients, sulfur tends to remain more concentrated in the soil of barren lands, making it appear to have higher sulfur content compared to more fertile areas. On the other hand, the value of soil TN, P, K and S are comparatively higher in the topsoil than the deep soil because of active nutrient cycling and accumulation of plant residue. However, the present study investigated the dynamics of soil pH, organic matter and nutrient (TN, P, K and S) in order to the understate their trend in 3 different land use types under 2 soil depths (0-15 cm, and 15-30 cm). And finally, the insights of our findings and observations are essential for optimizing agricultural production, preserving soil health, reducing environmental impact, and promoting sustainable land management practices in Bandarban Sadar Upazila.

CONCLUSION:

Using Analysis of Variance and Post Hoc Analysis, this research examined how the soil parameters vary across 3 different land use patterns (agriculture, forest and barren) and 2 soil depths (0-15 cm and 15-30 cm) at Bandarban Sadar, Chittagong Hill Tracts of Bangladesh. The findings of this research revealed significant differences in the soil nutrient levels among forest, agricultural, & barren lands, with specific implications for each land use type. Moreover, the study highlighted the vertical distribution of soil nutrients, with topsoil generally exhibiting higher nutrient concentrations compared to deeper soil layers. The results appeared that the agricultural land generally had higher soil S content and pH levels compared to forest land, while organic matter, total nitrogen, phosphorus and potassium levels were relatively higher in forest land because of more litters and forest residue. The study also revealed that the topsoil tended to have higher nutrient concentrations than the deep soil layer due to biological activity and nutrients cycling. The correlation analyses provided valuable insights into the interplay of soil variables that can aid in understanding nutrient interactions. Although the study has some limitations including relatively small sample size, the focusing on a specific region, not considering seasonal variations, the significance of the study concluded the successfully. For future research, it is suggested that longitudinal studies be conducted to observe soil nutrient dynamics over time, encompassing multiple regions with varying soil types and environmental conditions for improved generalization. However, the overall research underscores the significance of land use practices and soil depth as crucial determinants in shaping soil nutrient dynamics. The findings emphasize the importance of adopting sustainable land management strategies to maintain soil health, preserve soil fertility, & promote long-term agricultural productivity at the Bandarban Sadar, Chittagong Hill Tracts of the Bangladesh.

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CONFLICTS OF INTEREST:

The authors declare no conflict of interest

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