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Editorial

Carbon Sequestration and Stability and Soil Erosion in Forest Ecosystems

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1. Introduction

Soil is the largest carbon pool in terrestrial ecosystems, being about three to four times larger than the vegetation carbon pool and two to three times larger than the atmospheric carbon pool. The development of effective measures to enhance the capacity of soil carbon sinks is an important way to achieve carbon neutrality and mitigate global climate change. The carbon stock in forest soils is the result of a dynamic balance between carbon inputs and carbon outputs. As an important part of the soil carbon pool, changes in the accumulation and decomposition of organic carbon in forest soils directly impact the carbon storage capacity of terrestrial ecosystems, which not only provide carbon sources for plant growth and maintain the good physical structure of the soil, but also release carbon into the atmosphere in the form of greenhouse gasses. It is crucial, therefore, to comprehensively understand the process of changes in the organic carbon stored in forest soils and the key factors controlling it. Forest soil carbon inputs depend largely on forest productivity, the decomposition rates of litter and plant roots, while carbon outputs are accomplished through the mineralization and decomposition of organic carbon and soil respiration. In recent decades, many scholars have paid attention to the impact of management on forest soil carbon stocks and carbon processes, and have carried out research on the management of the forest soil carbon cycle in different forest types around the world, showing that improving the level of forest management can enhance the potential of carbon sinks in the aboveground and belowground parts of forest ecosystems. This Special Issue aims to determine plant, soil, and ecosystem carbon storage and soil C stability changes in forest ecosystems, and to identify key factors that best explain carbon storage and stability changes. The articles presented in this Special Issue can be divided into the following three topics, which are directly related to soil ecology.

2. The Impact of Nitrogen Deposition on Soil Organic Carbon

Two articles are devoted to understanding the effect of nitrogen deposition on soil organic carbon (SOC). In recent decades, the increase in atmospheric nitrogen (N) deposition has increased the effectiveness of N in forest soils, which will affect the soil nutrient status and microbial communities and alter the decomposition of plant litter and SOC dynamics.

Chen et al. [1] carried out a N addition experiment in a subtropical Castanopsis fabri forest to investigate the effects of short-term N addition on particulate organic carbon (POC) and mineral-associated organic carbon (MAOC) as well as the underlying mechanisms thereof. The results showed the following: (1) N addition showed a positive effect on POC and SOC contents but did not significantly affect MAOC content; (2) POC content

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was negatively correlated with pH and soil enzyme activity and positively correlated with aboveground litter production, suggesting that POC accumulation was influenced by aboveground litter inputs and microbial decomposition; (3) a close negative relationship was observed between exchangeable Al^{3+} and Ca^{2+} or K^{+} contents, indicating that there is likely to be a trade-off between mineral sorption and desorption, thus resulting in an insignificant reaction of MAOC to N addition. Overall, the accumulation of SOC under short-term N addition was found to be primarily driven by POC, and the response of different SOC functional fractions to N addition was inconsistent. By incorporating these nuances into ecosystem models, it is possible to predict SOC dynamics more accurately in response to global change.

In the other article, Yang et al. [2] conducted a global analysis to evaluate the effects of the nitrogen application rate, nitrogen addition duration (time), and humidity on SOC and TN accumulation rates using 257 data points (63 articles). Nitrogen addition increased SOC and TN by 4.48% and 10.18%, respectively. The SOC and TN accumulation rates were 0.65 and 0.11 g kg^{-1} yr^{-1}, respectively. The variations in SOC and TN increased overall with the nitrogen application rate and duration of nitrogen addition; however, the accumulation rates of SOC and TN decreased overall with the nitrogen application rate and the duration of nitrogen addition. In addition, the percentage changes and change rates of SOC and TN increased overall with the humidity index. In conclusion, nitrogen addition promoted SOC and TN accumulation in forest soils, and the nitrogen application rate and nitrogen addition duration increased the percentage changes in SOC and TN; however, they decreased the accumulation rate, while humidity increased the accumulation rates of SOC and TN.

3. Soil Erodibility and Erosion Risk

Soil erosion mainly refers to the status of soils and their parent materials on the surface of the earth under the action of forces such as water, wind, ice melting, or gravity as well as internal and external camping forces. Soil erosion not only directly causes the loss of soil nutrients and water pollution, leading to land degradation, reduced soil quality, reduced agricultural yields, and the degradation of ecological functions, but also leads to the migration of soil carbon, which significantly alters the spatial distribution pattern of carbon and global climate change, causing serious damage to human ecology and the basis of development.

Nieto et al. [3] investigated water erosion in the southeast of the Ría de Arosa (Ponte vedra, Spain), utilizing the revised universal soil loss equation model and geographic information system technologies. The key factors analyzed included rainfall erosivity, soil erodibility, topography, land cover, and conservation practices. High-resolution maps (1 × 1 m pixels) identified areas at high risk of erosion. Vulnerable zones, such as coastal cliffs and vineyards, show severe erosion rates exceeding 50 t/ha/year (>5 mm/year), with the most extreme zones reaching up to 200 t/ha/year (>200 mm/year). These results emphasize that intervention could be required or recommended. Suggested measures include reforestation, effective agricultural land management, or the implementation of vegetative barriers to reduce erosion. These areas, characterized by steep slopes and sparse vegetation, are particularly susceptible to soil loss, necessitating specific conservation efforts. The results underscore the need for sustainable coastal management practices and preventive strategies to protect this vulnerable coastal zone. Implementing these measures is crucial to mitigating the impacts of soil erosion, preserving natural resources, and ensuring long-term ecological and economic resilience in the region.

In the other article, Yang et al. [4] explored variation in the characteristics of soil erodibility during a vegetation restoration period after the 5.12 Wenchuan earthquake. Field soil sampling, geostatistics, and spatial interpolation were used to explore the spatiotemporal changes in soil physicochemical properties and soil erodibility during a natural restoration in 2013 (5 years after the earthquake) and in 2022 (14 years after the earthquake). The results show that the comprehensive soil erodibility index (CSEI) was mainly composed of five soil factors, which were soil pH, soil total nitrogen (TN), mean weight diameter of soil aggregates (MWD), the fractal dimension of soil water stable aggregates (D), and soil erodibility (Kepic). The CSEI of the landslide area was slightly lower than that of the non-landslide area. The CSEI was gradually increased during the process of natural restoration after the earthquake. From 2013 to 2022, the increase rates of the CSEI were 6.9%, 10.0%, and 41.5% for the landslide area, non-landslide area, and transition area, respectively. Along attitude segments, the spatial distribution of soil erodibility in 2022 was more uniform than that in 2013. The highest values of the CSEI were located in the upper parts of the research areas. The spatial distribution of the CSEI in 2013 and 2022 appeared as a moderate autocorrelation. The variable ranges of the CSEI in 2013 and 2022 were about 20 m. In the early stage of vegetation restoration, soil and water conservation engineering was recommended in the landslide area.

4. Thinning Intensities on Soil Organic Carbon Cycle

Conservation thinning is an effective forest management method to improve stand structure, forest health, and biodiversity. As one of the most important forest management tools, the effect of thinning on soil carbon stocks should not be underestimated. Appropriate thinning can enhance the carbon sequestration capacity of forest soils and help combat climate change [5]. Therefore, the development and implementation of a scientifically sound thinning program is crucial for sustainable forest management. Research needs to explore the mechanism of the effects of thinning on soil carbon pools and optimize management measures to maximize its positive effects and minimize its negative effects. Forest management practices need to be tailored to specific forest types, soils, and climatic conditions.

Zhang et al. [5] examined how different thinning intensities influence seasonal soil carbon cycling in degraded forests. Their results show that thinning significantly altered the soil's attributes, as revealed by field experiments and data analysis. Moderate thinning (20% intensity) significantly enhanced litter retention and soil nutrient levels year round ($p < 0.05$). Seasonal variations affected soil carbon dynamics and lower thinning intensities improved carbon sequestration in spring and summer. Conversely, higher thinning intensities led to carbon loss in autumn and winter. Litter carbon, fine root carbon, and the correction factor significantly respond to thinning intensities year round as examined through redundancy analysis and random forest analyses. The findings indicate that moderate thinning effectively enhances soil carbon sequestration in degraded forests. Strategically planned thinning could aid climate change mitigation by boosting forest soil carbon storage, influencing forest management and conservation.

5. Conclusions

This Special Issue presents a valuable collection of studies on carbon sequestration and stability and soil erosion in forest ecosystems. The collected articles serve to improve understanding of the complex mechanisms underpinning biological and ecological problems caused by global changes (such as warming, drought, etc.), forest management (such as forest thinning, fertilization, nitrogen and phosphorus addition, etc.), succession, vegetation restoration, greenhouse experiments, field experiments, litter decomposition, soil microbial activity, soil animals, soil carbon, and soil erosion. The research reports contained in this Special Issue provide important insights for the realization of the sustainable development of forest ecological systems.

Conflicts of Interest: The authors declare no conflicts of interest.

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