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Soil Properties Variation Valued in Relation to Land Use and Management Practices in Vietnam

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ABSTRACT

Background: Land use and management practices (LUMPs) have been accelerated globally to serve the increasing socio-economic requirements in recent decades.

Methods: This study focuses to assess the impacts of the LUMPs on the properties and composition of soil in the Lam River Basin (LRB), Vietnam based on analysis of ninety-six soil samples collected in the soil profiles (0_60 cm).

Result: The results indicated that the sand and clay ratios (34.0~35.7% and 16.2~19.9%) and bulk density (BD) (1.07±0.05~1.34 ± 0.06 Mg m^{-3}) in the natural forest lands (NFLs) were lower and higher perturbed than the plantation forest lands (PFLs) (31.1~ 51.5%, 5.7~38.2% and 0.86 ± 0.03~1.12±0.05 Mg m^{-3}) in the 0-20 cm topsoil layer. The soil texture is mainly sandy clay to clay loam and the BD tends slightly increase in the topsoil layer, then decrease in the 20-60 cm subsoil layer. There is no difference in soil pH between collected soil samples (CSSs) and tends to increase with increasing the subsoil layer. The base cations (BCs) (Ca^{2+}, K^{+}, Mg^{2+}: 0.01~0.29, 0.06~0.11 and 0.06~0.07 Cmolc kg^{-1}) and total organic contents (TOCs) (total carbon (TC), total nitrogen (TN), total phosphorus (TP): 24.11; 2.80 and 0.19 g kg^{-1}) of the NFLs are higher than those of the CSSs (TC, TN, TP: 14.37~23.91, 1.62~2.28 and 0.08~0.17 g kg^{-1}) in the topsoil layer while these values were not different in the topsoil layer.

Key words: Degradation, Forest land, Land-use management, Soil function, Texture.

INTRODUCTION

Globally, land use and management practices (LUMPs) are causing potential risks of soil degradation, leading to critical consequences for the soil environment and the services of the ecosystem (Cambi *et al.*, 2017; Dai *et al.*, 2019). Agricultural expansion activities (AEAs) to serve numerous human purposes under the background of increasing food demand due to population growth were a trend of social development and it is one of the top causes of the recession in the global forests (Jinquan *et al.*, 2020; Negasa *et al.*, 2017). LUMPs can cause negative effects on the properties and composition of soil, leading to soil degradation and further ecosystem imbalance (Fachin *et al.*, 2021; Hung *et al.*, 2017). According to Qi *et al.* (2018), land reclamation activities for the purpose of agricultural expansion can negatively affect nutrient uptake of soil. LUMPs are expected to strongly influence the processes and capacity of the ecosystem, causing the change in soil functions (Arévalo-Gardini *et al.*, 2015; de Blécourt *et al.*, 2019). Hence, variation in soil properties as an inevitable consequence of LUMPs has caught much attention worldwide (Amonum *et al.*, 2019; Zajicova and Chuman, 2019). It is assessed as a critically important issue for maintaining, managing and restoring the ecosystem (Tesfaye *et al.*, 2016; Li *et al.*, 2020; Wu *et al.*, 2018).

Understanding the environmental consequences of land use conversion is critical for maintaining ecosystem functions (de Souza *et al.*, 2016; Wu *et al.*, 2018). Therefore, the conversion of land use from natural to agricultural ecosystems can cause substantial changes in the properties and other functions of soil (Amonum *et al.*, 2019; Francisco *et al.*, 2021). According to Zajicova and Chuman (2019), LUMPs can affect not only the nutrient composition of soil but also the imbalance in the ecosystem. Numerous studies reveal that the concentration of total carbon (TC) is affected by many factors, but the LUMPs are an important factor, leading to the altering in organic carbon input (Anderson *et al.*, 2017; Zissimos *et al.*, 2019). According to Zhou *et al.* (2019), soil texture is an important factor that influences the accumulation of soil organic matters while the bulk density (BD) reflects the size, shape and arrangement of particles. The soil pH is considered a factor that governs total carbon content (Hong *et al.*, 2019; Jinquan *et al.*, 2020). Ebeling *et al.* (2016) reported that lands disturbed due to uncontrolled reclamation activities can take up to 20 years or more to self-fully recover.

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The AEAs to serve the increasing demands of local socio-economic development have caused numerous challenges in terms of land degradation for Lam River Basin (LRB), Vietnam. The effect of LUMPs on the properties and soil functions have not been assessed to contribute to the effective management of land resources as well as maintaining harmonious land-forest resources. This study investigates the effects of the LUMPs on the LRB as an insight case in the context of the forest lands being uncontrollably employed for AEAs and infrastructure construction.

MATERIALS AND METHODS

The study area is within the Lam River Basin (LRB), which is located in northeastern Nghe An province, Vietnam (17°50′-20°50′N and 103°14′-106°10′E) and it covers an area of 17730 km^2 (Fig 1). The geography is gradually tilted from northern to southern and eastern to western; the altitudes from 120 a.m.s.l to 1200 m a.m.s.l and strongly separated with three typical zones the plains, midlands and highlands (Nguyen *et al.*, 2021; Hung *et al.*, 2017). There areas of forestry, agricultural lands and other types of land are irregularly distributed on the whole study basin (Dinh and Sima, 2022; Dung *et al.*, 2021). The area has a tropical monsoon climate which comprises a dry season and a rainy season all year round, creating the background of a mean annual temperature approximately of 24.5°C, rainfall of about 2100 mm and a relative humidity of 85% (Nguyen *et al.*, 2021).

To achieve the aim of this study, ninety-six soil samples were collected at seven sites in the subsoil layer, representing one natural forest lands (NFLs) (the ST1 site: bamboo forest), four plantation forest lands (PFLs) (the ST2, ST3, ST5 and ST6 sites) and two bare lands (the ST4 and ST7 sites) (Table 1). Specifically, collected soil samples (CSS) at the ST1 site represents the NFLs where the lands have not been reclaimed and the bamboo forests are presenting while the ST2, ST3, ST5 and ST6 sites represent the PFLs where the lands have been reclaimed using the slash-and-burn agriculture and clear-cutting using heavy machinery for agricultural expansion (*e.g.*, acacia, cassava and grass) and the ST4 and ST7 sites represent the bare land after the lands have been reclaimed.

Soil samples were perceived as plastic bags under dry air state with low humidity and signified appropriately in such a way that it is possible to safeguard and evade confusion. To analyze texture, the centrifuge method, sieving in combination with hydrometer analysis were applied. Accordingly, to remove the gravel, plant roots and organic matter, hydrogen peroxide (H_2O_2) method was used adding 10 ml of H_2O_2 and mixing them together at 80°C until no more frothing occurs. The samples were dried in the oven at 105°C for 24 hours and then sieved using the 2.0 mm diameter sieving device. The international soil classification system (ISSS) was used to cataloge soil texture as shown in Table 2.

The current study applied the cylinder method to determine the BD through subtraction between two weights of the samples after drying in a conventional oven at 105°C. There were two types of cylinders used including one cylinder with height (h_1=5.1 cm) and volume (V_1=100 cm^3) and the second one with height (h_2=2.55 cm) and volume (V_2=50 cm^3), respectively. The internal diameter of each cylinder (d) was the same 5.0 cm (r = 2.5 cm). Dry soil weight (W_D) is defined by Eq. 1.

$$W_D = W_2 - W_1 \quad ....(1)$$

Where,

W_1 - The weight of an oven-proof container.

W_2 - The weight of the sample after dried in a conventional oven at 105°C.

And soil volume (V_s) is defined by Eq. 2.

$$V_s = 3.14 \times r^2 \times h \quad ....(2)$$

Where:

r – The radius of the sampling tube.

h – The height of the sampling tube.

Finally, BD was estimated dividing the dry weight of soil by the soil volume (de Souz *et al.*, 2016).

$$BD = \frac{W_D}{V_s} \quad ....(3)$$

Where:

W_D - The dry weight of soil.

V_s - The soil volume.

The soil pH (H_2O) was measured using the electrode pH meter (PCE-228) based on extracting the soil with deionized water at a ratio of 1:5 (soil: water, w: v) and shaking for 10 gram of air-dried mineral soil (< 2 mm) with 50 ml distilled water in 30 minutes (Phuong *et al.*, 2020). Base cations BCs (K^+, Ca^{2+} and Mg^{2+}) are enucleated using the neutral normal ammonium acetate at rate 1:5 of soil (1N CH_3COONH_4, pH 7.0) by the EDTA-(Ethylene Diaminete Traacetic Acid) titration method while total nitrogen (TN) was determined by dry combustion using C-N coder equipment (CORDER MT–700, Yanaco, Japan) and total phosphorus (TP) was measured by Olsen’s sodium bicarbonate extraction method after ashing at 560°C for 8 hours and dissolving with HCl 50% (Phuong *et al.*, 2020; Marty *et al.*, 2017).

One-way ANOVA followed by a test HSD of Tukey was applied to assess the effect of LUMPs on the properties and compositions of soil. In addition, correlation analysis between variables was conducted using Pearson correlation with different significance levels (*i.e.*, p = 0.001, 0.01 and 0.05) based on the function “rcorr” from “Hmisc” package and the linear model function with R statistical software (Version R3.4.2).

RESULTS AND DISCUSSION

Analysis results of soil properties from ninety-six CSS at seven sites cross the LRB were presented in Table 3. For soil texture, results point out that the average percentage of

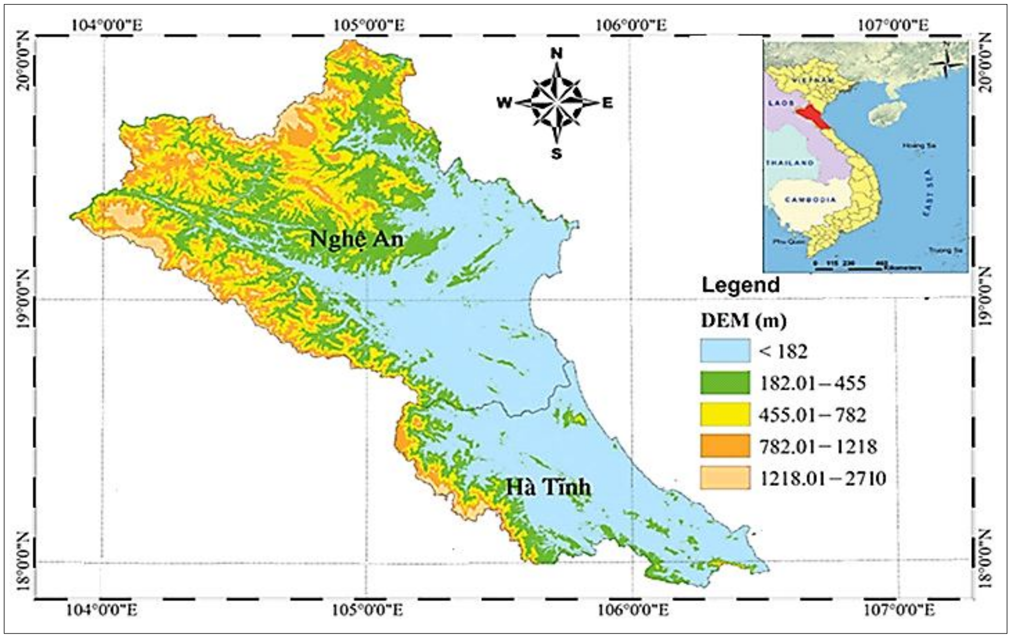

Fig 1: Illustration of the study area (Source: Nguyen *et al.*, 2021).

Table 1: General description of collected sample positions.

Sampling point	Latitude (N)	Longitude (E)	Land use type	Describe the history of the land.
ST1	18°45′10.86″	105°12′31.45″	Bamboo forest	0-60 cm: Natural forest land with the presence of bamboo.
ST2	18°45′15.60″	105°12′16.60″	Cassava field	0-60 cm: Plantation forest land was reclaimed and then cassava was sown during the period 2007-2017.
ST3	18°45′17.83″	105°12′22.75″	Acacia field	0-60 cm: Plantation forest land was reclaimed and then acacia was planted during the period 2007-2017.
ST4	18°45′10.41″	105°12′19.76″	Bare land	0-60 cm: Plantation forest land was reclaimed and maintain the state of bare land in the stage 2007-2009.
ST5	18°45′06.60″	105°12′30.80″	Acacia field	0-60 cm: Plantation forest land was reclaimed and then acacia is planted in the period 2010-2017.
ST6	18°45′01.20″	105°07′23.26″	Cassava field	0-60 cm: Plantation forest land was reclaimed and then acacia and cassava are planted in the stage 2010-2017.
ST7	18°45′12.42″	105°12′18.00″	Bare land	0-60 cm: Plantation forest land was reclaimed and then maintain the state of bare land in the stage 2007-2009.

sand, clay and silt representing the CSS are 37.66, 48.43 and 13.91%, respectively in the topsoil layer. There is no significant difference in the soil texture between the CSS (*e.g.,* 33.1~43.4% for sand, 44.6~51.4% for clay and 10.3~17.6% for silt). Among the CSS, the percentage ratio of sand at the ST7 site is the highest up to 43.4%, followed by ST4 site with 39.9% while the ST3 site recorded the lowest percentage ratio of sand (approximately 33.1%). The main reasons are that the topsoil layer at the ST7 and ST4 sites have been reclaimed and maintained in the state of bare lands during the stage 2007-2009 clay and silt are, therefore, washed away by weathered (*i.e.*, wind and heavy rainfall events) while the soil at the ST3 site was covered acacia fields.

Although clay and silt are smaller in size than sand and easily washed away by rainfall and wind weathering, they still maintain a high proportion of CSS at the ST3 site. Overally, the soil texture is predominantly by clay and sand in the topsoil layer (Fig 2). Results indicate that the average percentage of sand, clay and silt representing the CSPs are 37.77, 49.33 and 12.90%, respectively (Table 4). Among the CSS, the percentage ratio of sand at the ST7 site is the

Table 2: Soil texture categorized based on the international ISSS.

Particle	Soil texture classifications
Clay	< 2 µm
Slit	2-20 µm
Sand	20-2000 µm
Fine sand	20-200 µm
Coarse sand	200-2000 µm

Source: Tomoki *et al.* (2020).

Table 3: Properties of soil at collected sample sites in the topsoil layer.

Sampling point	BD	pH	K^+	Mg^{2+}	Ca^{2+}	TC	TN	TP	C/N	Sand	Silt	Clay
				(g kg^{-1})			(g kg^{-1})				(%)	
ST1	0.87	4.4	0.08	0.11	0.34	24.11	2.80	0.19	8.44	35.7	17.6	46.8
ST2	1.07	4.58	0.09	0.09	0.14	23.91	2.28	0.14	10.46	33.1	15.5	51.4
ST3	0.97	4.59	0.08	0.06	0.07	22.70	2.49	0.08	9.09	32.9	16.8	50.4
ST4	1.03	3.87	0.09	0.09	0.08	19.29	2.01	0.17	9.56	39.9	14.4	45.6
ST5	1.06	3.81	0.08	0.11	0.16	19.17	2.04	0.15	9.23	39.1	10.9	50.1
ST6	1.32	4.71	0.08	0.08	0.08	18.15	1.80	0.14	9.85	39.5	10.3	50.3
ST7	1.19	4.18	0.07	0.05	0.04	14.37	1.62	0.10	8.57	43.4	11.9	44.6
Average	1.07	4.31	0.08	0.08	0.13	20.24	2.15	0.14	9.31	37.66	13.91	48.43

Table 4: Properties of soil at collected sample sites in the subsoil layer.

Sampling point	BD	pH	K^+	Mg^{2+}	Ca^{2+}	TC	TN	TP	C/N	Sand	Silt	Clay
				(g kg^{-1})			(g kg^{-1})				(%)	
ST1	1.16	4.64	0.05	0.02	0.02	9.22	1.46	0.14	6.28	35.6	16.7	47.7
ST2	1.30	4.77	0.05	0.03	0.04	6.64	1.00	0.09	6.68	34.9	11.9	53.2
ST3	1.11	4.61	0.05	0.03	0.03	12.71	1.67	0.11	7.76	33.7	20.7	45.6
ST4	1.03	3.87	0.09	0.09	0.08	10.78	2.01	0.17	9.98	39.9	14.4	45.7
ST5	1.21	3.97	0.05	0.11	0.05	10.26	1.26	0.08	8.14	38.0	9.9	52.1
ST6	1.34	4.85	0.05	0.03	0.03	7.79	0.95	0.11	8.16	39.6	7.9	52.5
ST7	1.32	3.97	0.06	0.03	0.03	6.13	1.02	0.07	6.06	42.7	8.8	48.5
Mean	1.21	4.38	0.06	0.05	0.04	9.08	1.34	0.11	7.58	37.77	12.90	49.33

highest at 42.7%, followed by the ST4 site with 39.9% while the ST3 site recorded the lowest percentage ratio of sand (37.7%) (Fig 3). The main cause is that the forest lands at the ST7 and ST4 sites have been reclaimed and maintained in the state of bare lands during the stage 2007-2009. Clay and silt, therefore, have faced the high-risk potential of being washed away by heavy rainfall events and especially rainfall that occurred in the tropical typhoon periods. While the land at the ST3 site was covered with acacia forest after the land was reclaimed clay and silt, therefore, have less washed away by rainfalls and they occupy a high percentage ratio in texture.

There is no significant difference in the percentage ratio of sand (34.9~39.6%) at the ST1, ST2, ST5 and ST6 sites (Fig 3) in the the CSPs. The main reason is that the forest land of those were covered by bamboo, cassava and acacia. The land land at those positions is, therefore, less disturbance. According to Hong *et al.* (2019), the average contents of samples commonly contain more sand and clay in the subsoil layer while the silt is less than those of samples in the topsoil layer. From the perspective of soil texture and the difference between the percentage of clay, silt and sand ratios, it is confirmed that texture in the below soil layers 20 cm across the study area is relatively stable and there is no significant difference in sand, clay and silt. The analysis pointed out that the average value of BD in the topsoil layer is around 1.07 Mg m^{-3}, in there the lowest value of BD is detected as 0.87 Mg m^{-3} at the ST1 site while the highest value is defined up to 1.32 Mg m^{-3} at the ST6 site, followed by the ST7 site with 1.19 Mg m^{-3} (Table 3).

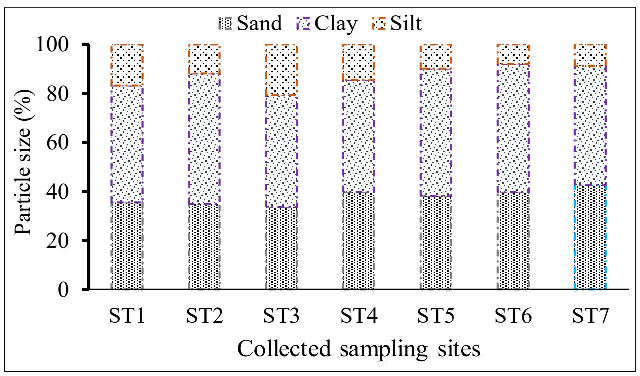

Fig 2: Soil particle size among different collected samples sites in the topsoil layer.

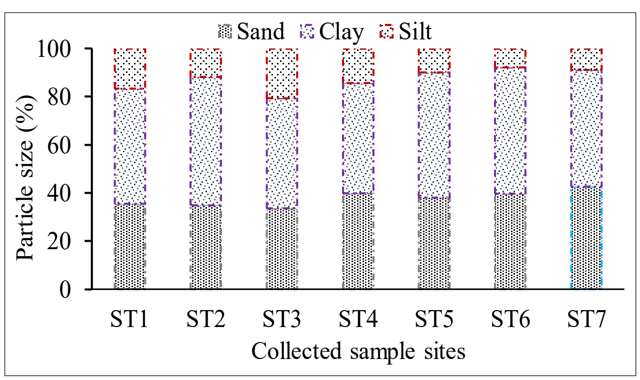

Fig 3: Soil particle size among different collected samples sites in the subsoil layer.

The main reason is that the forest land at the ST3 site has not been reclaimed maintaining in the state of the covered bamboo forest and they are, therefore, less compacted by anthropogenic activities on the surface. While the forest land at the ST6 and ST7 sites has been reclaimed to serve the requests of expanding agriculture of local people (*e.g.*, acacia and cassava crops) and they are, therefore, effected by anthropogenic activities (Table 1). According to de Souza *et al.* (2016), LUMPs can greatly cause compaction in the topsoil layer. The BD was less variable (1.03~1.34 Mg m^{-3}) for CSPs. The lowest value of BD was recorded at the ST4 site (1.03 Mg m^{-3}) while the highest value recorded up to 1.34 Mg m^{-3} at the ST6 site. The results demonstrated that BD is less affected by anthropogenic activities in the subsoil layer. A study on variation of soil properties in the Yellow River Delta, China by Jiao *et al.* (2020) reported that significant difference of BD of soil were occurred in the topsoil layer.

The analysis pointed out that the soil pH is lower than five at all CSPs, ranging from 4.4 to 4.7 in the topsoil layer while similar results were also recorded in the subsoil layer and soil pH tends to slightly increase with increasing soil depth. According to Hong *et al.* (2019), the soil pH in the topsoil layer is commonly lower in the subsoil layer because it is commonly rich in organic matter and the decomposition of organic matter will lead to the production of more organic acids. Generally, soil pH is mildly acidic and less dominated by LUMPs.

For total organic contents (TOCs), the results indicated that the values of total carbon (TC), total nitrogen (TN) and total phosphorus (TP) were approximately 20.24, 2.15 and 0.14 g kg^{-1} in the topsoil layer (Fig 4A, B, C, D, E, F, G). The highest value of TOCs (TC: 24.11, TN: 2.80 and TP: 0.19 g kg^{-1}) was recorded at the ST1 site (Fig 4A), followed by the ST2 site (TC: 23.91, TN: 2.28 and TP: 0.14 g kg^{-1}) (Fig 4B) while their lowest value (TC:14.37, TN: 1.62 and TP: 0.08 g kg^{-1}) were detected at the ST3 and ST7 sites (Fig 4C, G). The TOCs in the forest lands are higher than that from other kinds of lands, because it is plant residues and animal material that provide raw materials to produce TC, TN and TP in the topsoil layer.

For subsoil layer, the average values of TC, TN and TP were around 9.08, 1.34 and 0.11 g kg^{-1}, respectively while their highest value 10.78, 2.01and 0.17 g kg^{-1} were recorded at the ST4 site and their lowest value 6.13, 0.95 and 0.07 g kg^{-1} were detected at the ST6 and ST7 sites (Table 4). In general, TOCs decrease along with subsoil layer (Fig 4H, I, J, K, L, M, N). Results indicated that the C/N ratios were less distinctive between all the SCPs (from 8.44 to 10.46 g kg^{-1}) in the topsoil layer. The lowest C/N ratio recored at the ST1 site (bamboo forest) where the lands have not been reclaimed and it maybe, therefore, receive less organic matter while the highest C/N ratio recorded at the ST2 site where the lands were reclaimed by slash-and-burn agriculture and using heavy machinery to clear-cut and then cassava and acacia were alternately planted during the period 2007-2017. The C/N ratio has recorded a slight downtrend in the subsoil layer, except for the ST7 site which has fallen from 8.57 down to 6.06 g kg^{-1} (Table 3).

Analysis indicated that the concentration of BCs (Ca^{2+}, Mg^{2+} and K^+) ranges from 0.04±0.001 to 0.34±0.003; 0.05±0.002 to 0.11±0.004 and 0.07±0.001 to 0.09±0.003 g kg^{-1} in the topsoil layer (Fig 5A). The highest value of BCs (Ca^{2+}: 0.34± 0.003, Mg^{2+}: 0.11± 0.004 and K^+: 0.09± 0.003 g kg^{-1}) was defined at the ST1 and ST2 sites while their lowest value (Ca^{2+}: 0.04± 0.001, Mg^{2+}: 0.05±0.002 and K^+: 0.07±0.001 g kg^{-1}) were found at the ST7 site. For subsoil layer, Ca^{2+}, Mg^{2+} and K^+ ranges from 0.02±0.001 to 0.08±0.002, 0.02±0.001 to 0.11±0.002 and 0.05±0.003 to 0.09±0.003 g kg^{-1}, respectively. The BCs slightly var-^{1}) and ST5 site (Mg^{2+}: 0.11±0.004 g kg^{-1}). In general, a slight downward trend in the subsoil layer recorded from 0.08±0.002 to 0.05±0.002 g kg^{-1} for Mg^{2+} and 0.08±0.003 to 0.06±0.002 g kg^{-1} for K^+ and a significant downward trend from 0.013±0.005 to 0.04±0.004 g kg^{-1} recorded for Ca^{2+} (Fig 5B). Generally, the low values of BCs may be caused by soil nutrient losses through anthropogenic activities (cultivation, harvesting) and climatic factors that can contribute to mobilization and immobilization of these cations.

The BD has a positive correlation with chemical properties of soil (TOMs and BCs) (Table 5). Pearson's

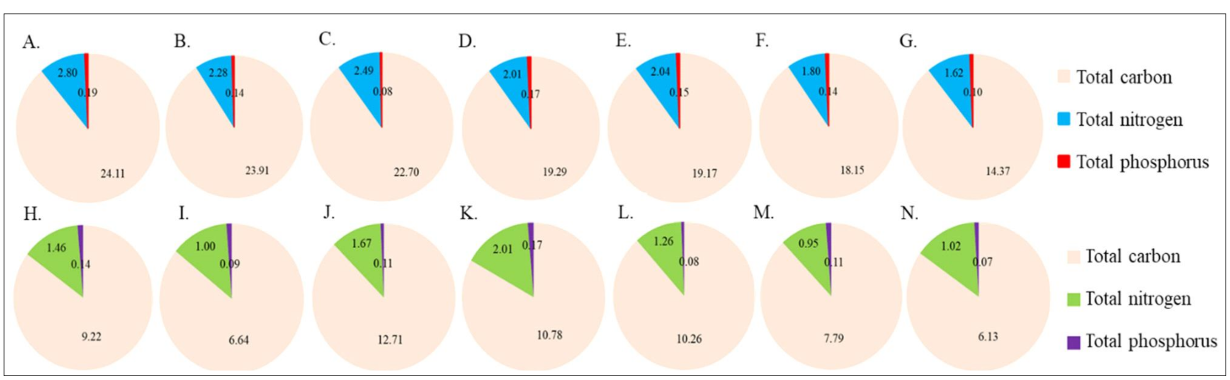

Fig 4: Total organic contents of collected sampling sites of the (A) ST1, (B) ST2, (C) ST3, (D) ST4, (E) ST5, (F) ST6 and (G) ST7 sites in the topsoil layer and (H) ST1, (I) ST2, (J) ST3, (K) ST4, (L) ST5, (M) ST6 and (N) ST7 sites in the subsoil layer.

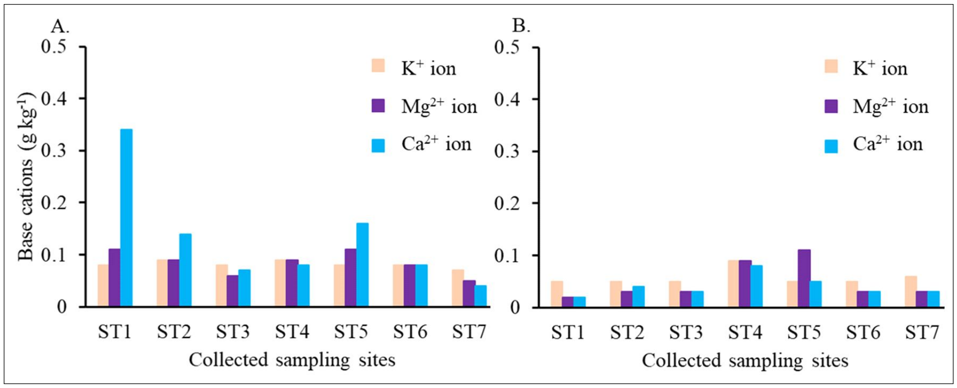

Fig 5: Base cations of collected sampling sites in the (A) topsoil layer and (B) subsoil layer.

Table 5: Pearson correlation between bulk density, soil pH with TOMs and BCs.

	ST1	ST2	ST3	ST4	ST5	ST6	ST7
Correlation between bulk density with total organic matters and base cations							
TC	-0.96A	-0.90	-0.70	-0.69	-0.45	-0.67	-0.96A
TN	-0.97A	-0.92	-0.60	-0.81	-0.43	-0.66	-0.97A
TP	-0.92	-0.90	-0.13	-0.77	-0.51	-0.63	-0.93
K^+	-0.98A	-0.85	-0.84	-0.74	-0.11	-0.82	-0.60
Ca^{2+}	-0.73	-0.69	-0.44	-0.55	-0.32	-0.85	-0.95A
Mg^{2+}	-0.82	-0.88	-0.54	-0.59	-0.39	-0.53	-0.97A
Correlation between pH with total organic matters and base cations							
TC	-0.66	-1.00B	-0.05	0.42	-0.82	-0.30	-0.86
TN	-0.68	-1.00C	0.17	0.52	-0.86	-0.30	-0.79
TP	-0.62	-0.97A	-0.76	0.88	-0.97A	-0.33	-0.42
K^+	-0.68	-0.95A	-0.71	0.22	-0.81	0.07	-0.30
Ca^{2+}	-0.25	-0.86	-0.61	0.17	-0.80	-0.38	-0.65
Mg^{2+}	-0.41	-0.99A	-0.87	0.08	-0.88	-0.40	-0.86

Notes: A, B and C are correlation at the 0.05, 0.01 and 0.001 significant level.

correlation indicated that the BD was negatively correlated with chemical properties of soil at significantly levels (p = 0.05, 0.001 and 0.0001). This means that the BD at CSPs decreases the BCs and TOMs in the soil also decreases. Pearson's correlation revealed that the soil pH was negatively correlated coefficients with chemical properties of soil at (p = 0.05, 0.001 and 0.0001) significantly levels (Table 5). One exception is that the soil pH at the ST4 site is positively correlated with chemical properties of soil including TOMs (TC: 0.42, TN: 0.52 and TP: 0.88) and BCs (K^+: 0.22; Ca^{2+}: 0.17 and Mg^{2+}: 0.08). This means that the soil pH in the most CSPs decreases and the BCs as well as TOMs in the soil also decreases, except at the ST4 site. Pearson correlation between soil texture with TOMs and BCs was presented in Table 6. For sand, negative correlations were found between sand with BCs (Ca^{2+}: -0.87~-0.73, Mg^{2+}: -0.96~-0.67 and K^+: -0.93~-0.71) and with TOMs (TC: -0.98~-0.66, TN: -0.97~-0.63 and TP: -0.92~-0.59) at the ST1 and ST2 sites while positive correlations were defined between sand with BCs (Ca^{2+}: 0.32~0.84, Mg^{2+}:0.18~0.92 and K^+: 0.007~-0.92) and with TOMs (TC: 0.26~0.87, TN: 0.25~0.81 and TP: 0.24~0.83) at all CSPs, except at ST1 and ST2 sites. This implies that the percentage of sand at the ST1 and ST2 sites decreases, the concentration of BCs and TOMs at the CSPs also decreases while the percentage of sand increases, the concentration of BCs and TOMs of the CSPs also increase.

Negative correlations were found between clay with BCs (Ca^{2+}: -0.97~-0.51, Mg^{2+}: -0.98~-0.47 and K^+: -0.76~-0.007) and with TOMs (TC: -0.97~-0.18, TN: -0.97~-0.17 and TP: -0.89~-0.34) at all the CSPs, except for ST3 site. Positive correlations were recorded at the ST3 site between clay with BCs (Ca^{2+}: 0.30, Mg^{2+}: 0.06 and K^+: 0.32) and with TOMs (TC: 0.78 and TN: 0.85). It means that the percentage of clay at the ST3 site increases the concentration of BCs and TOMs will increases while negative correlation coefficients expose that the percentage of clay at other remaining sites decreases, the concentration of BCs and TOMs also decreases. Negative correlations were pointed out between silt with BCs (Ca^{2+}: -0.82, Mg^{2+}: -0.95 and K^+: -0.95) and with TOMs (TC: -0.56, TN: -0.37 and TP: -0.48) at the ST3 site while high positive correlations were recorded at the ST1 and ST2 sites between silt with BCs (Ca^{2+}: 0.78~0.89, Mg^{2+}: 0.60~0.72 and K^+: 0.65~0.68) and with

Table 6: Pearson correlation between soil texture with TOMs and BCs.

	ST1	ST2	ST3	ST4	ST5	ST6	ST7
			Correlation between sand with total organic matters and base cations				
TC	-0.66	-0.98A	-0.015	0.74	0.47	0.26	0.87
TN	-0.63	-0.97A	-0.24	0.72	0.42	0.25	0.81
TP	-0.59	-0.92	0.83	0.25	0.40	0.24	0.44
K^+	-0.71	-0.93	0.65	0.92	0.007	0.31	0.31
Ca^{2+}	-0.73	-0.87	0.57	0.84	0.32	0.54	0.68
Mg^{2+}	-0.67	-0.96A	0.83	0.92	0.35	0.18	0.87
			Correlation between clay with total organic matters and base cations				
TC	-0.18	-0.64	0.78	-0.74	-0.66	-0.75	-0.97A
TN	-0.17	-0.62	0.85	-0.68	-0.66	-0.74	-0.97A
TP	-0.34	-0.78	-0.57	-0.78	-0.73	-0.75	-0.89
K^+	-0.007	-0.76	0.32	-0.45	-0.38	-0.51	-0.63
Ca^{2+}	-0.51	-0.72	0.30	-0.65	-0.56	-0.84	-0.97A
Mg^{2+}	-0.47	-0.69	0.06	-0.51	-0.63	-0.76	-0.98A
			Correlation between silt with total organic matters and base cations				
TC	0.70	0.99B	-0.56	0.44	0.53	0.83	0.58
TN	0.67	0.99B	-0.37	0.38	0.62	0.83	0.64
TP	0.69	0.98A	-0.48	0.67	0.82	0.85	0.92
K^+	0.68	0.96A	-0.95A	0.08	0.89	0.46	0.65
Ca^{2+}	0.89	0.86	-0.82	0.31	0.62	0.75	0.78
Mg^{2+}	0.82	0.98A	-0.95A	0.14	0.71	0.91	0.60

Notes: A, B and C are correlation at the 0.05, 0.01 and 0.001 significant level.

TOMs (TC: 0.58~0.70, TN: 0.64~0.67 and TP: 0.69~0.92) and positive correlations were found between silt with BCs (Ca^{2+}: 0.31~0.75, Mg^{2+}: 0.14~0.91 and K^+: 0.08~0.89) and with TOMs (TC: 0.44~0.83, TN: 0.38~0.83 and TP: 0.67~0.85) at the ST4, ST5 and ST6 sites. Positive correlation coefficients between silt with TOMs and BCs expose that the percentage of silt at the CSPs increases the concentration of BCs and TOMs will increases while negative correlation coefficients will reflect the opposite trend. Overall, the sand is one of the soil components was a high correlation with other properties of soil while the clay and silt were not significantly correlated with other properties of soil.

CONCLUSION

The land use and management practices dominated significantly the texture of soil in the surface layer across the study area. The sand, clay ratios and bulk density in the plantation forest and bare lands were higher in the natural forest lands for the topsoil layer. The soil containing less silt has higher base cations and total organic contents in the the topsoil layer while those values were not different in the subsoil layer. Bulk density, soil pH and clay tend to be negatively correlated with total organic matters and base cations in most soil profiles, revealing the link relationship between Bulk density, soil pH and clay and total organic matters and base cations. In the assessment of the properties and composition of the soil, the research shed light on the variations of soil properties influenced by land use and management practices of the forest land regions across the study area.

Conflict of interest

Authors confirm that we have no conflict of interest.

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