



Land Use Practices Effects on Soil Organic Carbon and Nitrogen in North-central Vietnam

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10.18805/ag.DF-623

ABSTRACT

Background: Soil organic carbon (SOC) and soil nitrogen (SN) are critical for maintaining soil health, fertility and sustainable cultivation practices. These indicators of soil quality are influenced by anthropogenic activities and global climate change (GCC). To effectively manage soil, it is essential to understand the dynamics of the soil properties, especially SOC and SN.

Methods: The study aims to evaluate how different land use practices (LUPs) impact SOC and SN contents in North-Central Vietnam. The study focuses on the effects of anthropogenic activities and GCC. A total of 48 soil samples were collected in the field surveys during 2021-2023 from three typical land use types (LUTs), including natural forest land (NFL), crop cultivation land (CCL) and bare hill land (BHL) at the 0-10 cm surface topsoil. The samples were analyzed for soil texture, pH, bulk density (BD), SOC and SN. The effects of LUPs on SOC and SN contents were assessed using ANOVA software.

Result: The predominant soil textures observed in all samples were clay and sandy loam, with low silt percentages. The NFL and CCL areas exhibited lower bulk density compared to BHL. The results indicate that CCL had the highest SOC and SN stocks, followed by BHL and NFL. The C/N ratio in CCL and NFL was greater than 10, suggesting a high decomposition rate of organic matter in cultivated and bare land areas. The pH of all soil samples was uniformly acidic. These findings highlight the importance of evaluating the impact of LUPs, specifically on SOC and SN contents and other soil properties.

Key words: ANOVA, Bulk density, Cultivation land, Soil nitrogen, Soil-water method.

INTRODUCTION

The expansion of agriculture to meet the increasing demands of a growing global population has led to a decline in soil quality worldwide (Ren *et al.*, 2020). LUPs have a significant influence on the storage of SOC and SN on a global scale (Sakin, 2012). SOC and SN levels are crucial indicators for assessing soil quality and fertility (Chemada *et al.*, 2017; Olorunfemi *et al.*, 2020). These components play a vital role in soil environments, contributing to overall soil health and fertility (Pires *et al.*, 2023; Jiao *et al.*, 2020). They also serve as essential nutrients for plant growth and development (Dinh and Dang, 2023; Hiederer, 2009). Additionally, SOC and SN contribute to the carbon and nitrogen cycles, converting atmospheric carbon and nitrogen into forms that are readily usable by plants (Pires *et al.*, 2023; Jobbágy and Jackson, 2000).

However, SOC and SN are influenced by various soil properties, primarily caused by anthropogenic activities and GCC (Dinh and Shima, 2024; Pouyat and Trammell, 2019). LUPs, in conjunction with climate factors, are crucial determinants of SOC and SN contents (Osakwe and Igwe, 2013; Schillaci *et al.*, 2017). Urbanization and agricultural expansion, in particular, contribute to deforestation and the depletion of SOC and SN stocks (Dinh and Dang, 2022; Vasenev *et al.*, 2013). Furthermore, urban soil undergoes significant transformations, leading to changes in organic carbon and nitrogen content (Deng *et al.*, 2016). GCC characterized by increasing droughts, floods and extreme rainfall events, also has a significant impact on LUPs (Ren

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How to cite this article: Hoang, T.V.H. (2024). Land Use Practices Effects on Soil Organic Carbon and Nitrogen in North-central Vietnam. Agricultural Science Digest. doi: 10.18805/ag.DF-623.

Submitted: 22-05-2024 **Accepted:** 25-07-2024 **Online:** 22-08-2024

et al., 2020). Climate variables, such as precipitation intensity and temperature, influence the levels of SOC and SN (Pires *et al.*, 2023) and LUPs strongly affect SOC and SN content (Schillaci *et al.*, 2017; Ren *et al.*, 2020).

For example, Ben *et al.* (2024) conducted a study in the Southeast of Spain and found that SOC and SN stocks were highest in CCL, followed by grass and urban land. In another study by Gelaw *et al.* (2014) in the Tigray semi-arid watershed in Ethiopia, it was discovered that converting CCL to grass plant land had significant potential for sequestering SOC and TN. Tedone *et al.* (2023) also assessed the effects of LUPs on SOC and SN contents in Southern Italy and found no significant differences among the conventional, minimum and no tillage. In the context of anthropogenic interference and GCC's impact on LUPs, this study aims to assess the influence of LUPs on SOC and SN contents in the topsoil across North-Central Vietnam.

MATERIALS AND METHODS

The study was conducted in the mountainous district of Nghe An province, located in Northern Vietnam, within the geographical coordinates of 18°33'00"N to 19°09'36"N latitude and 104°54'00"E to 105°37'12"E longitude (Fig 1). Nghe An province experiences a hot and humid tropical climate, with an average annual temperature of approximately 24.0°C and an annual rainfall of around 1800 mm (Giang, 2020). The majority of rainfall occurs between the months of August and October, accounting for up to 81.5% of the total annual rainfall (Fig 2). This high concentration of rainfall during the rainy months is a significant factor contributing to the reduction in SOC and SN content in the topsoil layer in hilly areas (Nguyen *et al.*, 2023; Tran *et al.*, 2022).

A total of 48 soil samples were collected during the field survey, representing different LUPs within the study area (Fig 3). These included 16 samples from NFL (primary and plantation forests), 24 samples from CCL (annual crops, grass and rice) and 8 samples from BHL. The selection of

these specific areas aimed to accurately reflect the LUPs present in the study area.

The collected soil samples were then air-dried at 100°C for 24 hours. The samples were carefully disaggregated and passed through a 2 mm mesh sieve, removing any coarse fragments larger than 2 mm. The fine soil portion of the samples was analyzed for various properties, including soil texture, soil pH, SOC and SN. Soil pH was determined using the United States Laboratory procedure at a temperature of 25°C, with a soil-to-water ratio of 1:2.5 (w/v). The soil composition, specifically the percentages of sand, silt and clay, was determined using the sieve method according to the classification scheme established by the United States Department of Agriculture (USDA). The analysis of SN was conducted using the Kjeldahl method, while the estimation of SOC was performed using the Walkley-Black method. For detailed procedures, refer to Roger *et al.* (2017). Soil BD was determined using the core method.

Descriptive statistics, including mean, maximum, minimum and standard deviation, were defined for the soil

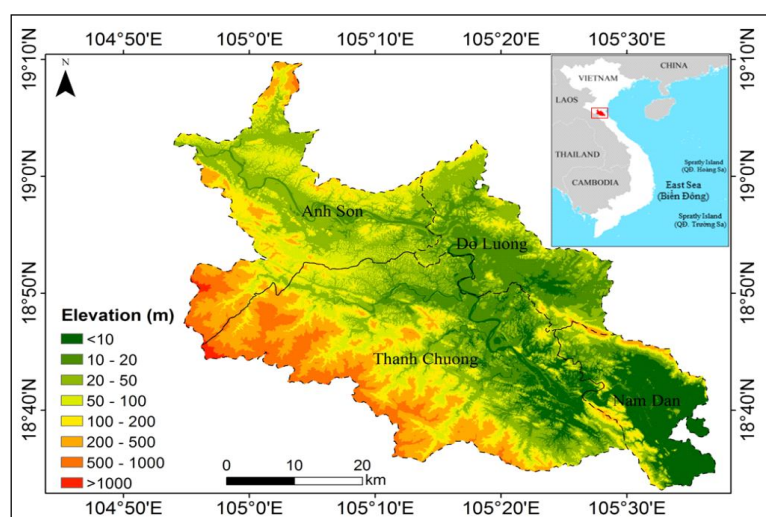


Fig 1: Map of the study area.

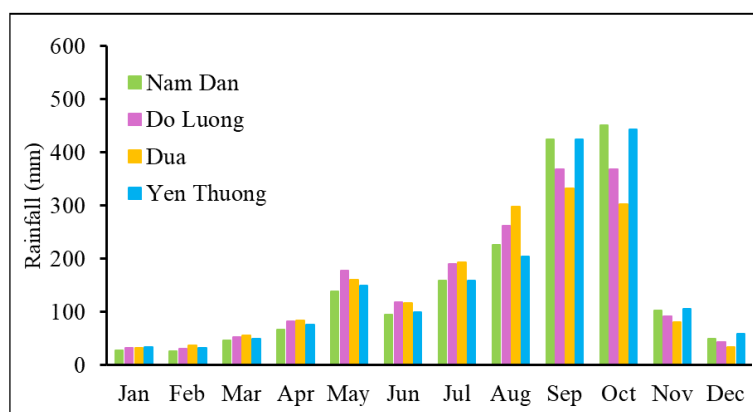


Fig 2: Distribution of rainfall at the observation stations in the period 2000-2022.

samples using Microsoft Excel. Correlation analysis of the principal variables was performed using SPSS Statistics 19.0. One-way analysis of variance (ANOVA) was applied to assess for differences in soil properties, with a significance level of $\alpha = 0.05$. In this study, a total of 7 physicochemical variables were

analyzed. To ensure the reliability of the principal component analysis results, the original data were standardized to eliminate the influence of different dimensions and orders of magnitude. Table 1 provides basic information on the characteristics analyzed in the soils across the study area.

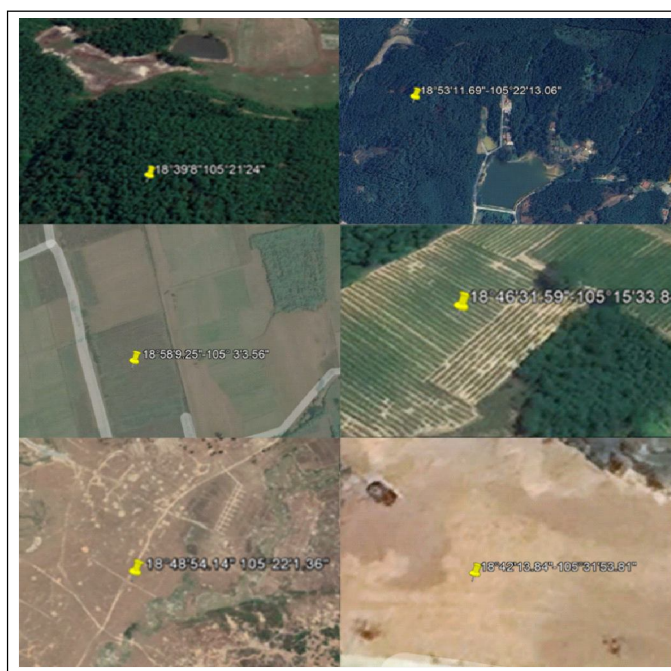


Fig 3: The marked collection positions representing the three land use types across the study area.

Table 1: Based statistical characteristic of soil properties across the study area.

Land use practices		Soil texture			Soil pH	Soil BD (Mg.m^{-3})	Organic matter content	
		Sand (%)	Clay (%)	Silt (%)			SOC (g.kg^{-1})	SN (g.kg^{-1})
Natural forest land(NFL)	Ave	35.13	46.47	18.40	4.41	0.88	18.86	2.25
	Min	34.21	46.14	17.35	4.36	0.83	18.37	2.74
	Max	35.43	47.59	19.13	4.72	0.95	19.29	3.65
	CV (%)	3.9	4.4	3.2	2.17	0.94	3.7	5.9
	SD	0.8	1.42	1.27	0.09	0.76	6.8	0.39
	Skewness	0.29	0.08	0.25	0.57	0.07	0.14	0.05
Crop cultivation land (CCL)	Ave	34.1	46.3	19.6	4.58	1.05	26.49	2.47
	Min	30.8	42.7	18.9	4.35	1.03	24.12	2.24
	Max	36.5	48.9	19.8	4.67	1.08	27.34	2.82
	CV (%)	7.4	5.7	4.3	2.8	12.3	5.2	9.7
	SD	1.1	1.64	1.38	0.12	0.14	11.2	0.57
	Skewness	0.41	-0.13	0.34	0.81	0.09	0.19	0.09
Bare hill land (BHL)	Ave	38.6	44.6	16.6	4.47	1.09	18.45	1.87
	Min	36.8	44.1	13.9	4.43	0.99	17.09	1.63
	Max	39.3	45.5	17.4	4.53	1.15	19.84	1.98
	CV (%)	6.3	5.1	4.1	2.49	10.3	4.5	7.3
	SD	1.0	1.57	1.32	0.11	0.99	9.7	0.64
	Skewness	0.27	-0.10	0.28	0.76	0.08	0.17	0.07

Notes: Min: Minimum; Max: Maximum; Ave: Average; SD: Standard deviation; CV: Coefficient of variation, BD: Soil bulk density, SOC: Soil organic carbon, SN: Soil nitrogen.

RESULTS AND DISCUSSION

The analyzed results of the basic characteristics of soil samples collected from three surveyed positions are presented in Table 1. When considering soil texture, the NFL exhibited an average sand content of 35.2%, clay content of 46.5% and silt content of 18.3%. Similarly, the CCL showed a similar trend with slight variations (34.1%, 46.3% and 19.6%). On the other hand, the BHL displayed higher sand content (38.6%), lower clay content (44.6%) and lower silt content (16.8%). The NFL demonstrated CV values of 3.9%, 4.4% and 3.2% for sand, clay and silt, respectively. In contrast, the CCL exhibited higher CV values (7.4%, 5.7% and 4.3%), indicating greater variability. The BHL had CV values of 6.3%, 5.1% and 4.1% for sand, clay and silt, respectively. The skewness values, which represent the asymmetry of the distribution, were generally close to zero for all land types, indicating a relatively symmetrical distribution of soil texture characteristics.

In terms of soil BD, the average values for NFL, CCL and BHL were 0.88 g/cm³, 1.05 g/cm³ and 1.09 g/cm³, respectively. The NFL exhibited the lowest minimum value of 0.83 g/cm³, while the CCL had the highest maximum value of 1.09 g/cm³. The CV for soil BD ranged from 0.94% to 12.3%, suggesting varying levels of density within each land type. For soil pH, the average values for NFL, CCL and BHL were 4.41, 4.58 and 4.47, respectively. The minimum and maximum values for pH varied slightly across the land types. The CV for soil pH ranged from 2.17% to 2.83%, indicating relatively low variability in pH levels within each land type.

Table 2: The soil organic carbon, soil nitrogen and C/N rates in the three land use types.

Land use practices	SOC (g.kg ⁻¹)	SN (g.kg ⁻¹)	C/N
Natural forest land	21.85	2.16	10.11
Crop cultivation land	26.49	2.47	10.72
Bare hill land	18.45	1.87	9.86

Regarding SOC content, the NFL displayed an average value of 18.86 g/kg, while the CCL and BHL showed average values of 26.49 g/kg and 18.45 g/kg, respectively. The CV for SOC content ranged from 3.7% to 5.2%, indicating moderate variability within each land type. For SN levels, the average values for CCL, NFL and BHL were 2.47 g/kg, 2.25 g/kg and 1.87 g/kg, respectively. The CV for SN ranged from 5.9% to 9.7%, indicating moderate variability within each land type.

Overall, the analysis of these fundamental soil characteristics provides valuable insights into the physicochemical properties of soil across the study area. These analyses contribute to a better understanding of soil health, fertility and inform LUPs within the study area.

The analysis of soil characteristics in the three LUPs reveals relationships between soil texture, soil BD, soil pH, SOC and SN (Table 2). For soil texture, it is observed that the average sand content is similar across all land types, ranging from 34.1% to 38.6%. However, there is slight variation in the silt content, with the CCL having the highest average (19.8%) and the BHL having the lowest (16.6%). This suggests that the LUTs have comparable sand content but differ in terms of silt content (Fig 4). Soil BD shows minimal variation among three LUTs, with average values ranging from 0.88 to 1.09 g/cm³.

This implies that the compactness of the soil is relatively consistent across the different land types while soil pH levels are consistent across all land types, with an average of 4.48. This indicates that the acidity of the soil is similar regardless of land use. Examining SOC content, it is evident that the CCL has the highest average (26.49 g/kg), followed by the NFL (18.86 g/kg) and the BHL (18.45 g/kg). As previously analyzed, variations in SOC and SN contents among the LUTs can be attributed to various factors, including LUPs and environmental factors (Pires *et al.*, 2023; Pouyat and Trammell, 2019). Several studies have demonstrated the influence of LUPs on these soil characteristics (Benslama *et al.*, 2024; Chemada *et al.*, 2017). The analyzed results align with previous studies,

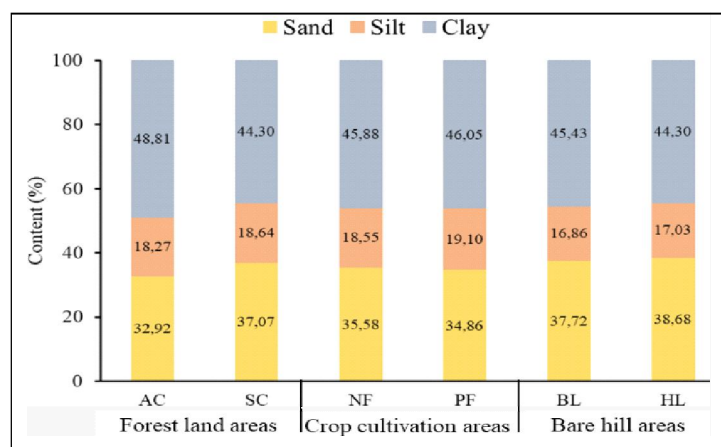
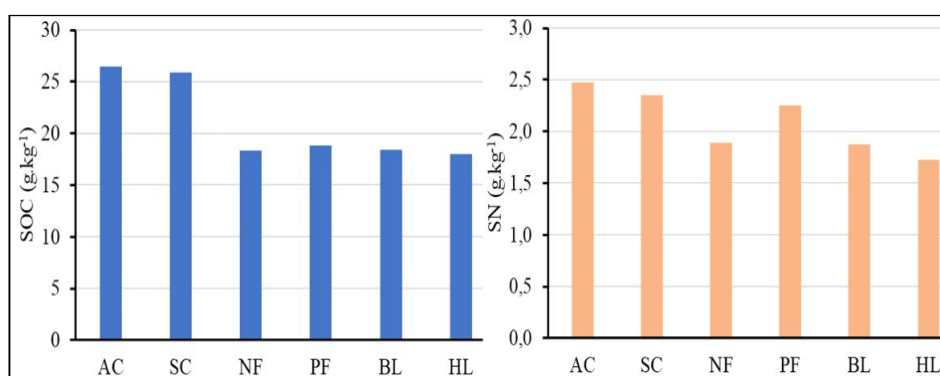


Fig 4: Distribution of soil texture at the representative sampling positions across the study area.

Table 3: Pearson's correlation between selected variables.

Parameters	Sand	Silt	Clay	BD	pH	SOC	TN
Sand	1.000						
Silt	-0.872	1.000					
Clay	-0.06	-0.317	1.000				
BD	0.618	-0.671	-0.034	1.000			
pH	0.017	0.076	-0.272	0.871	1.000		
SOC	-0.649	0.781	-0.201	-0.946*	-0.636	1.000	
TN	-0.636	0.647	-0.182	-0.915*	-0.637	0.891*	1.000

SOC: Soil organic carbon; TN: Soil nitrogen; *correlation is significant at the 0.05 level.

**Fig 5:** Distribution of SOC and SN at the representative sampling positions across the study area.

confirming significant variations in SOC and SN contents associated with LUPs (Fig 5). This indicates that CCL has a higher SOC content compared to the other land types while SN content also follows a similar trend as SOC, with the CCL exhibiting the highest average (2.82 g/kg), followed by the NFL (2.25 g/kg) and the BHL (1.87 g/kg).

There is a strong negative correlation between sand content and silt content (-0.872), indicating an inverse relationship between these two soil texture components (Table 3). Similarly, there is a weak negative correlation between sand content and clay content (-0.06), suggesting a slight inverse relationship between these variables. Soil BD shows a moderate positive correlation with sand content (0.618) and a moderate negative correlation with silt content (-0.671). This implies that as sand content increases, soil BD also tends to increase, while a higher silt content is associated with lower soil BD. Soil pH demonstrates a strong positive correlation with BD (0.871) and a weak positive correlation with sand content (0.017). This indicates that higher soil pH values are associated with higher soil BD and a slightly higher proportion of sand in the soil.

Furthermore, SOC exhibits a strong negative correlation with BD (-0.946) and a strong positive correlation with silt content (0.781). This suggests that as soil BD decreases, the amount of organic carbon in the soil tends to increase and a higher silt content is associated with higher organic carbon levels. Soil nitrogen shows a strong positive correlation with SOC (0.891) and a moderate negative

correlation with sand content (-0.636). This implies that as the organic carbon content increases, there is a corresponding increase in soil nitrogen, while a higher proportion of sand is associated with lower nitrogen levels.

In conclusion, the correlation analysis highlights the interrelationships among soil texture, soil BD, soil pH, SOC and SN in the LUTs. These findings provide insights into the complex dynamics of soil properties and their potential implications for soil fertility and nutrient cycling in different LUMs use contexts.

CONCLUSION

The study conducted in North-Central Vietnam aimed to assess the effects of LUPs on SOC and SN contents. These indicators are crucial for maintaining soil health, fertility and sustainable cultivation practices. Anthropogenic activities and GCC have an influence on SOC and SN. A total of 48 soil samples representing the LUTs were analyzed for various soil properties. The results showed that CCL had the highest SOC and SN stocks, followed by BHL and NFL. The study emphasized the importance of evaluating the impact of LUPs on SOC, SN and other soil properties. The findings contribute to our understanding of the relationship between LUPs and soil characteristics in the study area.

Conflict of interest statement

Authors have not received research grants from any agency or organization. Authors confirm that we have no conflict of interest.

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