

Soil Carbon: A Critical Link in Climate Change and Food Security

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ARTICLE ID: 51

Abstract

Climate change has major implications for agricultural productivity and food security, making it crucial to examine the role of soil carbon in mitigating these effects. This article provides an overview of the effects of climate change on soil carbon and explores strategies for promoting soil carbon sequestration through land management practices. It discusses the impacts of changing temperature and precipitation patterns on soil carbon, and highlights the importance of restoring degraded soils to increase soil carbon storage. We examined various land management practices, including cover cropping, conservation tillage, and organic amendments, and their potential to enhance soil carbon sequestration and suggests that site specific managemental practices should be chosen to conserve the habitat and promote carbon sequestration without compromising food security. It is important to improve soil health and carbon storage for increasing agricultural resilience and mitigating the effects of climate change on food security.

Keywords: Climate change, Soil carbon, Carbon sequestration, Climate change mitigation and Food security

Introduction

Climate change has become a major concern for global food security as it threatens to disrupt agricultural production through extreme weather events such as floods, droughts and heat waves. These events can cause crop failure, soil erosion and reduced crop yields, which in turn can exacerbate food insecurity. Soil carbon sequestration, the process of storing carbon in the soil through natural or human-induced methods, has emerged as a promising strategy for mitigating the impacts of climate change on food security. The soil plays a critical role in



regulating the Earth's climate, as it stores more carbon than the atmosphere and oceans combined. The carbon stored in soil helps to improve soil quality, increase water retention and reduce nutrient loss, which are all crucial for sustainable agricultural production. Sustainable land management practices such as cover cropping, conservation tillage and organic amendments can enhance soil carbon storage and provide multiple benefits for both agricultural production and environmental sustainability. However, there are limitations and challenges associated with promoting soil carbon sequestration, including the cost of implementation, the need for technical expertise and the lack of appropriate policies and incentives. Soil carbon offset programs, which allow individuals and businesses to offset their carbon emissions by investing in soil carbon sequestration projects, can play a critical role in promoting sustainable land management practices and mitigating the effects of climate change on food security. In this article, we will examine the effects of climate change on soil carbon, explore the potential for sustainable land management practices to promote soil carbon sequestration, and discuss the role of soil carbon offset programs in mitigating the effects of climate change on food security.

Effects of Climate Change on Soil Carbon

Changes in temperature Changes in temperature can greatly impact the amount of carbon stored in the soil. Shifts in patterns of precipitation and increases in temperature are two major components of ongoing climate change (IPCC, 2018). Warmer temperatures can increase the rate of decomposition of soil organic matter, which releases carbon into the atmosphere as carbon dioxide. This can lead to a reduction in soil carbon stocks over time and thus contribute to increased levels of atmospheric carbon dioxide. Additionally, increased temperatures can lead to changes in soil microbial activity and nutrient cycling, which can further impact soil carbon levels. According to research, an increase in soil temperature from 21°C to 38°C accelerates the breakdown of organic materials (Broadbent, 2015). This effect is attributed to the stimulation of microbial activity (Fang *et al.*, 2005) and the enhanced transport of soluble substrates within the soil (Fierer *et al.*, 2005). Furthermore, as temperatures rise, it can lead to changes in plant growth and root exudation patterns. Plants typically release more carbon into the soil through their roots when temperatures are higher, which can stimulate microbial



activity and enhance soil carbon storage. However, if plant growth is affected by other factors such as water availability, nutrient availability or disease, it can lead to a decrease in root exudation and soil carbon storage. In general, changes in temperature resulting from climate change can have both direct and indirect impacts on soil carbon storage. Understanding these effects is crucial in developing strategies to mitigate the impacts of climate change on soil carbon, such as implementing sustainable land management practices and promoting soil health.

Changes in precipitation patterns

Changes in precipitation patterns due to climate change can have a significant impact on soil carbon. Alterations in the timing, frequency, and intensity of rainfall can affect the amount of carbon stored in the soil by influencing plant growth, soil microbial activity, and nutrient cycling. In regions where precipitation is decreasing due to climate change, soil carbon stocks can be depleted. This is because the amount of carbon that can be stored in the soil is often limited by the amount of water available. In areas where rainfall is already scarce, a reduction in precipitation can lead to lower plant productivity, less organic matter input, and lower microbial activity. Research has found that at wet areas, higher precipitation causes a decrease in dissolved organic carbon and microbial biomass carbon (Chen *et al.*, 2023). All of these factors can result in a decline in soil carbon storage.

Changes in land use and management practices

Changes in land use and management practices refer to alterations made to the way land is used and managed for agricultural or other purposes. These changes can include modifications to crop rotations, tillage practices, fertilization methods, irrigation systems, and the use of cover crops, among others. Land use changes may involve the conversion of forest or grassland to cropland or pasture, while management practices may involve the application of organic amendments or other soil-improvement techniques. The goal of such changes is often to improve soil health and fertility, increase agricultural productivity, and reduce the negative impacts of farming on the environment, including soil erosion and greenhouse gas emissions. These changes can have significant impacts on soil carbon storage and play a key role in mitigating the effects of climate change on food security

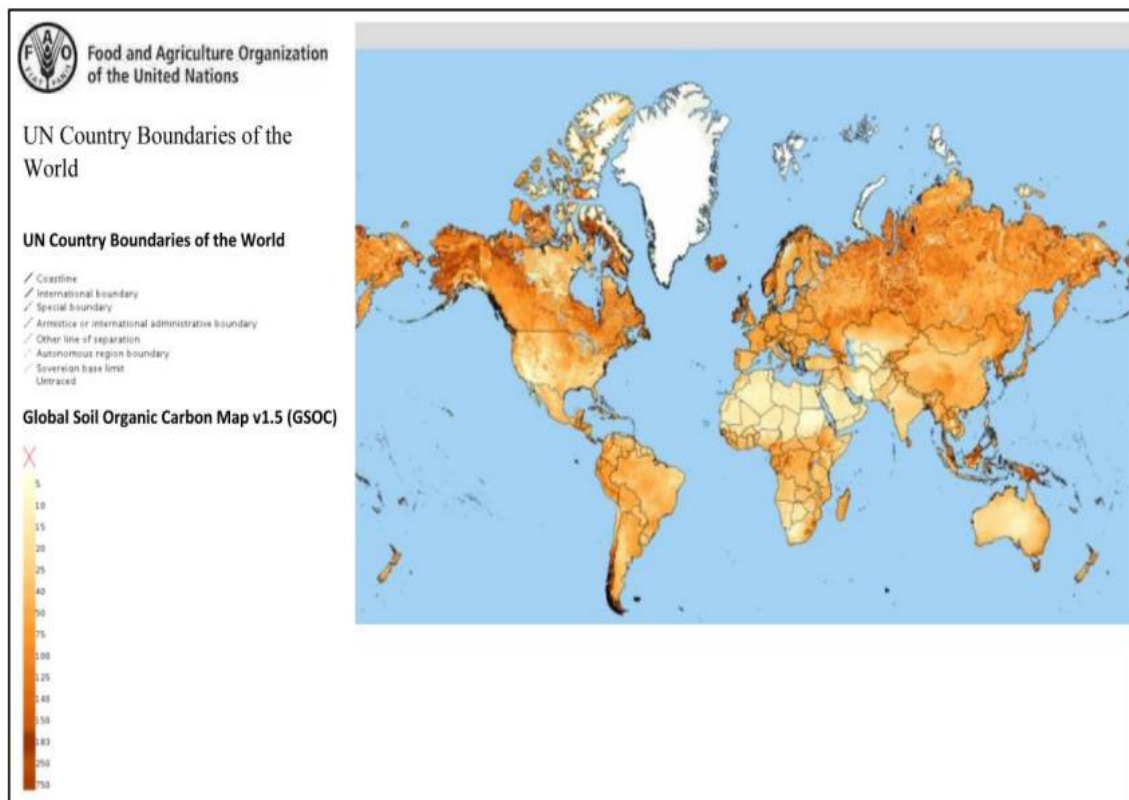


Figure 1. Global soil carbon content in the topsoil (0-30 cm depth) (Source: FAO, 2023)

Mitigating Climate Change Through Soil Carbon Sequestration

Soil carbon sequestration is the process of capturing and storing atmospheric carbon in the soil. Figure 1 gives the present scenario of Soil Organic Carbon (SOC) content in the topsoil (0-30 cm depth) for different countries. Increasing soil carbon levels can help mitigate the effects of climate change by reducing atmospheric carbon dioxide levels. There are several sustainable land management practices that can promote soil carbon sequestration, including carbon storage, cover cropping, conservation tillage, organic amendments and fertilizers, crop rotation, fertilizers and reducing soil erosion.

Restoring Soil Carbon in Degraded Soils

Soil degradation is a major issue worldwide, and degraded soils have significantly lower levels of soil organic carbon. This not only results in decreased soil fertility and productivity but also contributes to climate change. Therefore, restoring soil carbon in degraded soils is an important goal for both improving soil health and mitigating climate change. Restoring of degraded soils helps in improving soil health and climate change mitigation.

Techniques for Enhancing Soil Carbon Storage

- ✚ **Soil carbon sequestration:** Sequestering atmospheric carbon in the soil can be achieved through techniques such as conservation agriculture, no-till farming and cover cropping.
- ✚ **Biochar:** Incorporating biochar into the soil can help increase soil organic matter content and promote soil carbon storage. Biochar applications were found to be the most effective approach for increasing soil organic carbon content, resulting in an average increase of 39%. Cover crops and conservation tillage had less pronounced effects, with average increases of 6% and 5%, respectively, according to the findings of Bai *et al.* (2019).
- ✚ **Soil inoculants:** Using soil inoculants such as mycorrhizal fungi and rhizobia can enhance soil microbial activity, leading to greater nutrient cycling and increased soil carbon storage. In brief, restoring soil carbon in degraded soils is crucial for improving soil health, enhancing agricultural productivity, and mitigating climate change. The use of sustainable land management practices and the incorporation of organic amendments can promote soil carbon storage and help restore degraded soils. Techniques such as soil carbon sequestration, biochar and soil inoculants can also be effective strategies for enhancing soil carbon storage.
- ✚ **Soil health for climate change adaptation and mitigation:** Soil health plays a critical role in both mitigating and adapting to climate change. The health of soil ecosystems is closely linked to their ability to store and cycle carbon, making soil health an important factor in reducing greenhouse gas emissions and increasing the resilience of agroecosystems to climate change impacts.

Improving Soil Health for Climate Change Mitigation and Ensuring Food Security

- ✚ **Soil biodiversity:** Soil biodiversity refers to the variety of living organisms found in soil, including bacteria, fungi, protozoa, nematodes, arthropods, and earthworms. Soil biodiversity plays a crucial role in maintaining healthy soils and supporting plant growth. These organisms responsible for breaking down organic matter and releasing nutrients, which are essential for carbon sequestration. Soil organisms play a key role in storing carbon in the soil, which helps to plant growth are.



- ✚ **Soil structure:** The physical structure of soil is important for water and air movement, nutrient cycling, carbon sequestration and plant growth. Improving soil structure through practices such as cover cropping and reduced tillage can enhance soil health and in turn crop yield.
- ✚ **Organic matter:** Increasing soil organic matter content through the use of organic amendments such as compost, manure and biochar can help promote soil health and enhance soil carbon storage. Soils rich in organic carbon provides an ideal medium by improving various soil properties and thus could make the soil best suitable for plant growth. Loss in soil fertility is a major concern that we are currently facing and it could be a serious threat for our future as well since we need food to feed our ever-increasing population. Hence, increasing organic matter by returning it to the soil rather than the atmosphere could help solve two major threats, namely, food security and global warming.

Conclusion

In Conclusion, the importance of soil carbon in mitigating the effects of climate change on food security cannot be overstated. The potential for soil carbon sequestration through land management practices such as cover cropping, conservation tillage, and organic amendments is significant, and restoring degraded soils can increase soil carbon storage. It is imperative that we take action to promote soil health and carbon storage through sustainable land management practices which are site specific. By doing so, we can increase agricultural resilience and mitigate the impact of climate change on food security. It is essential that we increase awareness of the importance of soil carbon and take action to promote its storage and sequestration for the benefit of current and future generations.

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