

Biochar for Sustainable Farming and Recultivation

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1. Introduction

Food shortage is a severe problem, with an estimated 720 to 811 million people globally facing hunger in 2020, as reported by the FAO [1]. The availability of adequate food relies on efficient farming practices and fertile land. Unfortunately, land degradation is prevalent and manifests in various forms, including soil erosion, sedimentation, desertification, compaction, and shallowing of the tillage layer. Additionally, pollution from heavy metals and organic matter, acidification, nutrient imbalances, excessive fertilization, salinization, biodiversity loss, decay in biological functions, disease bioaccumulation, over-cropping, and mis-management of agricultural activities further contribute to this problem. Therefore, it is imperative to prioritize land recultivation and improve farming techniques in order to enhance agricultural productivity.

Recently, it has been reported that biochar can bring many benefits for agricultural soils. Due to their porous and carbonaceous structure, with huge surface areas and high pH and cation exchange capacities, biochar application has been shown to decrease soil bulk density, increase soil aggregate structure, increase soil pH in acidic soils, increase soil nutrient efficiency, improve soil microbial diversity, and reduce the bioavailability of heavy metals, thus increasing crop yield and improving crop quality [2–4]. Therefore, there is high potential to use biochar as a soil amendment for sustainable farming and recultivation. However, although there are abundant studies on biochar from pot and simulated studies, long-term field experiments are lacking, and some critical processes are not well understood. Before extensively applying biochar to sustainable farming and recultivation, it is important to further investigate its effects on soil organic carbon transformation and composition, carbon sequestration and emissions, soil aggregation, the humification process of organic waste, etc.

The aim of this Special Issue is not to comprehensively cover the entire domain of “biochar for sustainable farming and recultivation”; however, it does offer valuable insights for future research and potential applications in those related aspects.

2. Special Issue Overview

When assembling this Special Issue, we extended invitations to contributors to explore the effects of biochar on soil degradation control, land recultivation, and farming from both theoretical and practical perspectives. We received 13 manuscripts between 12 August 2022, and 22 May 2023, and after rigorous review by qualified researchers, 5 papers were published. The Special Issue consists of four subjects centered around “Biochar for Sustainable Farming and Recultivation”. These subjects are: (1) the research progress of biochar in carbon sequestration and emission reduction [5]; (2) the consequences of biochar application on soil aggregation [6,7]; (3) the influence of biochar addition on the humification process of organic wastes [8]; and (4) the effects of biochar addition on soil organic carbon transformation and composition [9]. This Special Issue covers both theoretical mechanisms and practical applications, including laboratory incubations and field experiments. All



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studies featured in this Special Issue are highly innovative and will serve as valuable references for researchers in related fields. Section 2.1 provides a concise overview of each study included in this Special Issue.

2.1. The Research Progress of Biochar in Carbon Sequestration and Emission Reduction

Despite intensive research on the impact of biochar on climate change [10,11], limited studies have examined its effect on carbon reduction in paddy soils. Hence, Fei Bu et al. [5] conducted a meta-analysis and life cycle modeling to assess the potential of biochar for carbon sequestration in paddy soils. The findings reveal that biochar application significantly increases soil carbon content and rice yield, while having no significant impact on methane and carbon dioxide emissions, and reducing nitrous oxide emissions. Factors such as the biochar application rate, nitrogen fertilizer application, biochar pyrolysis temperature, soil type, and climate play crucial roles in shaping rice yield and carbon emissions. In conclusion, this study suggests that applying biochar to paddy soils has the potential to mitigate carbon emissions. However, further long-term field experiments are necessary to validate the model's predicted results.

2.2. The Consequences of Biochar Application on Soil Aggregation

Soil aggregation plays a crucial role in sustainable farming practices, benefiting both field crop production and facility agriculture. The structure of soil aggregates is closely linked to the presence of microbial residues in the soil [12,13], which can be quantified by analyzing the amino sugar content of the microbial cell wall. In a two-year field experiment focusing on the impact of biochar addition on soil microbial residues, Cheng et al. [7] investigated the potential of biochar to improve soil quality and promote carbon sequestration, using wheat crops grown in fluvo-aquic soil. The researchers found that particle size had a significant impact on microbial residues, with 0.25–2 mm soil aggregates exhibiting the highest levels of amino sugars and microbial residue carbon (MRC). Compared with the NPK treatment, the addition of biochar significantly elevated the levels of glucosamine, galactosamine, total amino sugars, and MRC in the entire soil profile and 0.05–0.25 mm aggregates. Bacterial biomass and N-acetylglucosaminidase activity positively influence the carbon content of amino sugars and microbial residues. Overall, the 0.25–2 mm soil aggregates exhibited the highest accumulation of soil microbial residues, and the combined application of NPK with biochar enhanced the accumulation of microbial residues in soil aggregates, offering a promising fertilization strategy to improve soil microenvironments and the overall quality.

In the context of facility agriculture, Xu et al. [6] examined the impact of biochar addition on the content of soil organic carbon (SOC) and the stability of aggregates in Mollisols cultivated with eggplants in a greenhouse environment. The study revealed that the incorporation of biochar and reduced water–fertilizer inputs has a significant effect on SOC content and the stability of aggregates. The results illustrate that combining the addition of biochar with an 80% reduction in water and fertilizer inputs results in a significant boost in SOC content and the average diameter of soil aggregates, exhibiting increments of 56.1% and 32.6%, respectively. The researchers conclude that incorporating biochar and implementing optimized water–fertilizer management is a viable approach for enhancing the soil quality and crop cultivation environment in Mollisols.

2.3. The Influence of Biochar Addition on the Humification Process of Organic Wastes

Many studies have shown that the application of biochar can increase soil organic content and alter the soil humification process in relation to plant and microbial residues [14–16]. However, there have been few reports on the humification process of actual food waste after the addition of biochar. Ming et al. [8] investigated the impact of biochar addition on the composition of humic-acid-like substances (HALs) and the structure of humic substances during the humification process of real food waste. The results indicated that the addition of biochar shortened the time for the reactor to enter the high-temperature period, extended

the duration of the high-temperature period, and consequently resulted in a more mature replication of the reactor. Additionally, it reduced the content of total organic carbon and fulvic-acid-like compounds, while enhancing the relative contents of total nitrogen, HALs, and the humification index value. The inclusion of biochar also led to changes in the structural characteristics of HALs, making them more complex and less lipidic, while increasing the degree of aromatization and thermal stability. These alterations further facilitated the replication process of the reactor and promoted the maturation of the composting materials.

2.4. The Effects of Biochar Addition on Soil Organic Carbon Transformation and Composition

In order to preserve soil productivity, it is imperative to enhance our understanding of soil organic carbon transformation and composition. Hu et al. [9] conducted a study illustrating that the utilization of *Cipangopaludina chinensis* shell powder and biochar resulted in increases in soil organic carbon, microbial biomass carbon, and dissolved organic carbon contents, as well as enhanced urease, catalase, and sucrase activities. Additionally, this treatment led to decreases in oxidizable organic carbon and available potassium contents. Remarkably, the application of 2.6% orange peel residue biochar accompanied by 1.3% shell powder yielded the most favorable outcomes in terms of soil organic carbon components and enzyme activities. From their findings, it can be inferred that both biochar and shell powder contribute positively to the transformation of soil organic carbon.

3. Conclusions

This Special Issue provides a snapshot overview of the current progress in research related to the application of biochar for sustainable farming and recultivation. The studies included in this Special Issue investigate the various impacts of biochar, such as its effects on carbon sequestration, emissions, soil aggregation, the organic waste humification process, and soil organic carbon transformation and composition. The findings consistently demonstrate that the application of biochar effectively enhances the total carbon content in soil and improves crop yield. Furthermore, it significantly reduces nitrous oxide emissions, while having minimal influence on methane and carbon dioxide emissions. The introduction of biochar also contributes to the enrichment of amino sugars and microbial residues in soil aggregates, leading to an improved soil microenvironment and better quality. Additionally, biochar application accelerates the humification process of organic wastes, consequently elevating the thermal stability and complexity of humic substances and enhancing soil fertility. Notably, the combined application of orange-winged shell powder and biochar demonstrates positive effects on soil organic carbon transformation and composition. These noteworthy findings offer valuable insights into the practical application of biochar in agriculture and land reclamation.

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