Research article

Assessing Soil Carbon Sequestration in Salt-Affected Areas Managed with Vermicompost and Organic Waste Materials: A Geographic Information System Approach

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Abstract Global warming is a significant challenge faced by many countries worldwide. It adversely affects the environment, climate, society, agriculture, and human life as a whole. The primary cause of global warming is the accumulation of greenhouse gases, which leads to issues such as droughts, decreased agricultural productivity, and climate change. Notably, soil and plants can store more carbon than the atmosphere can. Salt-affected soils are a prevalent issue in many regions worldwide. Therefore, monitoring and surveying soil carbon storage are essential. This study aimed to utilize geographic information systems (GIS) to assess organic carbon levels in salt-affected soils in an area where vermicomposting was applied with organic waste materials. The results showed that the saline soils treated with vermicompost, and organic waste had a higher SOC of 0.560% compared to the unmanaged areas, which had an SOC of 0.350%. Moreover, the soil electrical conductivity in the managed areas with vermicompost was lower (10.16 dSm-1) than that in the unmanaged areas (13.69 dSm-1), and the soil salinity levels during the rainy season were also reduced. The electrical conductivity (ECa) values at a depth of 0-0.75 m were higher than those at 0-1.5 m, indicating that soil with a high organic carbon content had a lower electrical conductivity. In contrast, soils with low organic carbon content exhibited higher conductivities. In conclusion, the experiment demonstrated that managing saline soil areas with vermicompost and organic waste materials effectively increased soil carbon sequestration and reduced soil electrical conductivity, with more benefits observed during the rainy season than during the dry season.

Keywords land use, carbon storage in soil, economic crops, climate change

INTRODUCTION

The long-term increase in the global average temperature is due to the accumulation of greenhouse gases in the atmosphere. These gases, such as carbon dioxide (CO_2), trap heat from the sun and prevent it from escaping into space, causing a gradual rise in global temperatures. This phenomenon is primarily caused by human activities, such as burning fossil fuels, industrial processes, deforestation, and agriculture, which release large amounts of greenhouse gases into the atmosphere.

The consequences of global warming include rising sea levels, more frequent and severe weather events, loss of biodiversity, and ecosystem disruption (Nazir et al., 2024). Salt-affected soils, or soils with high concentrations of soluble salts, include sodium (Na), calcium (Ca), magnesium (Mg), and potassium (K). Soil salinity can occur naturally in arid and semi-arid areas or be caused by human activities, such as saline irrigation or overuse of fertilizers. Soil salinity adversely affects plant growth and yield. High salt concentrations in soil disrupt the water absorption balance of plant roots and interfere with plant nutrient absorption, leading to nutrient deficiency in plants. Additionally, the presence of salt can affect soil structure and reduce soil fertility (Petmuenwai et al., 2024). Moreover, reducing soil organic carbon (SOC), an outcome of soil degradation and mismanagement, has intensified atmospheric CO_2 levels.

However, by implementing state-of-the-art land applications and contemporary management systems in agriculture, it is possible to slow the rate of CO_2 emissions (Nazir et al., 2024). The combination of vermicompost and organic fertilizers can improve the quality of salt-affected soil and yield in severely salt-affected areas, resulting in increased crop yields and plant nutritional value. This is a suitable and cost-effective approach. Vermicompost can increase the available potassium and, at the same time, reduce the exchangeable Na compared with non-salt-affected soil, indicating that vermicompost application can reduce soil salinity and increase plant nutrients (Petmuenwai et al., 2024). Generally, soil carbon storage assessments use laboratory methods such as dry combustion (Nelson et al., 2018) and wet oxidation (Walkley and Black, 1934). However, these methods are expensive to analyze. Currently, geographic information technology is used to assess soil carbon storage using geographic information system techniques and remote sensing data (Bilgili, 2013), which helps to identify the distribution of carbon storage in soil in the area efficiently. Therefore, this study aimed to assess soil carbon sequestration in salt-affected areas managed with vermicompost and organic waste materials using a Geographic Information System (GIS) approach.

OBJECTIVE

The objective is to assess soil carbon sequestration in salt-affected areas managed with vermicompost and organic waste materials applying a geographic information system approach.

METHODOLOGY

Fieldwork was conducted in June 2024 in Ban Phai, Khon Kaen Province in Northeast Thailand. Figure 1 shows an outline of the study area (plot). This plot (~16.125 rai (1 rai = 1,600 m^2)) was abandoned because of excessive soil salinity. In 2019, drainage ditches and trenches were dug in the center and around the western part of the plot to remove salt by improving the drainage. After digging drainage ditches and trenches, vermicompost and organic fertilizers were applied to cultivate the salt-tolerant crops. After improving the drainage, we confirmed that these plants continued to grow until 2021.

Electrical Conductivity Measurement Method

The ECa at each depth range (V: 0-1.50 m, H: 0-0.75 m) was measured at 80 points in the field using an electromagnetic induction instrument (EM38-MK2, GEONICS Limited). Surface soil, ~3.0-cm thick, was sampled at 80 points, and pH and EC1:1 (three replicates) was measured after air drying. All measurement and sampling sites were located using GPS (GPSmap 60CX).

The soil salinity level was classified via ECe, as follows: non-saline: 0–2 dS/m; slightly saline: ≥2–4dS/m; moderately saline: >4–8dS/m; highly saline: >8–16dS/m; severely saline: >16dS/m. The soil salinity in this study was moderate to high.

Soil Organic Measurement Method

Soil organic carbon (SOC) was measured using the Walkley and Black method of wet oxidation (Walkley and Black, 1934). The classification of soil based on Soil Organic Carbon content is as follows: <1 = very low; 1.0-2.0 = low; 2.0-4.3 = medium; 4.3-6.0 = high; >6 = very high. (Tan, l986).

Spatial Mapping

The SOC and ECa maps were created by loading the ECa data with location information into ArcGIS and interpolating the ECa data using the Kriging method.

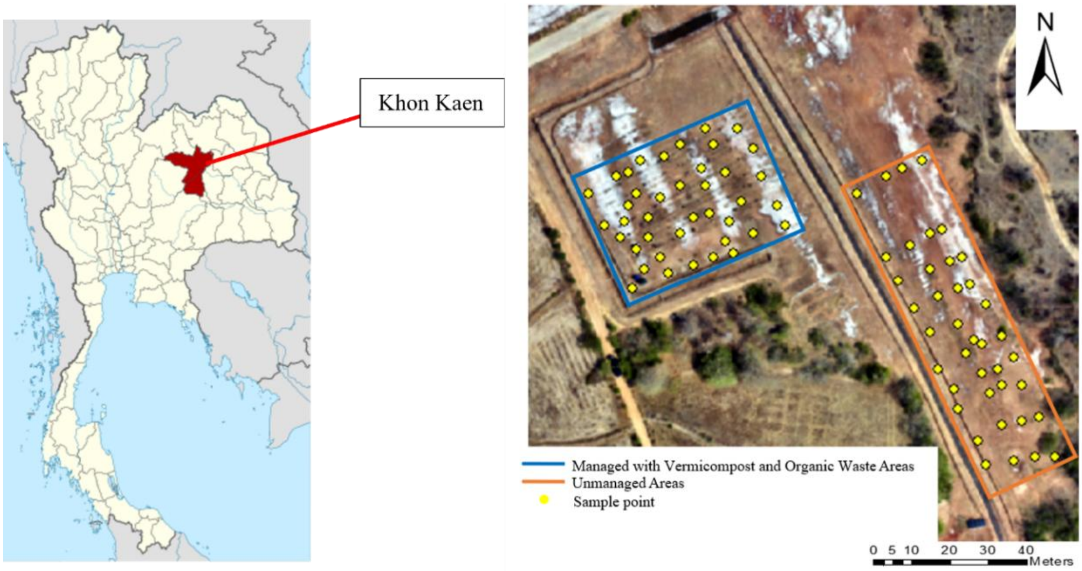

Fig. 1 Outline of the study area (field)

RESULTS AND DISCUSSION

The results of the study found that the organic carbon in the managed areas in the rainy season was low (SOC: 0.338%) and decreased to a very low level in the dry season (SOC: 0.192%), which was significantly different ($p<0.001$). The saline soil area managed with vermicompost combined with organic waste had higher organic carbon (SOC: 0.560%) than the unmanaged area (SOC: 0.350%). In managed areas, there is low SOC in the dry season; in the rainy season, SOC is low in 50 percent of the area and very low in 50 percent. In unmanaged areas during the dry season, SOC was low in 50% of the area and very low in SOC 50%, and in the rainy season, SOC was very low (Fig. 2).

Figure 3 shows that the soil electrical conductivity in the managed area was lower (10.16 dSm-1) than that in the unmanaged area (13.69 dSm-1), and the soil salinity level in the rainy season was already lower.

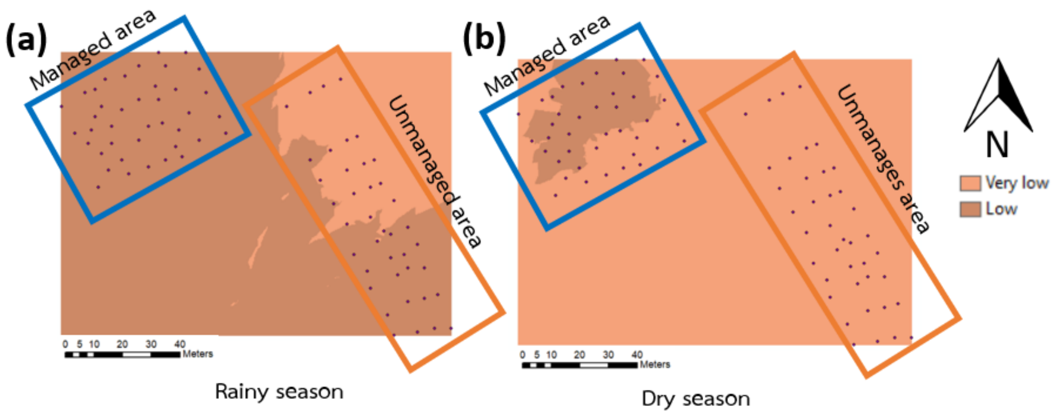

Fig. 2 SOC% surface soil (~3 cm) during rainy season (a) and dry season (b)

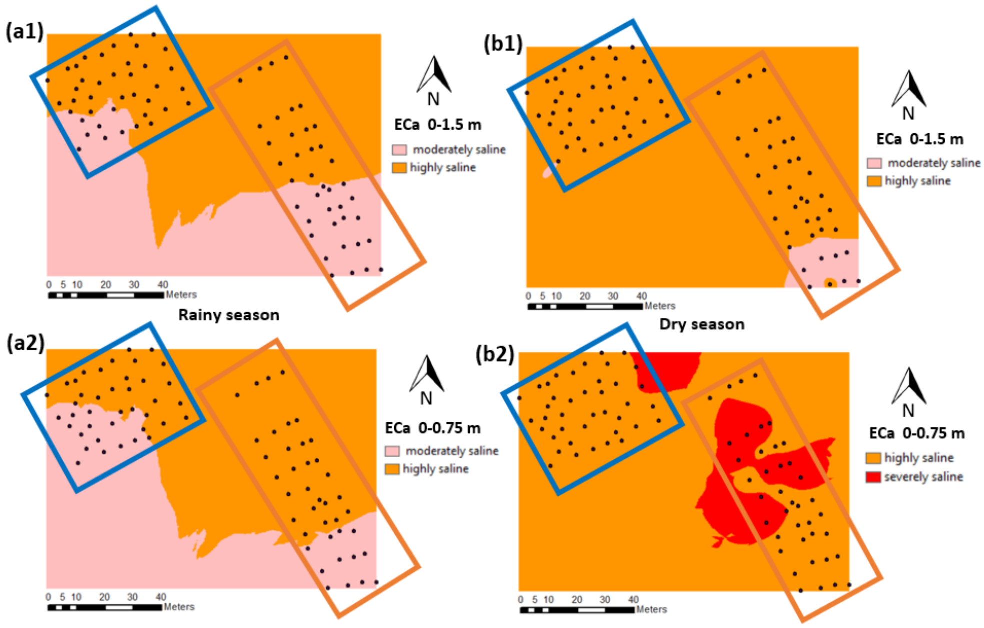

Fig. 3 ECa map in depth ranges during rainy season (a1 and a2) and dry season (b1 and b2)

The ECa value at a depth of 0-0.75 meters had higher soil electrical conductivity than at 0-1.5 meters. In the managed area, at ECa 0-1.5 m in the dry season, the soil was highly saline with shallow SOC in 70% of the area and moderately saline in 30%. At Eca 0-1.5 m during the rainy season, the soil was highly saline. At ECa 0-0.75 m, in the dry season, 50% of the area was highly saline, and 50% was moderately saline. At ECa 0-0.75 m in the rainy season, 95% of the area was highly saline and 5% was severely saline. In the unmanaged area, at ECa 0-0.1.5 m in the dry season, 50% of the area was highly saline, and 50% was moderately saline. At ECa 0-1.5 m in the rainy season, 80% of the area was highly saline and 20% was moderately saline. At ECa 0-0.75 m in the dry season, 50% of the area was highly saline and 50% was moderately saline. At ECa 0-0.75 m in the rainy season, 65% of the area was highly saline and 35% was severely saline. Some areas had highly saline (11.02 dSm^{-1}) and very low SOC (0.290%) soil. In areas with moderate salinity (6.10 dSm^{-1}), SOC was low (0.340%).

Vermicompost and organic materials enhance carbon sequestration efficiency by forming stable humic compounds, facilitating carbon binding with soil minerals through organomineral interactions, and reducing carbon loss in the gas form. Soil structure improvement by vermicomposting improves soil particle stability. Organic materials increase soil pore space for carbon accumulation and bind to soil particles (Xie et al., 2023). Soil carbon sequestration in salt-affected areas managed with vermicompost and organic waste materials results in long-term carbon sequestration, increasing the amount of stable organic carbon, reducing the rate of carbon loss from the soil, and extending the carbon retention time in the soil. It also adapts to the soil ecosystem, increases the tolerance of plants and microorganisms to salinity, restores the balance of the carbon cycle, and creates an environment suitable for plant growth.

CONCLUSION

The results of the experiment concluded that saline areas managed using vermicompost and organic waste helped increase carbon sequestration in the soil. They also reduced the soil electrical conductivity, with a more significant effect in the rainy season than in the dry season. Applying a Geographic Information System (GIS) to assess soil carbon sequestration in salt-affected areas significantly reduces the costs and resources required for soil sampling. GIS can analyze and predict soil properties across large areas using data from selected sampling points through spatial interpolation techniques, thereby eliminating the need for comprehensive soil sampling across every location. This approach substantially saves time, labor, and laboratory analysis costs. Moreover, the data collected can be used for the long-term monitoring of soil carbon changes. This research will be helpful in policy development and planning to assist in the development of regional strategies for managing salt-affected soils.

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