Research article

Soil Biota, Soil Biological Activity, and Soil Carbon Storage in Different Land Uses in Northeast Thailand

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Abstract Soil biota plays important roles in the storage of soil organic carbon and in the provision of many ecosystem services which significantly improve our well-being. Additionally, the soil respiration activity of soil microorganisms affects the dynamic release of carbon dioxide (CO_2) into the atmosphere. Assessing soil organisms as well as microorganism activity affecting carbon storage in the soil is essential to help understand and mitigate greenhouse gas emissions. The objectives of this study were to evaluate soil biota, soil biological activity, and soil carbon storage across different types of land use in the northeastern region of Thailand. Utilizing data derived from a case study of Ban Hua Bueng, Sai Mun Subdistrict, Nam Phong District, Khon Kaen Province, we focused on six land use types including the Ban Hua Bueng community forest (Fr); two sugarcane fields - one managed with burning and chemical fertilizers (Sc) and another employing soil conservation without chemical fertilizers (Sc-O); two cassava fields - one using tillage and chemical fertilizers (Cs) and another practicing soil conservation without chemical fertilizers (Cs-O); and a paddy field (Pd). The study monitored earthworms, soil microorganisms, soil respiration by microorganisms, and carbon storage in the soil across the different land use types. The study found significant differences in the population of earthworms and soil microorganisms which were greatest in the community forest, followed by the cassava field managed by conserving the soil without the use of chemical fertilizers. Community forests contained the greatest soil organic carbon levels among all land uses studied. Microbial respiration differed significantly across land use types. While the community forest had greater respiration rates than the agricultural fields and the paddy fields, the results were not significantly different.

Keywords carbon storage, soil microorganism activity, earthworm, land use

INTRODUCTION

The conversion of natural forests to cultivated areas is a key driver of soil degradation, manifesting multiple adverse impacts on soil health. This transformation process significantly diminishes soil fertility inducing alterations in soil moisture level and influencing the activities of soil fauna integral to the intricate balance of terrestrial ecosystems (Akinde et al., 2020). Earthworms serve as ecosystem engineers, exerting a significant influence on various crucial soil functions essential in agriculture. Through their burrowing and casting activities, earthworms enhance nutrient mineralization, litter decomposition, and the formation of soil structure. The adverse impact on earthworms from conventional tillage practices, such as moldboard and rotary plowing, are well-documented.

Soil microorganisms affect soil biochemical cycles essential in global nutrient cycling and litter decomposition and are useful indicators of soil functioning and fertility (Buivydaitė et al., 2023).

Microbial activities are affected by multiple factors, with endpoints involved in nutrient cycling and carbon sequestration issues. In particular, soil respiration is critical to the global carbon cycle as global soils store twice as much carbon as the atmosphere. Soil biota play a crucial role in the global carbon cycle and their possible contribution to carbon sequestration (Sofi et al., 2016). In 2015, all 193 United Nations member countries adopted Sustainable Development Goal (SDG) 15, which addresses the conservation, restoration, and sustainable use of land resources. Therefore, it is important to understand changes in soil properties resulting from land use changes especially related to agriculture.

OBJECTIVE

The purpose of this research was to study soil biota and soil biological activity in different land use types in Ban Hua Bueng, Sai Mun Subdistrict, Nam Phong District, Khon Kaen Province, Northeast Thailand.

METHODOLOGY

Study Area and Soil Sampling

The study was conducted in 2023 during the month of May, which is in Thailand's winter season. The study site was the Ban Hua Bueng, Sai Mun Subdistrict, Nam Phong District, Khon Kaen Province (Fig. 1).

Fig. 1 Map of study site in Ban Hua Bueng, Sai Mun Sub-district, Nam Phong District, Khon Kaen Province, Northeast Thailand

Table 1 Soil moisture (%) and temperature (^{O}C) as of May 2023

	Land use type	Soil moisture (%)	Temperature (^{O}C)
1	Ban Hua Bueng community forest (Fr)	9.6	26.3
2	Sugarcane fields are managed by burning sugarcane with the use of chemical fertilizers (Sc)	0.4	31.3
3	Sugarcane fields managed by soil conservation without the use of chemical fertilizers (Sc-O)	7.4	29.0
4	Cassava field managed by tillage with the use of chemical fertilizers (Cs)	0.3	27.7
5	Cassava area managed by soil conservation without the use of chemical fertilizers (Cs-O)	1.4	30.7
6	Paddy Field (Pd)	47.1	27.7

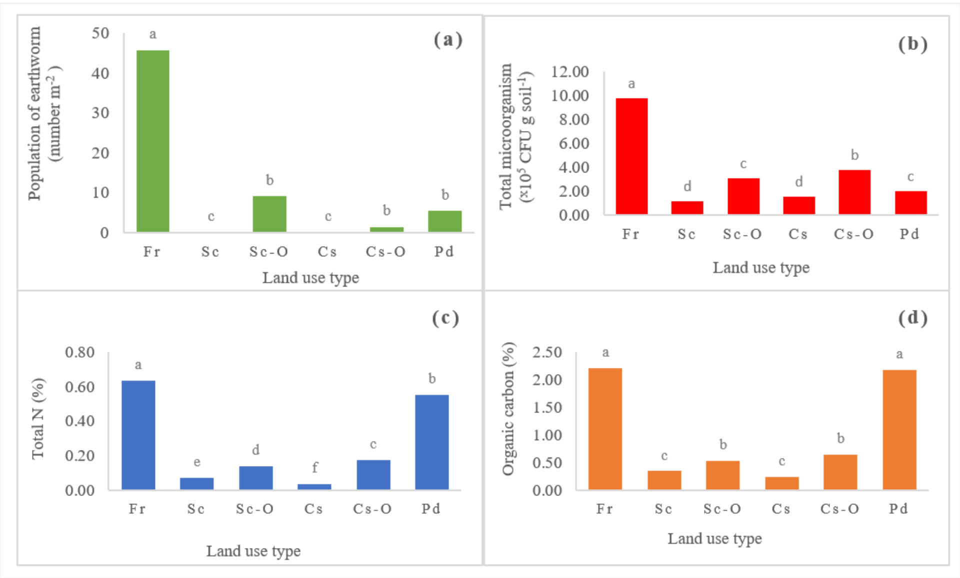
We focused on six land use types including the Ban Hua Bueng community forest (Fr), a sugarcane field managed by burning sugarcane with the use of chemical fertilizers (Sc), a sugarcane field managed by soil conservation without use of chemical fertilizers (Sc-O), a cassava field managed by tillage with the use of chemical fertilizers (Cs), a cassava field managed by soil conservation without use of chemical fertilizers (Cs-O), and a paddy field (Pd). Study samples were randomly collected at a depth of 0-15 cm at more than 20 points for each land use type and agricultural management model. Samples were air-dried, gently crushed, and then sieved through a 2 mm sieve. Land use types and the soil moisture (%) and temperature (^{O}C) for each are shown in Table 1.

Soil Biological and Chemical Characterization

Soil samples from all six land use types were analyzed for biological and chemical properties. Data includes soil organic carbon (%) measured by using the Walkley and Black method (FAO, 2019), total N (%) measured by using the Kjeldahl method (Vinklarkova et al., 2015), soil respiration measured by trapping CO_2 in 0.05M NaOH, followed by titration with HCl (Alef and Nannipieri, 1995), and the counting of soil microorganisms using soil dilution plate in the culture medium including the number of bacteria (NA), the number of actinomycetes (SCA with rose bengal), and the number of fungi (PDA). All data were analyzed using the Statistix 10 program. Significant variations at $p \leq 0.05$ were identified by Least Squares Differences (LSD) and computed to compare means.

RESULTS AND DISCUSSION

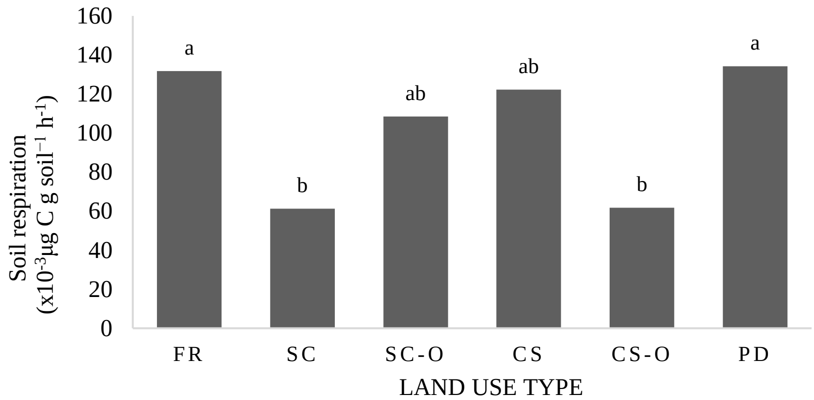
The results demonstrate that the population of soil biota, including the number of earthworms and the total number of microorganisms, was greatest in the forest area, with the number of earthworms at 46 earthworms / m^2 and total microorganisms at 9.77 x 10^5 CFU g $soil^{-1}$ (Fig. 2a, b). The forest area stores more carbon than agricultural areas; the forest area had the greatest total N and organic carbon at 0.64% and 2.21% respectively (Fig. 2c, d). High carbon in the soil is consistent with research indicating that forests accumulate large amounts of carbon, and deforestation or a change from forest to land use can release carbon previously stored in the soil (Wasige et al., 2014). Environmental factors contribute to the accumulation of carbon and nitrogen, as seen in the paddy field where rice straw is added, which has greater carbon and nitrogen accumulation than other agricultural areas.



Mean (n=3), numbers followed by the same letters are not significantly different (p<0.05) (LSD)

Fig. 2 Shows population of soil biota and soil chemical properties in different land use types
(a) Population of earthworm, (b) Total microorganism, (c) Total N, and (d) Organic Carbon

Soil respiration was highest in paddy fields (134 x 10^{-3}μg C g soil^{-1} h^{-1}), closely followed by forest (132 x 10^{-3}μg C g soil^{-1} h^{-1}) (Fig. 3). These elevated rates stem from efficient microbial activity, facilitated by abundant surface organic matter. Forests contain significantly more soil biota and carbon than agricultural lands. While the paddy field showed the highest biological activity, the difference compared to the forest was not statistically significant.



Mean (n=3) numbers followed by the same letters are not significantly different ($p<0.05$) (LSD)

Fig. 3 Microorganism activity via soil respiration rate in different land use types in Ban Hua Bueng, Sai Mun Subdistrict, Nam Phong District, Khon Kaen Province Northeast Thailand

The relationship between earthworms, soil microorganisms, organic carbon, and nutrients in the soil is well-established in soil science. Earthworms play a crucial role in soil health by enhancing soil structure, nutrient cycling, and organic matter decomposition (Edwards and Arancon, 2022). The results from this study found that soil biota and soil biological activity had a high correlation with soil carbon storage in different land uses in Northeast Thailand.

Most of the agricultural areas in the northeastern region of Thailand utilize intensive agriculture practices, particularly in sugarcane-growing fields where pre-harvest burning is common. Intensive agriculture refers to farming methods that prioritize maximizing crop yield by using high inputs of fertilizers, pesticides, and mechanization, often at the cost of long-term soil health and sustainability (Barreiro and Díaz-Raviña, 2021). The pre-harvest burning and combustion of plant residues reduce organic matter input to the soil, disrupt nutrient cycling, and may lead to the loss of beneficial soil organisms. Intensive agriculture, including excessive use of synthetic fertilizers and pesticides, can also negatively impact soil health, resulting in soil degradation, loss of organic carbon, and decline in soil biodiversity.

CONCLUSION

Understanding and appreciating the roles of earthworms and soil microorganisms in organic Carbon and nutrient dynamics are essential for sustainable soil management. By fostering healthy soil ecosystems, we can promote agricultural productivity, carbon sequestration, and overall environmental resilience.

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