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Assessment of Roadside Grassland Soil Carbon Characteristics

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ABSTRACT

Carbon is a vital component of soil health and plays a crucial role in supporting plant growth and ecosystem functioning. By understanding the carbon content and characteristics of roadside grassland soil, we can evaluate its fertility and potential for supporting vegetation. Assessing roadside grassland soil carbon characteristics is important for understanding soil fertility, carbon sequestration potential, and the impact of human activities on soil health. The investigation includes elemental analysis of grassland soil and on that base calculation of ratios, soil organic carbon, soil carbon stocks, the carbon dioxide equivalent emissions from SCS soil carbon stocks loss. The samples have more percentage of element hydrogen which contribute to anaerobic conditions in grassland soil include waterlogging or poor drainage, high organic matter content, and compacted soil. The C/N (Carbon to Nitrogen) ratio is low and this is the reason of delayed decomposition and difficulties of nutrient cycling processes within the ecosystem. The soil organic carbon varies between 1 % and 2 %. Soil carbon stock between 304gC and 474 gC may be considered relatively low. The carbon dioxide equivalent emissions from SCS soil carbon stocks loss was between 2 and 3 %. This loss in carbon dioxide equivalent emissions from soil carbon stocks can be considered relatively low and potentially beneficial. Implementing practices that promote carbon sequestration, such as reducing soil disturbance, implementing cover cropping, and adopting sustainable land management practices, can help mitigate soil carbon loss and reduce emissions.

Keywords: soil organic carbon, soil carbon stocks, CO_2 equivalent emissions.

INTRODUCTION

Soil contamination along major roads is a serious global environmental problem. Many studies have noted that these pollutants are hazardous to vegetation located near highway easements. This would lead to possible changes in the biogeochemical processes in the soil and variability in the ecosystem and plant community. And it could affect endangered species [1, 2]. The other negative scenario is connected with the health-related aspects and the possibility of bioaccumulation of pollutants in the identified plant species, then bioaccumulation along the trophic levels of the food chain. Such

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pollutants released from vehicle exhaust can be nitrogen oxide (NO), nitrogen dioxide (NO_2), ammonia (NH_3), potentially toxic metals (TM), polyaromatic hydrocarbons (PAH) and carbon dioxide (CO_2) [3]. Restoring near-natural grasslands on roadsides is an excellent opportunity to support native biodiversity and provide ecosystem, to act as an important carbon sink in the soil [4]. Increasing soil organic carbon in grassland soil near roads is important for nutrient cycling: Soil organic carbon is a key component of nutrient cycling in grassland ecosystems. It serves as a source of energy and nutrients for soil microorganisms, which break down organic matter and release nutrients that are essential for plant growth [5]. Increasing soil organic carbon can enhance nutrient availability and promote healthier vegetation near roads [3].

Soil organic carbon contributes to soil fertility by improving soil structure, water-holding capacity, and nutrient retention. Grassland soils near roads are often subjected to disturbances such as vehicle emissions, road salt, and soil compaction. Increasing soil organic carbon can help mitigate these negative impacts and improve soil fertility, leading to better plant growth and ecosystem resilience [6].

On the other side grassland soils near roads are prone to erosion due to increased runoff and traffic-induced disturbances. Soil organic carbon plays a crucial role in stabilizing soil aggregates and enhancing soil structure, which helps prevent erosion [1, 2].

Increasing soil organic carbon in grassland soils near roads can contribute to carbon sequestration, which helps mitigate climate change as a potential to store carbon in their soils and reduce the concentration of greenhouse gases in the atmosphere. Enhancing soil structure, which helps to prevent erosion. By increasing soil organic carbon, the soil's ability to resist erosion is improved, reducing the loss of topsoil and preserving the integrity of the grassland ecosystem [1, 2].

Increasing soil organic carbon in grassland soils near roads can contribute to carbon sequestration, which helps mitigate climate change. Grasslands have the potential to store significant amounts of carbon in their soils, and by increasing soil organic carbon, we can enhance carbon sequestration and reduce the concentration of greenhouse gases in the atmosphere. The achievable SOC sequestration potential in global grasslands is 2.3 to 7.3 billion tons of carbon dioxide equivalents per year (CO_2e $year^{-1}$) for biodiversity restoration, 148 to 699 megatons of CO_2 $year^{-1}$ for improved grazing management [1].

Overall, increasing soil organic carbon in grassland soil near roads is important for promoting nutrient cycling, improving soil fertility, controlling erosion, and contributing to carbon sequestration. These benefits can help maintain the health and sustainability of grassland ecosystems in proximity to roads.

Grasslands are sensitive to climate change, which impacts on carbon sequestration. Rising temperatures associated with climate change can accelerate the decomposition of organic matter in grassland soils. This increased decomposition can lead to a decrease in SOC sequestration as more carbon is released into the atmosphere as CO_2. Higher temperatures can also affect soil microbial activity, potentially altering the balance between carbon inputs and outputs in the soil. Changes in precipitation patterns, such as increased frequency of extreme weather events like droughts or heavy rainfall, can impact SOC sequestration in grassland soils. Drought conditions can reduce plant productivity and limit the input of organic matter into the soil, resulting in decreased SOC sequestration. Conversely, heavy rainfall events can lead to increased erosion and loss of topsoil, which can reduce SOC levels [1, 2].

Climate change can influence the composition and distribution of plant species in grassland ecosystems. Some plant species may be more efficient at sequestering carbon than others. If climate change leads to shifts in vegetation towards species with lower carbon sequestration potential, it could result in reduced SOC sequestration in grassland soils near roads. Elevated atmospheric CO_2 concentrations, a key driver of climate change, can stimulate plant growth and photosynthesis. This can potentially increase carbon inputs into the soil through plant litter and root exudates, leading to enhanced SOC sequestration. However, the extent to which elevated CO_2 levels will impact SOC sequestration in grassland soils near roads depends on various factors, including nutrient availability and other environmental conditions [1 - 5].

It is important to note that the specific impacts of climate change on SOC sequestration in grassland soils near roads can vary depending on regional climate patterns, soil characteristics, and management practices. Monitoring and understanding these impacts are crucial for developing effective strategies to mitigate climate change and promote sustainable SOC sequestration in grassland ecosystems.

The aim of this paper is to investigate the elemental analysis in grassland soil located next to major roads and to assess soil capacity to act as carbon sink. It allows us to evaluate the effectiveness of management practices in preserving or enhancing soil carbon levels. Assessing roadside grassland soil carbon characteristics is important for understanding soil fertility, carbon sequestration potential, and the impact of human activities on soil health.

Soil carbon stocks are important because they play a crucial role in various ecosystem processes and functions. Carbon stored in the soil helps to improve soil fertility, water-holding capacity, and nutrient availability. It also contributes to the overall health and productivity of plants and microorganisms in the soil. Furthermore, soil carbon stocks have implications for climate change mitigation. Soils can act as a sink for atmospheric carbon dioxide (CO_2) through a process called carbon sequestration. Increasing soil carbon stocks can help offset greenhouse gas emissions by removing CO_2 from the atmosphere and storing it in the soil for extended periods.

EXPERIMENTAL

Test zone description

Preliminary field work was carried out, as a result of which 2 suitable roads were identified near the Capital, of which 1 along AM Hemus, and 1 along Road II-81 (Sofia - Petrokhan).

GIS procedure

Based on a visual interpretation of satellite images (Google Earth 7.3.6.9345), in a GIS environment (QGIS 3.4.6-Madeira) within the boundaries of each of the two polygons, 3 transects were randomly located, along which 10 sampling points were marked, every 10 m (the first one was 10 m from the edge of the road).

Sampling

The soil samples were taken during June 2023 at depth 0 - 20 cm, according to Ordinance №3 from 2008 [7].

Sample preparation

The soil samples have been dried at room temperature for 48 h and at 105 ± 5°C in an oven for additional 24 h. The dried samples were grinded by agate mortar and sowed through a sieve 3 mm. Subsequently the samples were homogenized, subdivided by quartering and sowed through a sieve 2mm. The prepared representative soil samples have been stored at 4°C. Quantitative elemental analysis of dry soil samples for the content of carbon, nitrogen and hydrogen was carried out with an automatic analyzer EA 3000 of the Italian company Euro Vector. The method of analysis is by burning the sample at a high temperature (980°C -1100°C) and determining the component by gas chromatography.

Evaluation methods for soil carbon levels

Soil organic carbon (SOC) is important because it is playing a crucial role in various ecosystem processes and functions. By multiplying the SOC content (Eq. 1) by the bulk density and soil depth, can determine the amount of SOC stored in a given volume of soil in the grassland soil [1, 2].

$$SOC\ (in\ grams) = SOC\ content\ x\ .\ x\ Bulk\ Density\ \ x\ Soil\ Depth \quad (1)$$

where:

- SOC content (%) represents the percentage of organic carbon in the soil sample.
- Bulk Density (in grams per cubic centimeter) is the mass of soil per unit volume.
- Soil Depth (in centimeters) refers to the depth at which the soil sample was collected.

The average bulk density in grassland soil can vary depending on several factors, including soil type, organic matter content, compaction, and land management practices. However, a general range for the average bulk density in grassland soil is typically between 1.0 to 1.6 g cm^{-3}.

Soil carbon stocks refer to the amount of carbon stored in the soil. It represents the total quantity of carbon present in the soil, including both organic carbon and inorganic carbon. Soil carbon stocks are measured in units of mass per unit area (e.g., grams or kilograms of carbon per square meter) (Eq. 2) [1, 2].

$$Soil\ Carbon\ Stocks = Bulk\ Density\ \times\ \times\ Soil\ Depth\ \times\ Soil\ Organic\ Carbon\ Content \quad (2)$$

In this formula, the bulk density represents the mass of soil per unit volume, measured in grams per cubic centimeter (g cm^{-3}). The soil depth refers to the thickness of the soil layer being considered for carbon stock estimation, measured in centimeters (cm). The soil organic carbon content represents the percentage of organic carbon present in the soil. By multiplying these three factors together, can determine the soil carbon stocks, which are expressed in units of mass per unit area (e.g., kilograms of carbon per square meter or tons of carbon per hectare).

The carbon dioxide equivalent emissions from SCS soil carbon stocks loss is estimated as the amount of carbon in the oxidized form using Eq. 3 [1, 2]:

$$CO_2eq = C\ (\%) \times 44/12 \quad (3)$$

RESULTS AND DISCUSSION

All calculations were made on the basis of the formulas and analyzes presented above, and are collected in Table 1. It includes the characteristics of grassland soil from the elemental analysis, the calculated ratios SOC, SCS, CO_2 equivalent.

A possible reason for the more hydrogen content in grassland soil could be the presence of anaerobic conditions. Anaerobic conditions occur when there is limited oxygen availability in the soil, which can promote the growth of anaerobic microorganisms. Factors that can contribute to anaerobic conditions in grassland soil include waterlogging or poor drainage, high organic matter content, and compacted soil. The organic matter, such as decomposed plant material or animal residues, can contribute to the overall hydrogen content in the soil. Additionally, certain soil management practices, such as the addition of organic fertilizers or compost, can increase the organic matter content and subsequently the hydrogen concentration in the soil. It's important to note that the specific conditions and factors influencing hydrogen levels in grassland soil can vary and may require further analysis or investigation.

The Carbon to Nitrogen (C/N) ratio is an important parameter in grassland soil because it provides insights into the decomposition and nutrient cycling processes within the ecosystem. The C/N ratio affects the availability of nitrogen (N) to plants. A balanced C/N ratio (around 20-30:1) promotes efficient nitrogen mineralization, ensuring an adequate supply of nitrogen for plant growth. If the C/N ratio is too high (indicating more carbon relative to nitrogen), nitrogen immobilization may occur, leading to nitrogen deficiency in plants. Conversely, if the C/N ratio is too low, nitrogen may be rapidly released, potentially leading to nutrient leaching and environmental issues. The C/N ratio influences

Table 1. Characteristics of soil in grassland.

No	No sample	N, %	C, %	H, %	C/N	C/H	SOC (gC m^{-2})	SCS (gC)	CO_2eq
1	273	0.53	0.78	1.4	1.47	0.56	17.16	377.52	2.86
2	274	0.45	0.65	1.28	1.44	0.51	14.30	314.60	2.38
3	275	0.46	0.63	1.23	1.37	0.51	13.86	304.92	2.31
4	276	0.35	0.73	1.26	2.09	0.58	16.06	353.32	2.68
5	277	0.19	0.93	2.98	4.89	0.31	20.46	450.12	3.41
6	278	1.12	0.71	2.18	0.63	0.33	15.62	343.64	2.60
7	279	0.18	0.98	3.11	5.44	0.32	21.56	474.32	3.59
8	280	0.51	0.71	1.41	1.39	0.50	15.62	343.64	2.60
9	281	0.59	0.81	1.53	1.37	0.53	17.82	392.04	2.97
10	282	0.3	0.92	3.18	3.07	0.29	20.24	445.28	3.37
11	283	0.17	0.74	1.8	4.35	0.41	16.28	358.16	2.71
12	284	0.47	0.72	1.43	1.53	0.50	15.84	348.48	2.64
13	285	0.46	0.68	3.41	1.48	0.20	14.96	329.12	2.49
14	286	0.22	0.7	1.1	3.18	0.64	15.40	338.80	2.57
15	287	0.59	0.76	1.18	1.29	0.64	16.72	367.84	2.79
16	288	0.3	0.86	2.76	2.87	0.31	18.92	416.24	3.15
17	289	0.43	0.7	1.23	1.63	0.57	15.40	338.80	2.57
18	290	0.6	0.7	1.21	1.17	0.58	15.40	338.80	2.57

the rate at which organic matter decomposes in the soil. Microorganisms responsible for decomposition require a balanced C/N ratio to efficiently break down organic materials. A higher C/N ratio indicates more recalcitrant organic matter that decomposes slowly, while a lower C/N ratio, as in this case, suggests more labile organic matter that decomposes rapidly. The C/N ratio impacts soil fertility and productivity. A suitable C/N ratio supports nutrient cycling, organic matter accumulation, and soil structure improvement. It helps maintain a healthy soil ecosystem, which is crucial for sustaining plant growth and productivity in grassland systems. The C/N ratio is linked to soil carbon sequestration potential. A balanced C/N ratio promotes the accumulation of stable soil organic carbon, contributing to long-term carbon storage in grassland soils. This is important for mitigating climate change by reducing atmospheric carbon dioxide levels.

The range of soil organic carbon (SOC) content can vary depending on factors such as soil type, climate, vegetation cover, and management practices. In mineral soils, the typical range for SOC content is between 1 % and 6 %. This range in these samples varies between 1 % and 2 %, depending on factors such as soil texture, depth, and organic matter inputs.

Soil carbon stocks can vary depending on the specific area and location. However, a soil carbon stock between 304 gC and 474 gC may be considered relatively low. Higher soil carbon stocks are desirable as they indicate greater organic matter content and can contribute to improved soil fertility, water retention, and overall soil health. Increasing soil carbon stocks is often a goal in sustainable land management practices, as it can help mitigate climate change by sequestering carbon from the atmosphere. The CO_2 equivalent emissions from SCS soil carbon stocks loss are between 2 % and 3 %. This loss in carbon dioxide equivalent emissions from soil carbon stocks can be considered relatively low and potentially beneficial. However, it is important to note that the significance of this percentage depends on the timeframe being considered. Soil carbon stocks play a crucial role in carbon sequestration and mitigating climate change. When soil carbon is lost, it can contribute to increased carbon dioxide equivalent emissions, which can have negative environmental impacts. Therefore, minimizing soil carbon loss is generally desirable.

CONCLUSIONS

Understanding the C/N ratio in grassland soil helps to optimize soil fertility, productivity, and carbon sequestration potential.

The carbon dioxide equivalent emissions from SCS in soil carbon stocks loss are between 2 % and 3 %. This indicates that a small portion of the soil carbon stocks has been emitted as carbon dioxide equivalents. While this percentage may be considered low, it is still important to monitor and manage soil carbon stocks to minimize further losses. Implementing practices that promote carbon sequestration, such as reducing soil disturbance, implementing cover cropping, and adopting sustainable land management practices, can help mitigate soil carbon loss and reduce emissions.

The goal should be to increase or maintain soil carbon stocks rather than accepting any level of loss. Strategies to enhance soil carbon sequestration can have multiple benefits, including improved soil fertility, water retention, and ecosystem health

Monitoring and managing soil carbon stocks is essential for sustainable land management and agricultural practices. It involves assessing the current levels of soil carbon, implementing practices that enhance carbon sequestration, and minimizing practices that lead to carbon loss, such as excessive tillage or deforestation. By maintaining and increasing soil carbon stocks, we can promote soil health, enhance ecosystem resilience, and contribute to climate change mitigation efforts.

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