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Investigating the Long-Term Effects of Anthropogenic Practices on Soil Features

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सार – सामाजिक-आर्थिक विकास की बढ़ती मांगों को पूरा करने के लिए मानवजनित प्रथाओं का तेजी से संचालन किया जा रहा है, जिसके परिणामस्वरूप भूमि पारिस्थितिकी तंत्र पर महत्वपूर्ण प्रभाव पड़ रहा है। यह शोध वियतनाम के पहाड़ी क्षेत्रों में मिट्टी की विशेषताओं पर मानवजनित गतिविधियों के प्रभाव का मूल्यांकन करने का प्रयास करता है, जिसमें लैम नदी बेसिन में 12 स्थानों से एकत्र किए गए 84 नमूनों पर ध्यान केंद्रित किया गया है, जो सात मिट्टी प्रोफाइल (0-10, 10-20, 20-30, 30-40, 40-60, 60-80 और 80-100 सेमी) पर आधारित हैं।

निष्कर्षों से भूमि उपयोग प्रकारों (LUTs) के बीच मिट्टी की बनावट में उल्लेखनीय अंतर का पता चलता है। वन आच्छादित भूमि (FCLs) में रेत की मात्रा सबसे कम थी, जो 29.7% से 37.6% तक थी, जबकि बिना बोए और खाली भूमि (UBLs) में रेत का अनुपात सबसे अधिक था, जो 53.9% तक था। FCLs में सबसे कम थोक घनत्व (BD), मिट्टी की सरंध्रता (SP) और मिट्टी की विद्युत चालकता (EC) और C:N अनुपात क्रमशः 0.93-1.29 g.cm^{-3}, 32.7-36.5%, 0.526-0.743 mS.m^{-1} और 6.74 -8.52 की संबंधित श्रेणियों के साथ प्रदर्शित हुआ।

इसके विपरीत, फसल की खेती वाली भूमि (सीसीएल) ने बीडी (1.17-1.25 ग्राम.सेमी^{3}), एसपी (39.25-43.19%), ईसी (0.583-0.792 एमएस.एम$^{-1}$) और सी:एन अनुपात (11.27-15.77) के लिए उच्च मूल्यों का प्रदर्शन किया। दूसरी ओर, यूबीएल ने 1.23-1.36 ग्राम.सेमी$^{-1}$, 43.19-49.62%, 0.437-0.619 एमएस.एम$^{-1}$ और 11.68-16.58% तक उच्चतम मूल्यों का प्रदर्शन किया और एफसीएल की तुलना में एक्सचेंज आयरन और मिट्टी में कार्बनिक सामग्री के उच्च स्तर को प्रदर्शित किया। अन्य कारक जैसे पीएच नमूने की गई मिट्टी के स्थानों और मिट्टी की प्रोफाइल के बीच की जगह में बहुत कम भिन्न थे। कुल मिलाकर, अध्ययन से संकेत मिलता है कि मानवजनित प्रथाओं का अध्ययन क्षेत्र में मिट्टी की विशेषताओं पर प्रभाव पड़ता है।

ABSTRACT. Anthropogenic practices have been increasingly conducted on the rise in addressing the escalating demands for socioeconomic development, resulting in significant impacts on land ecosystems. This research seeks to evaluate the influence of anthropogenic activities on soil features in mountainous regions of Vietnam by focusing 84 samples collected from 12 locations across Lam River Basin at seven soil profiles (0-10, 10-20, 20-30, 30-40, 40-60, 60-80 and 80-100 cm).

The findings reveal notable differences in soil texture among land use types (LUTs). Forest cover lands (FCLs), showed the least amount of sand content, varying from 29.7% to 37.6%, while unplanted and bare lands (UBLs) had the highest sand ratios, up to 53.9%. FCLs exhibited lowest bulk density (BD), soil porosity (SP) and soil electrical conductivity (EC) and C:N ratio with respective ranges of 0.93-1.29 g.cm^{-3}, 32.7-36.5%, 0.526-0.743 mS.m^{-1} and 6.74 -8.52, respectively.

In contrast, crop cultivation lands (CCLs) demonstrated higher values for BD (1.17-1.25 g/cm^{3}), SP (39.25-43.19%), EC (0.583-0.792 mS.m^{-1}) and C:N ratio (11.27-15.77). UBLs, on the other hand, exhibited even highest values up to 1.23-1.36 g.cm^{-1}, 43.19-49.62%, 0.437-0.619 mS.m^{-1} and 11.68-16.58% and displayed high levels of exchange irons and soil organic content compared to FCLs. Other factors such as pH varied little in space between the sampled soil locations and along the soil profiles. Overall, the study indicates that anthropogenic practices have impacts on the soil features across the study area.

Key words – Anthropogenic practices, Features, Land, Properties, Soil texture.

1. Introduction

Globally, anthropogenic practices, commonly driven by economic and societal needs, have the potential to significantly degrade soil health, with cascading consequences for terrestrial ecosystems & the vital services they provide (Arévalo-Gardini *et al*., 2015; Zajicova & Chuman, 2019). Anthropogenic practices such as slash & burn agriculture, timber extraction & other land-use conversions, while serving important human demands (Xu *et al*., 2021; Nguyen *et al*., 2024), have emerged as major drivers of environmental degradation globally (Zajicova & Chuman, 2019). These anthropogenic pressures can severely impair the ability of soils to function effectively (de Souza *et al*., 2016), leading to growing interest in understanding how anthropogenic practices alter soil features & their functions (Arévalo-Gardini *et al*., 2015; de Souza *et al*., 2016).

Effective conservation, management, and restoration of ecosystems hinge on a clear understanding of how anthropogenic practices impact the environment (Dai *et al*., 2019; Oraon *et al*., 2018). Research has shown that anthropogenic practices, particularly those associated with agricultural expansion, can disrupt nutrient cycling and availability within soils (Qi *et al*., 2018; Jinquan *et al*., 2020). The presence and intensity of human-induced land use change can profoundly influence ecosystem functions and overall capacity, leading to alterations in soil features and behavior (Oraon *et al*., 2018). Consequently, understanding how human activities, particularly those leading to land use transformations, affect soil properties and functions has become a focal point of research worldwide (Joshi and Negi, 2015; Li *et al*., 2020). This understanding is paramount for guiding effective ecosystem management, conservation and restoration efforts (de Souza *et al*., 2016; Garrett *et al*., 2018). The conversion of natural ecosystems, such as forests, to agricultural systems commonly results in substantial changes in soil features (Garrett *et al*., 2018; Shiferaw *et al*., 2023). Moreover, anthropogenic practices not only influence soil nutrient status but also disrupt the delicate ecological balance within these systems (Jiao *et al*., 2020). Previous studies have identified anthropogenic activities as key drivers of changes in soil features (Jiao *et al*., 2020; Zhou *et al*., 2019).

The study area is facing the challenges posed by increasing demands for socio-economic development, where land degradation due to anthropogenic activities is a growing concern. The study aims to investigate the impacts of anthropogenic activities on soil features in Lam River Basin, a region characterized by extensive forest conversion for various LUTs, serving as a representative case study for understanding these complex interactions.

2. Material and methods

2.1. *Study area*

The study area, encompassing an area extending from 103°14’ to 106°10’ E longitude and 17°50’ to 20°50’ N latitude, spans approximately 350 km in length (Fig. 1). Characterized by a complex topography, the basin exhibits a general west-to-east sloping pattern, with elevations reaching their highest points along the Truong Son range in the west and gradually decreasing towards the east (Minh, 2019). Mean annual rainfall within the basin demonstrates considerable spatial variability, ranging from 1,039 to 2,899 mm (Tue *et al*., 2015; Minh, 2019).

The mountainous regions of the Lam River Basin generally possess relatively fertile soils, with soil depths often exceeding 60 cm (Minh, 2019; Nguyen *et al*., 2021). The soils are heterogeneously distributed and can be broadly classified into four main groups: alluvial soils, red, yellow ferality soils, coastal sands, and mangrove soils (Minh, 2019; Dinh and Shima, 2022).

Land cover within the Lam River Basin is highly diverse, encompassing extensive areas of broadleaf evergreen forest, regenerating forest, mixed bamboo forest, residential areas, shrubland, agricultural land, bare land, cultivated aquatic land, and other land uses (Nguyen *et al*., 2021). The average slope gradients within the sub-basins comprising the study area range from 1 to 40%, resulting in relatively long slope lengths (Dung *et al*., 2021; Nguyen *et al.*, 2022).

2.2. *Field survey and laboratory analyses*

Field investigations were undertaken to collect soil data for analysis. A total of 84 soil samples were collected from 12 random positions at depth soil profiles (0-10, 10-20, 20-30, 30-40, 40-60, 60-80 and 80-100 cm), representing three major LUTs, including FCLs, CCLs, and UBLs (Table 1). Four sites were sampled within each land cover category: SP1, SP2, SP3 and SP4 for FCLs; SP5, SP6, SP7 and SP8 for CCLs; and SP9, SP10, SP11, and SP12 for UBLs (Table 1).

Soil features were analyzed following established laboratory protocols (Dinh and Sima, 2022). Soil texture was determined using the USDA classification system (USDA NRCS, 2014). The soil's pH and EC were determined in a 1:5 soil-to-water suspension using a Hach-Lange multiparameter measurement approach. SP was calculated based on bulk density and particle density. Following field sampling, laboratory analyses were conducted to determine key soil chemical properties. Soil pH was measured in a soil - to - water suspension.

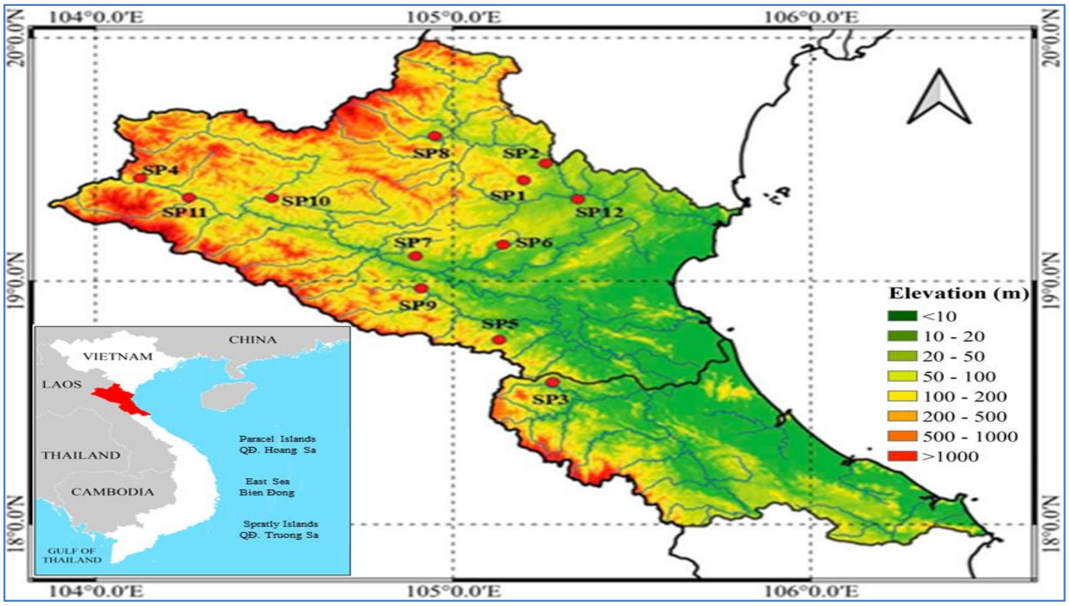

Fig. 1. Topographic map of the study area with investigation sampling positions marked red color.

TABLE 1

Fundamental features of soils under various land use types in the Lam River Basin

No.	Location	Latitude (N)	Longitude (E)	Land use types	Historical land use change
SP1	Quy Hop	19.4149	105.1980	Forest covered lands (FCLs)	The FCLs were characterized by a mixed-species composition, consisting of various pine family members, including Po Mu and Sa Mu. The FCLs have remained relatively undisturbed and have not experienced significant clearing.
SP2	Quy Chau	19.4843	105.2597		
SP3	Huong Son	18.7632	105.1883		
SP4	Ky Son	19.4233	104.1257		
SP5	Thanh Chuong	18.7589	105.1288	Crop cultivation lands (CCLs)	The areas originally under CCLs cover underwent a land use conversion, involving reclamation and subsequent rotational planting of acacia and cassava. During the phase of acacia cultivation, a dense understory of grasses established itself beneath the acacia canopy.
SP6	Tan Ky	19.1501	105.1401		
SP7	Con Cuong	19.1030	104.8955		
SP8	Que Phong	19.5966	104.9497		
SP9	Con Cuong	18.9706	104.9111	Unplanted and bare lands (UBLs)	In the early 21st century, the UBLs were subjected to further extensive land conversion. This period saw large-scale reclamation efforts, resulting in the transformation of these forested areas into predominantly UBLs. These converted areas are now characterized by a scarcity of vegetation cover and a marked absence of a developed topsoil layer.
SP10	Tuong Duong	19.3419	104.4938		
SP11	Ky Son	19.4162	104.1485		
SP12	Nghia Dan	19.4446	105.3021		

Soil organic content was determined using a dry combustion method, with samples heated at 550° C for 10 hours (USDA NRCS, 2014). Exchangeable iron concentrations were quantified using an ammonium acetate extraction method buffered at pH 7 (Locatelli *et al*., 2023).

Statistical analyses were performed using SPSS Statistics software (Version 24). To assess the influence of LUTs and soil layers on analyzing soil features, a one-way analysis of variance (ANOVA) was applied. Significant differences between mean values were identified using Duncan's multiple range test at a significance level of α = 0.05. Relationships between soil features were examined using Pearson's correlation analysis, also at a significance level of α = 0.05 (Zajicova and Chuman, 2019).

3. Results and discussion

3.1. *Descriptive statistics of soil properties*

Table 2 presents a summary of key statistical characteristics for the measured soil physical and chemical properties. Analysis of soil texture revealed mean sand,

TABLE 2

Based statistical features of the soil features in Lam River Basin

Type	Sampling	Minimum	Maximum	Average	Standard deviation	Coefficient of variation	Unit
Sand	108	30.6	51.2	43.4	8.4	19.13	%
Clay	108	14.5	36.8	44.7	5.7	12.05	%
Silt	108	11.7	27.3	11.9	3.9	24.8	%
BD	108	0.91	1.47	1.23	0.16	12.4	$g.cm^{-3}$
SP	108	35.8	51.7	44.6	5.13	12.7	%
pH	108	4.50	5.04	4.79	0.17	3.4	-
EC	108	117	15281	1926	2837	34.8	$\mu S.cm^{-1}$
Calcium	108	0.05	0.24	0.15	0.06	3.37	$Cmolc.kg^{-1}$
Magnesium	108	0.05	0.15	0.12	0.03	33.27	$Cmolc.kg^{-1}$
Potassium	108	0.07	0.11	0.07	0.03	21.18	$Cmolc.kg^{-1}$
Total P	108	0.08	0.30	0.13	0.04	23.19	$g.kg^{-1}$
Total N	108	0.92	2.83	1.71	0.56	34.2	$g.kg^{-1}$
Total C	108	13.23	21.41	18.15	2.46	13.37	$g.kg^{-1}$
C/N ratio	108	6.74	16.58	11.31	1.74	10.24	-

clay and silt contents of 43.4%, 44.7% and 11.9%, respectively. These results indicate that the soils in the study area are predominantly sandy clay in texture, with a relatively low silt fraction.

pH values ranged from 4.43 to 6.27, indicating slightly acidic soil conditions across the study area. Among the soil features examined, several exhibited relatively low variabilities, as reflected in their coefficients of variation (CV). These included sand content (CV = 18.98%), silt content (CV = 10.57%), bulk density (CV = 9.89%), EC (CV = 17.17%), pH (CV = 4.2%), exchangeable calcium (CV = 41.26%), and total carbon (CV = 12.57%). Moderate variability was observed for clay content (CV = 25.68%), exchangeable iron (CV = 21.82% for potassium), total organic carbon fractions (CV= 23.03% for total phosphorus and 32.22% for total nitrogen) and C: N ratio (CV = 27.25%).

The highest CV was associated with calcium iron (41.26%), followed by magnesium (32.68%) and total nitrogen (32.22%). These relatively high CV values suggest a degree of spatial heterogeneity in these soil properties across the study area. Specifically, total nitrogen and magnesium exhibited moderate spatial variability, with CV values over 32.00%.

3.2. *Analysis of soil properties*

Fig. 2 presented the soil texture for the LUTs investigated in this study. Clear differences in the relative proportions of sand, silt, and clay were observed between FCLs, CCLs and UBLs. FCLs exhibited mean sand, silt and clay percentages of 32.9%, 18.6% and 48.5%,

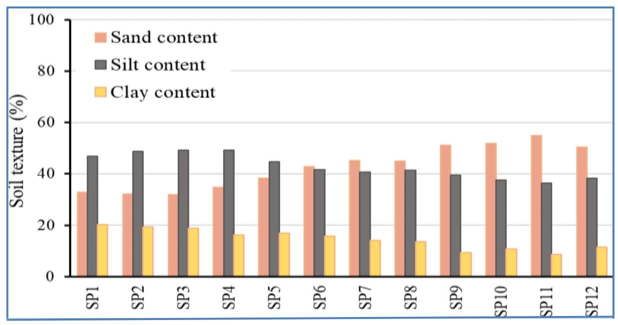

Fig. 2. Distribution of soil texture at all sampling positions across the study area.

respectively. In contrast, CCLs had higher sand content (average: 42.8%), lower silt content (average: 15.2%) and similar clay content (mean: 42.1%) compared to FCLs. UBLs showed the highest sand content (average: 52.1%), lowest silt content (average: 10.1%) and similar clay content (average: 37.8%) compared to both FCLs and CCLs.

Focusing on specific LUTs within these broader categories, FCLs characterized by the presence of Po Mu and Sa Mu, had the lowest sand contents, ranging from 31.8 ± 1.97% to 34.7 ± 2.03%. CCLs had sand content ranging from 38.3 ± 2.76% to 45.1 ± 3.745%, while UBLs exhibited the highest sand content (54.9 ± 4.08%) (Table 3). The lower sand content in FCLs compared to CCLs and UBLs is likely attributable to the removal of vegetation cover in the latter two LUTs due to anthropogenic activities. This loss of protective vegetation cover can increase the susceptibility of surface soils to erosion, leading to the preferential loss of finer soil particles like silt and clay during rainfall events.

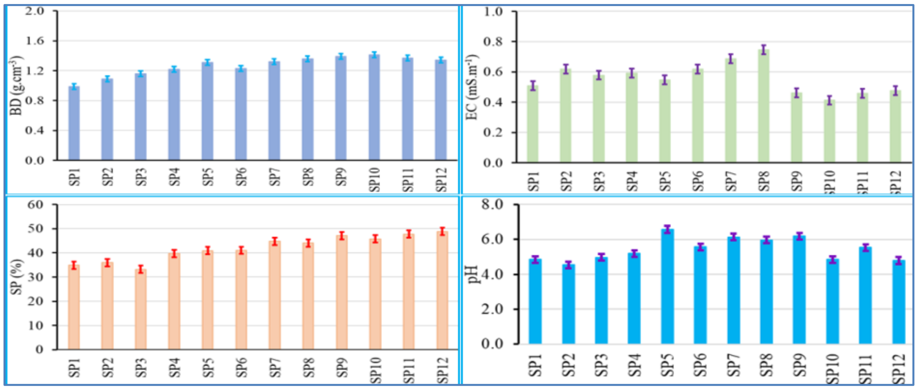

Fig. 3. Distribution of bulk density (BD), soil electrical conductivity (EC), soil porosity (SP) and soil pH at all sampling positions in Lam River Basin.

TABLE 3

Analysis results of soil texture, bulk density and soil porosity among collected sampling positions. Different letters such as A and B indicate a significant level 95% among collected sample positions

Site	Soil texture (%)			Bulk density ($g.cm^3$)	Soil porosity (%)
	Sand	Clay	Silt		
		(Ave. ± SD)		((Ave. ± SD)	(Ave. ± SD)
SP1	32.9±2.82B	20.2±1.73A	46.9±3.45B	0.99 ± 0.01A	34.93 ± 2.73A
SP2	32.1±2.71A	19.2±1.38B	48.7±4.18B	1.09 ± 0.02B	35.97 ± 3.19B
SP3	31.8±1.97A	18.9±1.17B	49.3±3.64A	1.16 ± 0.03B	33.16 ± 2.95B
SP4	34.7±2.03B	16.2±0.94A	49.1±4.01B	1.22 ± 0.03A	39.74 ± 3.11A
SP5	38.3±2.76A	16.9±1.14B	44.8±3.82B	1.31 ± 0.04B	40.93 ± 3.76B
SP6	42.7±3.09B	15.8±1.17B	41.5±3.79A	1.23 ± 0.03B	41.07 ± 3.72B
SP7	45.1±3.74B	14.2±0.97A	40.7±3.63A	1.32 ± 0.04A	44.82 ± 3.91A
SP8	44.9±2.97A	13.7±0.91B	41.4±3.75B	1.36 ± 0.03A	44.08 ± 3.78A
SP9	51.2±3.93A	9.4±0.78B	39.5±2.74B	1.39 ± 0.05B	47.13 ± 3.67B
SP10	51.8±3.84B	10.7±0.81A	37.3±2.46A	1.41 ± 0.04B	45.81 ± 3.92B
SP11	54.9±4.08A	8.7±0.69A	36.4±2.48A	1.37 ± 0.03A	47.76 ± 4.08A
SP12	50.3±4.32B	11.4±0.76B	38.3±3.01A	1.34 ± 0.04A	48.83 ± 4.15B

Bulk density is an important physical property influencing soil porosity, water retention & permeability. In this study, BD ranged from 0.99 ± 0.01 to 1.41 ± 0.04 g/cm^3. As shown in Fig. 3, CCLs exhibited BD values ranging from 1.23 ± 0.03 to 1.36 ± 0.03 $g.cm^{-3}$, while FCLs had a narrower range of 0.99 ± 0.01 to 1.22 ± 0.03 $g.cm^{-3}$. The highest BD (1.41 ± 0.04 $g.cm^{-3}$) was observed in UBLs. These findings suggest that soil BD is less variable in FCLs, where LUTs impact has been minimal. In contrast, CCLs and UBLs showed greater variation in BD, likely reflecting the influence of different land management practices and disturbance histories (Table 3). A slight increasing trend in BD with soil profiles was also observed, particularly at depths of 20-100 cm.

The influence of anthropogenic activities on soil compaction has been well-documented in the literature. For instance, de Souza *et al*. (2016) found that anthropogenic activities can lead to significant compaction in surface soil layers, with diminishing effects at greater depths. Soil porosity, a key factor influencing soil aeration, water infiltration and root growth, is intimately linked to BD and plays a crucial role in maintaining soil fertility (Zhou *et al*., 2019). Numerous studies have demonstrated the negative impacts of anthropogenic activities on soil porosity and overall soil function. Consistent with these findings, our study found that FCLs had lower soil porosity values, ranging from 33.16 ± 2.95 to 39.74 ± 3.11 $g.cm^{-3}$, compared to CCLs, which exhibited higher soil porosity values ranging from 40.93 ± 3.76 to 44.82 ± 3.91 $g.cm^{-3}$. The highest soil porosity values were observed in UBLs, reaching up to 48.83 ± 4.15 $g.cm^{-3}$. These results highlight the significant differences in soil porosity across the different LUTs examined, as illustrated in Fig. 3.

pH is another critical soil property that can influence various other soil features (Oraon *et al*., 2018). In Nghe an mountainous region, pH values ranged from 4.45 to 4.92 across all study sites. Analysis of pH revealed no

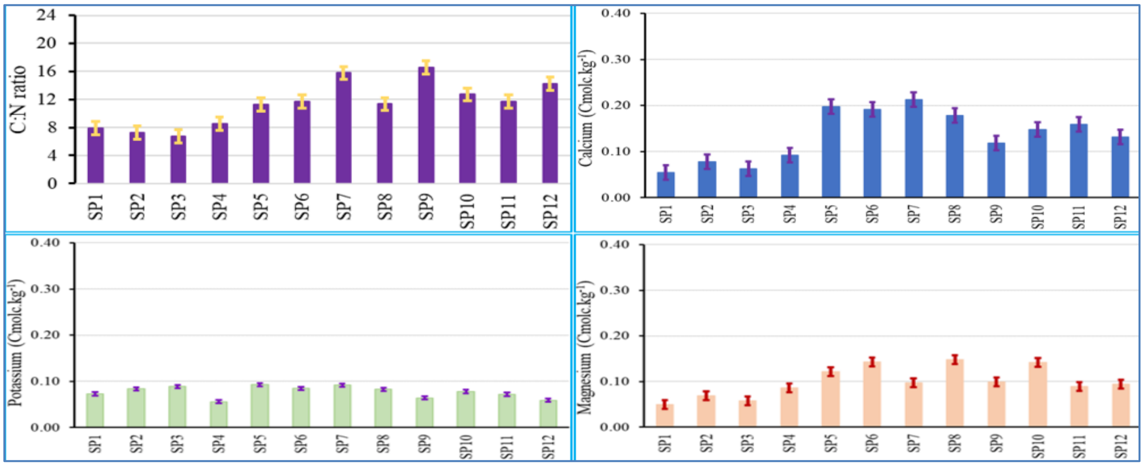

Fig. 4. Distribution of the C: N ratio and exchange ions at the investigated sampling positions in Lam River Basin.

TABLE 4

Analysis results of pH, exchange irons, and organic carbon content among collected sampling positions in Lam River Basin

Site	Exchange irons (Cmolc.kg^{-1})			Soil organic content (g.kg^{-1})			C: N ratio (Ave. ± SD)
	Calcium (Ave. ± SD)	Magnesium (Ave. ± SD)	Potassium (Ave. ± SD)	Total phosphorus (Ave. ± SD)	Total nitrogen (Ave. ± SD)	Total carbon (Ave. ± SD)	
SP1	0.055 ± 0.001A	0.057 ± 0.001B	0.073 ± 0.001B	0.182 ± 0.010B	2.38 ± 0.114B	18.86 ± 1.73A	7.92 ± 0.081B
SP2	0.078 ± 0.003B	0.069 ± 0.002A	0.084 ± 0.002B	0.164 ± 0.011B	2.43 ± 0.105B	17.69 ± 1.61B	7.27 ± 0.069A
SP3	0.063 ± 0.002A	0.058 ± 0.001B	0.089 ± 0.003A	0.175 ± 0.010A	2.75 ± 0.195A	18.53 ± 1.94B	6.74 ± 0.049A
SP4	0.092 ± 0.004A	0.086 ± 0.002B	0.056 ± 0.001A	0.163 ± 0.013B	2.13 ± 0.181B	18.15 ± 1.27A	8.52 ± 0.067A
SP5	0.198 ± 0.009B	0.122 ± 0.010A	0.093 ± 0.003B	0.157 ± 0.010B	1.86 ± 0.107A	20.97 ± 1.97A	11.27 ± 0.093B
SP6	0.192 ± 0.018A	0.143 ± 0.010A	0.085 ± 0.002A	0.139 ± 0.008A	1.63 ± 0.121B	19.14 ± 1.68B	11.74 ± 0.098A
SP7	0.213 ± 0.019B	0.097 ± 0.003A	0.092 ± 0.003B	0.136 ± 0.007A	1.29 ± 0.104A	19.45 ± 1.97A	15.77 ± 0.141A
SP8	0.178 ± 0.010A	0.148 ± 0.014B	0.083 ± 0.002B	0.151 ± 0.010B	1.74 ± 0.139B	19.75 ± 1.38A	11.35 ± 0.085A
SP9	0.119 ± 0.007A	0.099 ± 0.003B	0.064 ± 0.001A	0.127 ± 0.006B	1.08± 0.107A	17.91 ± 1.33B	16.58 ± 0.086B
SP10	0.148 ± 0.005B	0.142 ± 0.011A	0.078 ± 0.002A	0.104 ± 0.010A	1.27 ± 0.122A	16.13 ± 1.13A	12.71 ± 0.087A
SP11	0.159 ± 0.006B	0.089 ± 0.002B	0.072 ± 0.002B	0.092 ± 0.005A	1.12 ± 0.126B	13.09 ± 1.09B	11.68 ± 0.082A
SP12	0.132 ± 0.004B	0.094 ± 0.003A	0.059 ± 0.001A	0.117 ± 0.007A	0.98 ± 0.092A	13.94 ± 1.24A	14.22 ± 0.095B

substantial differences between the various LUTs investigated across the study area. However, a slight increasing trend in pH was observed with increasing soil depth (Table 4). This pattern aligns with findings from Neina *et al*. (2019), who reported that TSLtends to exhibit lower pH values due to the concentrated decomposition of plant and animal matter in this zone (Fig. 3). Overall, a slight upward trend in pH with increasing soil depth was observed, particularly between 20-100 cm.

Exchangeable irons showed varying concentrations within the TLs. Exchangeable calcium ranged from 0.055 ± 0.001 to 0.092 ± 0.004 g.kg^{-1}, magnesium ranged from 0.057 ± 0.001 to 0.086 ± 0.002 g.kg^{-1}, and potassium ranged from 0.056 ± 0.001 to 0.089 ± 0.003 g.kg^{-1}. The highest exchangeable iron values were observed in CCLs, with calcium reaching 0.213 ± 0.019 Cmolc.kg^{-1}, magnesium at 0.148 ± 0.014 Cmolc.kg^{-1} and potassium at 0.092 ± 0.003 Cmolc.kg^{-1}. In UBLs, the corresponding

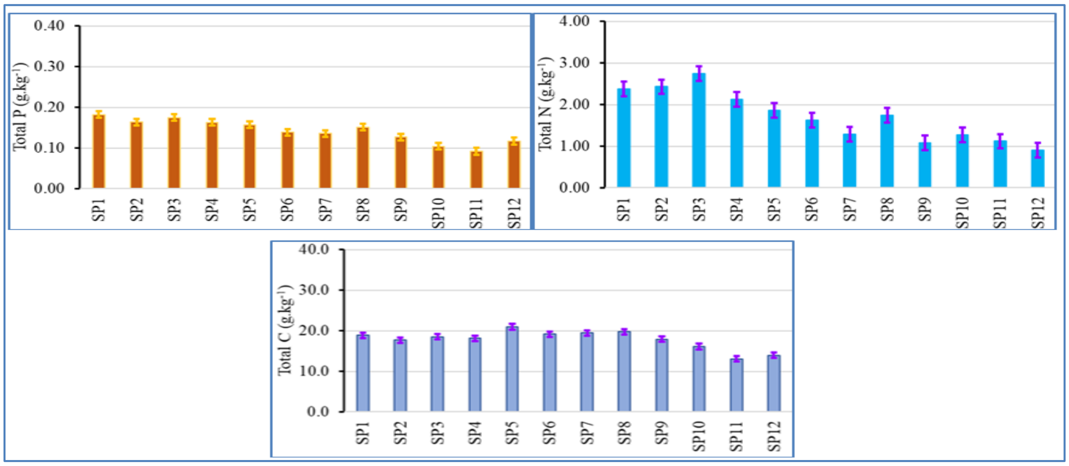

Fig. 5. Distribution of the soil organic contents at the investigated sampling positions in Lam River Basin.

values were 0.159 ± 0.006 cmolc.kg^{-1} for calcium, 0.142 ± 0.011 cmolc.kg^{-1} for magnesium, and 0.072 ± 0.002 cmolc.kg^{-1} for potassium. FCLs had the lowest exchangeable iron values, with 0.055 ± 0.003 cmolc.kg^{-1} for calcium, 0.058 ± 0.001 cmolc.kg^{-1} for magnesium and 0.0056 ± 0.001 cmolc.kg^{-1} for potassium (Fig. 4).

FCLs exhibited the highest organic carbon values, with total phosphorus and total nitrogen reaching 0.182 ± 0.010 g.kg^{-1} and 2.75 ± 0.195 g.kg^{-1}, respectively (Table 4). Conversely, CCLs had the highest organic carbon values, reaching 20.97 ± 1.97 g.kg^{-1}. Overall, FCLs exhibited higher organic carbon values compared to CCLs and UBLs. This difference can be attributed to the greater abundance of plant residues and organic matter inputs from vegetation and fauna in FCLs, which serve as source materials for organic carbon formation (Vanchikova *et al*., 2021).

As expected, organic carbon concentrations generally declined with increasing soil depth, varying from 20 to 100 cm. Significant differences in total N, total P, and total C concentrations were observed among the different LUTs (Fig. 5).

The higher organic carbon concentrations in FCLs suggest greater soil fertility in these areas compared to CCLs and UBLs. The lower exchangeable irons observed in the LUTs may reflect nutrient depletion resulting from anthropogenic activities such as agricultural practices or vegetation removal. Soil organic matter, a key indicator of soil quality, plays a crucial role in maintaining soil structure and function. The decline in soil organic matter commonly associated with human activities can lead to increased bulk density, reduced porosity, and overall degradation of soil health, particularly in deeper soil layers.

4. Conclusions

This study examined the long-term impacts of anthropogenic practices on soil features in Lam River Basin of Vietnam. Our findings reveal significant variations in key soil features across different LUTs and soil profiles. Notably, distinct differences in soil features were observed between FCLs, CCLs and UBLs.

The combined effects of anthropogenic practices have exerted a substantial influence on soil features across the study area. Specifically, surface layers in the CCLs and UBLs exhibited higher bulk densities, sand content, and clay contents compared to FCLs. Furthermore, exchange irons and soil organic content were markedly lower in areas subjected to CCLs and those converted to UBLs compared to FCLs.

Overall, the findings suggest that anthropogenic practices can have long-lasting detrimental effects on soil health and ecological functions. The observed alterations in soil physical and chemical properties can disrupt essential soil processes, compromise soil fertility, and ultimately undermine the overall sustainability of the ecosystem.

Disclaimer: The contents and views presented in this research article/paper are the views of the authors and do not necessarily reflect the views of the organizations they belongs to.

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