ISSN: 2710-0723

Effects of Organic Fertilizer Application on Cultivated Land Productivity and Carbon Pool

Yan Li[1,2,3,4], Nan Lu[1,2,3,4], Yuhu Luo[1,2,3,4]

[1] Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 712100, China

[2] Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 710021, China

[3] Key Laboratory of Degraded and Unused Land Consolidation Engineering, Ministry of Natural Resources, Xi'an 710075, China

[4] Key Laboratory of Cultivated Land Quality Monitoring and Conservation, Ministry of Agriculture and Rural Affairs, Xi'an 710075, China

Abstract

The promotion and application of organic fertilizers in agriculture not only enhance the soil organic carbon pool but also offer viable solutions for addressing climate change. This paper, grounded in a comprehensive review of existing literature, analyzes the effects of organic fertilizers on cultivated land productivity and soil carbon pools. It summarizes the mechanisms through which organic fertilizers improve agricultural productivity and evaluates their carbon sequestration potential within the soil carbon pool. Finally, the environmental impact of organic fertilizer application process was discussed. In the future, through scientific application methods, organic fertilizer will play a more positive role in achieving food security, protecting soil health, and promoting carbon sink capacity.

Keywords

Cultivated Land Quality; Organic Fertilizer; Soil Carbon Pool.

1. Introduction

In the global agricultural production system, the productivity of cultivated land is intricately linked to variations in the soil carbon pool. This productivity not only directly influences crop yield and quality but also impacts the stability and sustainable development of ecosystems. Soil carbon pools are critical components of the global carbon cycle and play a significant role in mitigating climate change. Consequently, enhancing cultivated land productivity while increasing soil organic carbon content has emerged as a pivotal research focus within agricultural and environmental sciences. As a natural fertilizer source, organic fertilizers enrich soils with organic matter and nutrients by transforming animal and plant residues into essential soil nutrients. In contrast to chemical fertilizers, organic fertilizers significantly enhance soil fertility, improve soil structure, boost biodiversity, reduce erosion risks, and ultimately foster increased productivity on cultivated lands. Recent studies have increasingly demonstrated that long-term application of organic fertilizers can augment soil organic carbon storage while playing an instrumental role in promoting agricultural soil carbon pools. However, concerns regarding potential carbon emissions during the application of these fertilizers-alongside environmental risks stemming from improper usage-pose challenges for both research and practical implementation. Considering global climate change considerations, achieving a synergistic outcome that enhances production alongside effective carbon

ISSN: 2710-0723

sequestration through judicious use of organic fertilizers has become an essential topic for advancing sustainable agriculture.

2. The Influence of Organic Fertilizer on Cultivated Land Productivity

2.1. Enhancement of Soil Structure through Organic Matter

Organic fertilizers are abundant in organic matter, which can significantly enhance soil structure and augment the productivity of cultivated land. Organic matter improves the stability of soil aggregates, thereby enhancing physical properties such as water retention, aeration, and permeability. The formation and stability of these aggregates form the foundation for soil fertility and bolster crop root systems' ability to absorb water and nutrients effectively. Research indicates that applying organic fertilizer markedly enhances soil water retention, particularly under drought conditions, which is crucial for improving crop drought resistance. Soils subjected to long-term organic fertilizer application exhibit significantly higher moisture content compared to those treated solely with chemical fertilizers, resulting in corresponding increases in crop yield [1]. Furthermore, increased organic matter reduces surface compaction within the soil, making it more conducive to plant root development while mitigating erosion and nutrient loss.

Organic fertilizers also improve the ion exchange capacity of soils, enhancing their absorption and buffering capabilities regarding nutrients. This effect not only elevates soil fertility but also renders soils more adaptable to external environmental changes-facilitating stable crop growth.

2.2. Improvement in Nutrient Supply and Utilization Efficiency

Organic fertilizers not only enhance soil structure by increasing organic matter but also supply essential macronutrients such as nitrogen (N), phosphorus (P), potassium (K), along with various trace elements. Unlike conventional fertilizers where nutrients are readily available for uptake by plants, those found in organic fertilizers exist in organically bound forms that undergo gradual release following microbial decomposition processes. This slow-release mechanism sustains nutrient availability over time while minimizing oversupply or losses associated with traditional fertilization practices.

Nitrogen present in organic fertilizer serves a dual purpose; it provides vital nutrition for plant growth while continuously replenishing nitrogen levels within the soil via mineralization processes over time. Studies have demonstrated that prolonged application of organic fertilizer promotes nitrogen cycling within soils leading to enhanced nitrogen use efficiency. For instance, one study revealed an increase exceeding 15% in nitrogen utilization rates among fields treated with organic versus conventional fertilization methods [2]. In addition to nitrogen benefits, these fertilizers contribute available phosphorus and potassium into the nutrient cycle through decomposed organic material-thereby reducing risks related to short-term fixation or loss of applied nutrients from synthetic sources. Moreover, trace elements like calcium (Ca), magnesium (Mg), and boron (B) contained within these products play critical roles during crop development; supplementation with these elements can substantially elevate both yield quality alongside overall production levels.

2.3. Effects on Soil Microbial Communities

The composition of microbial communities within soils plays a pivotal role concerning maintaining fertility levels while facilitating nutrient conversion necessary for improved cultivated land productivity outcomes overall. Organic fertilizer supplies ample carbon sources coupled with energy resources beneficially impacting microbial populations residing therein-stimulating reproduction alongside activity amongst advantageous microorganisms inhabiting this environment. For example, Organic materials furnish requisite carbon substrates supporting heterotrophic microorganisms metabolic activities thus enhancing biological

ISSN: 2710-0723

availability pertaining specifically towards key macro-nutrients including N, P, K etc., found throughout respective ecosystems [3].

Long-term applications involving said amendments lead not merely towards heightened microorganism counts but additionally enrich diversity across entire community structures observed locally too. Empirical evidence suggests significant upticks occur regarding fungal/bacterial/ actinobacterial types/numbers post-application events especially promoting active engagement surrounding decomposer species involved directly influencing breakdown /mineralization pathways yielding accessible nourishment ultimately benefiting crops grown thereafter.

Furthermore, the vigorous metabolic actions exhibited by resident microbes further promote stabilization efforts directed at preserving existing stocks relating back toward stored carbon reserves whilst, concurrently curtailing emissions released otherwise unregulated previously noted above mentioned scenarios altogether contributing positively towards. Establishing healthier environments fostering robust biological activity enriching overall ecosystem functionality enabling thriving agricultural outputs achieved consistently year-round without fail [4].

3. The Impact of Organic Fertilizer on Carbon Pool

3.1. Carbon Sequestration Effect of Soil Organic Carbon

Soils are an important part of the global terrestrial carbon pool, containing about one-third of the world's carbon reserves. The application of organic fertilizer helps to increase the organic carbon content in the soil, thus promoting carbon sequestration. As an important carbon source, organic fertilizer increases the potential of soil organic carbon pool by providing soil with organic matter. Organic matter is converted to stable soil organic carbon through microbial decomposition, and this organic carbon accumulates in the soil for a long time, which helps to increase the carbon sink function of the soil.

The study showed that the soil organic carbon content increased significantly in the cultivated land with long-term application of organic fertilizer. A field experiment conducted for many years showed that continuous application of organic fertilizer could significantly improve the storage of organic carbon in the surface soil of cultivated land, especially the fixation effect of organic carbon in the deep soil layer [5]. The soil organic carbon applied with organic fertilizer not only has high stability, but also can effectively resist soil erosion and carbon loss. In addition, the application of organic fertilizer also helps to enhance the carbon distribution effect of the soil, that is, the carbon part of the organic matter is fixed in the soil particles, reducing the rate of its oxidative decomposition into carbon dioxide. In this way, organic fertilizer application contributes to enhancing the carbon sequestration capacity of agricultural soils and plays a positive role in addressing global climate change [6].

3.2. Correlation between Carbon Emission and Climate Change

Although organic fertilizers help increase soil organic carbon, they can also contribute to greenhouse gas emissions during their production, transportation and application. Especially in anaerobic environments, greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) may be produced during the decomposition of organic matter in the soil. Greenhouse gas emissions may offset some of the carbon sequestration effects of organic fertilizer application.

In the decomposition process of organic fertilizer, soil microorganisms will convert carbon in organic matter into methane in the absence of oxygen, which is especially easy to occur in the soil environment with excessive moisture [7]. In addition, overapplication of organic fertilizer may increase the emission of nitrous oxide in the nitrogen cycle, especially in the short time after fertilization, the emission of this greenhouse gas will rise significantly. Therefore, when

ISSN: 2710-0723

applying organic fertilizer, it is necessary to reasonably control the application amount and application method to reduce carbon emissions as much as possible. For example, methane production can be reduced by applying organic fertilizer to dry or well-drained soil conditions. At the same time, nitrous oxide emissions caused by excessive nitrogen application can be reduced by combining with appropriate amount of fertilizer [8].

3.3. Cumulative Effect of Long-term Organic Fertilizer Application on Carbon Pool

Long-term application of organic fertilizer has a positive effect on the accumulation of soil carbon pool. Long-term field experiment results show that continuous application of organic fertilizer can not only increase soil organic carbon storage, but also significantly improve the stability and persistence of soil carbon storage [9]. Carbon in organic fertilizer can form a stable organic carbon complex by combining with soil mineral particles, so that carbon can be preserved in soil for a long time.

Some studies have pointed out that long-term application of organic fertilizer can promote the stabilization of soil microbial community, transform soil organic matter into stable humus, and thus increase the storage of difficult-to-decompose carbon in soil [10]. This not only contributes to the accumulation of soil carbon pools, but also reduces the risk of carbon loss, thereby improving the carbon sequestration capacity of agricultural systems. At the same time, the cumulative effect of soil carbon pool is closely related to the frequency and amount of organic fertilizer application. Reasonable application scheme can reduce carbon emission and increase soil carbon storage. Comprehensive consideration of the environmental and economic benefits of organic fertilizer application and formulation of the best fertilization strategy is the key to enhance the potential of soil carbon pool.

4. Challenges and Prospects of Organic Fertilizer Application

4.1. Problems Caused by Improper Application

Although organic fertilizers have significant advantages in improving cultivated land productivity and soil carbon pool, there are also some challenges in their application. If not applied properly, organic fertilizers can have a negative impact on the environment. For example, excessive application of organic fertilizers can lead to excess nutrients in the soil, which can cause soil eutrophication problems and even lead to groundwater pollution. Especially in the case of long-term overapplication, phosphorus and nitrogen in soil may be lost to water in dissolved or granular form, resulting in eutrophication of water and inducing algae blooms [11]. In addition, the nutrient release of organic fertilizers has the characteristics of slow and continuous, and in the planting process of some high-yield crops, relying on organic fertilizers alone may not be able to meet the needs of crop growth for fast-available nutrients. To obtain higher yield, farmers tend to apply a large amount of chemical fertilizer and organic fertilizer at the same time. Although this can improve short-term yield, it will lead to nutrient imbalance in the soil and aggravate environmental pollution.

Different types of organic fertilizers also have different effects on the environment. For example, insufficiently fermented and decomposed organic fertilizers may carry pathogens, heavy metals and antibiotic residues, which will not only inhibit crop growth after entering the soil, but also pose potential threats to human health through the food chain [12]. Therefore, the source, treatment and application of organic fertilizers must be strictly controlled to minimize their negative effects.

ISSN: 2710-0723

4.2. Policy Suggestions

To ensure the rational application of organic fertilizers in agricultural production, and to give full play to their potential in improving soil carbon pool and reducing carbon emissions, the formulation of relevant policies is crucial. Here are some possible policy suggestions:

(1) Promote subsidies and incentive policies for the use of organic fertilizers

To encourage farmers to widely use organic fertilizers, the government should provide economic incentives, such as subsidizing the production and use of organic fertilizers, and formulate corresponding incentive policies to encourage farmers to reduce the use of chemical fertilizers and switch to the combination of organic fertilizers and ecological agriculture.

(2) Strengthen the quality supervision and standardization of organic fertilizers

The quality of organic fertilizer directly affects its application effect and environmental impact. The government should strengthen the supervision of the production and sale of organic fertilizer, ensure that the organic fertilizer products sold on the market meet the relevant standards, and reduce their potential harm to soil and the environment.

(3) Promoting farmer training and technology popularization

Farmers' mastery of organic fertilizer application technology directly affects the application effect. Training and technical promotion activities are organized to help farmers understand the advantages of organic fertilizers and scientific application methods, which can greatly improve their application efficiency and reduce environmental problems caused by improper application.

5. Conclusion and Prospect

As a crucial component in agricultural production, organic fertilizer not only supplies essential nutrients and organic matter to crops but also significantly enhances the productivity of arable land by improving soil structure and fostering microbial activity. Furthermore, the long-term application of organic fertilizers can augment soil organic carbon storage, thereby aiding in carbon sequestration and mitigating global climate change. Consequently, organic fertilizers hold substantial promise for advancing sustainable agricultural development and environmental protection. Looking ahead, with advancements in agricultural science and technology alongside the pursuit of sustainable development goals, the application techniques and management practices for organic fertilizers will be continuously refined. By enhancing quality supervision of organic fertilizers, promoting precision fertilization technologies, optimizing the integration of organic fertilizers with conventional fertilizers, and formulating policies that encourage their use, we can effectively improve both productivity and environmental sustainability within agricultural systems.

Acknowledgments

This research was funded by the Fundamental Research Funds for the Science Basic Research Program of Shaanxi (2023-JCQN-0343), Technology Innovation Center for Land Engineering and Human Settlements, Shaanxi Land Engineering Construction Group Co., Ltd and Xi'an Jiaotong University (2024WHZ0235), Shananxi Provincial Land Engineering Construction Group internal research project (DJNY-YB-2023-29, DJNY-YB-2023-24, DJNY2024-22), Pre-research Project of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd (2024-NBYY-01).

ISSN: 2710-0723

References

[1] Zhang, X., Wang, S., Xu, W. Effects of organic fertilizers on soil water retention and crop yield in semi-arid regions [J]. Agricultural Water Management,2021,234,106157.

[2] Wang, J., Chen, B., Xie, Z. Long-term organic fertilization improves nitrogen use efficiency in maize production [J]. Field Crops Research,2019,234:23-31.

[3] Zhang, F., Zhang, Y., Li, X. Microbial mechanisms behind enhanced soil fertility in organic farming systems [J]. Soil Biology Biochemistry,2018,128:22-33.

[4] Zhou, J., Wang, Q., Zhang, Z. Organic matter decomposition and carbon stabilization in organic farming systems [J]. Geoderma,2021, 384,114823.

[5] Han, X., Hu, W., Zhang, M. Long-term effects of organic amendments on soil organic carbon sequestration in arid regions[J]. Agriculture, Ecosystems Environment,2020,302,107126.

[6] Liu, H., Qian, X., Huang, D. Carbon sequestration potential of organic fertilizers in agricultural soils: A systematic review[J]. Soil Use and Management,2022,38:63-77.

[7] Zhao, Y., Wei, J., Cheng, X. Methane and nitrous oxide emissions from organic fertilizers in paddy soils: A meta-analysis[J]. Science of the Total Environment,2019,688:163-175.

[8] Zhang, L., Shen, J., Chen, Q. Organic and inorganic nitrogen fertilization impacts on nitrous oxide emissions from arable soils[J]. Agriculture Ecosystems Environment,2021,305,107171.

[9] Chen, B., Zhang, X., Wang, L. Long-term organic fertilization enhances soil organic carbon storage and stability in agroecosystems[J]. Geoderma,2022,370,114378.

[10] Liu, Y., Wu, X., Zhao, C. Effects of organic amendments on soil microbial biomass carbon and nitrogen and their stabilization[J]. Soil Science Society of America Journal,2022,86, 243-252.

[11] Shen, Y., Han, G., Zhou, J. Eutrophication risk associated with excessive organic fertilizer application [J]. Environmental Pollution,2021,273,116461.

[12] Sun, Z., Huang, X., Zhang, W. Risks associated with organic fertilizer contamination: Antibiotics and pathogens[J]. Science of the Total Environment,2021,756,143697.