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Editorial

Sustainable Management and Tillage Practice in Agriculture

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1. Introduction

The global population is expected to rise from 7.7 billion today to 9.7 billion by 2050 [1], resulting in an increased demand for food production. Humanity will also become increasingly dependent on agriculture to supply fibers, food, and livestock feed. However, arable land remains limited, and challenges such as land degradation, water scarcity, and climate change are increasingly undermining agricultural productivity [2]. Modern agriculture primarily relies on the use of fertilizers, pesticides, and heavy machinery to maximize crop yields, but this approach has led to a range of issues affecting soil, plant, human, and environmental health [3]. As a result, the importance of sustainable agricultural management is receiving growing attention. Sustainable management promotes the stability and longevity of agricultural production while minimizing resource waste. Key principles of sustainable agriculture include improving agricultural value chain productivity, conserving environmental resources, enhancing human well-being and economic growth, strengthening ecosystem and community resilience, and supporting government policies and regulations. Currently, the primary goals of sustainable agriculture are crop production and food security. Other objectives include maintaining soil fertility, promoting biodiversity, improving ecological conditions and preventing pollution, reducing the consumption of non-renewable resources, supporting rural economic development, improving farmers' quality of life, and raising public awareness and responsibility regarding environmental issues.

Sustainable agricultural practices generally focus on transforming the use of fertilizers, implementing integrated pest management, adopting crop rotation, utilizing precision irrigation, practicing cover cropping, and employing conservation tillage, among other techniques. By integrating the benefits of these technologies, the goal is to enhance agricultural productivity and efficiency. In terms of tillage practices, conservation tillage reduces the frequency and intensity of soil disturbance, thereby promoting soil health. Conventional tillage can cause loss of soil structure and severe soil degradation in certain areas, while conservation tillage offers benefits such as improved soil moisture, increased porosity, higher soil organic carbon (SOC) content, and reduced bulk density [4]. Organic mulches help reduce water loss and soil erosion, suppress weed growth, minimize soil splash, regulate soil temperature, and improve crop yields [5]. Organic mulches can include straw, leaves, legumes, rapeseed, alfalfa, clover, and others. In soil nutrient management, a combination of manure, compost, and chemical fertilizers is often employed, along with various integrated strategies to ensure efficient nutrient use and maintain sustained high crop yields. In many agricultural regions, nutrient management is not reliant on a single type of fertilizer but requires the development of scientifically tailored fertilization programs based on the specific needs of different crops and soil conditions. Through precision fertilization, appropriate crop rotation, and the adoption of suitable tillage practices, soil productivity can be maximized while minimizing environmental impact. Rational crop rotation and intercropping also play key roles in nutrient management. Crop rotation helps reduce the

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long-term depletion of specific nutrients, lowers the risk of soil degradation, and promotes the diversity and activity of soil microorganisms, which aids in nutrient recycling [6]. Crop diversity is an effective strategy for preventing the oversimplification of agricultural systems and enhancing soil structure [7]. It encompasses aspects such as species diversity, varietal diversity within species, and genetic diversity within crop species.

Through the sustainable agricultural practices and management methods outlined above, crop yields and profitability can be maximized while minimizing negative environmental impacts and maintaining soil health and fertility. In this context, the Special Issue (SI) focuses on the practices and technological advancements that promote sustainable agriculture and enhance soil health through effective agricultural management.

2. Highlights of Results

Driven by the need to ensure food security while maintaining environmental integrity, significant progress has been made in sustainable management and tillage practices in agriculture. The SI brings together cutting-edge research and reviews, focusing on the application of technologies for sustainable management, with the goal of enhancing crop productivity and agricultural resilience.

Moreno-García et al. examined the long-term effects of no-tillage (NT) versus conventional tillage (CT) on arthropod biodiversity in rainfed and irrigated annual crops across four years in Southern Spain [8]. The study revealed that NT significantly enhanced the overall diversity and abundance of arthropod species, with a notable increase in morphospecies observed in rainfed crops (19.5 in NT vs. 16.2 in CT) and a higher average abundance in irrigated crops under NT (96.7) compared to CT (57.8). The research also demonstrated that NT practices led to a significant increase in SOC, particularly in the topsoil layer, which in turn influenced arthropod diversity. The study concluded that adopting no-tillage practices not only benefits soil biodiversity but also contributes to climate change mitigation by enhancing SOC sequestration, presenting a sustainable approach to agricultural management.

The study carried out by Qi et al. evaluated the stability of soil aggregates under various tillage practices during the summer fallow period in rainfed winter wheat fields on the Loess Plateau [9]. The findings revealed that the plow tillage (FPT) and subsoiling (FST) treatments significantly enhanced the stability of mechanical-stable aggregates (MSA) in the top 20 cm soil layer, while the minimum tillage (FMT) improved the stability of water-stable aggregates (WSA) in the 0–40 cm soil layer. The research demonstrated that different tillage methods have distinct impacts on soil aggregate composition and stability, with FPT and FST being more effective in enhancing MSA stability and FMT in improving WSA stability. These results underscore the importance of appropriate tillage strategies for soil health and the potential of these practices to influence soil quality in dryland agricultural systems.

An et al. conducted a meta-analysis to assess the impact of nitrogen application rates (NAR) on wheat grain protein content and composition in China [10]. The results indicated that NAR significantly increased the content of total protein and its fractions in wheat grain, with the optimal NAR found to be 240–300 kg ha^{-1}. The study also revealed that the effects of NAR varied under different geographical, climatic, and soil nutrient conditions, highlighting the importance of tailored nitrogen management strategies to enhance wheat protein content and related fractions. This comprehensive analysis provides insights into optimizing NAR to improve wheat quality and underscores the potential of systematic nitrogen application to boost grain protein content under diverse cropping conditions.

Hao et al. evaluated the impact of different mulching measures, including straw mulching (SM), plastic mulching (PM), and ridge-film mulching (RM), on soil chemical characteristics and crop productivity in the Loess Plateau [11]. They found that soil carbon, nitrogen, and phosphorus contents, as well as microbial biomass, were significantly enhanced under SM and RM. The stoichiometric ratios of soil available nutrients were effectively reduced by these mulching practices, particularly affecting the C:N and C:P balance. Crop yield was markedly increased under long-term SM and RM, with yields ranging from an increase of 18.18% to 62.43% compared to no mulching (NM). The study concluded that mulching, especially ridge-film mulching, can effectively enhance soil resource availability, alleviate soil stoichiometric imbalance, and improve agricultural productivity and sustainability in the Loess Plateau region.

The two studies offered comprehensive insights into the impact of tillage practices on soil health and rice quality [12,13]. The first paper highlighted the positive outcomes of organic matter addition on SOC, CO_2 emissions, and bacterial compositions in paddy fields, emphasizing the environmental and economic advantages of combining chemical and organic fertilizers in rice production systems. The second article explored the linkages between soil microbial functions, soil active carbon pools, and the 2-Acetyl-1-Pyrroline content in fragrant rice, suggesting that no-tillage practices can enhance rice aroma and yield by modulating soil microbial activities and carbon metabolism. Both studies underscore the importance of adopting sustainable tillage methods to improve soil quality and rice production in China, acknowledging the challenges and potential solutions for wider implementation.

The study by Ren et al. investigated the impact of sowing stages and nitrogen application rates on the light-temperature resource allocation and grain yield of rice over a 9-year period [14]. Early sowing combined with increased nitrogen supply (180 kg ha^{-1}), particularly in the high nitrogen early sowing (HNES) treatment, significantly enhanced rice grain yield by 9.5% to 12.7% compared to other treatments. This approach led to a notable increase in panicle number, grain weight, leaf area index (LAI), and harvest index (HI). The findings indicate that optimizing sowing time and nitrogen management can substantially improve rice yield and the efficient use of light-temperature resources.

The quantitative research provided a comprehensive overview of the evolution and scientific engagement in the field of agricultural intensification and sustainability [15]. Marked by an increase in publications and a significant influence from Asian countries, the study highlights the growing focus on sustainable practices amidst climate change and food security concerns. While sustainable intensification, including intercropping and conservation tillage, has shown potential in enhancing productivity and minimizing environmental impact, the adoption of such practices encounters challenges. These can be addressed through targeted technological solutions, emphasizing the need for continuous innovation in agricultural systems to ensure long-term sustainability and food security.

3. Conclusions

The SI highlights the critical role of sustainable management and tillage practices in the healthy development of agriculture. This is reflected not only in ensuring the safety and continuous supply of agricultural products but also in enhancing environmental resilience and resource efficiency. The studies and reviews featured in this issue emphasize the importance of adopting sustainable management technologies in agricultural production, focusing on strategies such as tillage practices, nitrogen fertilizer management, microbial functions, organic matter return, and seeding technologies. These strategies aim to promote sustainable land management, improve agricultural productivity, and enhance the resilience of agricultural systems. The research in the SI demonstrates that sustainable management and tillage practices can improve soil fertility, increase farm productivity, and yield long-term environmental benefits.

In conclusion, the research presented in the SI collectively highlights the potential of sustainability-driven agricultural management practices in addressing contemporary agricultural challenges. By adopting these practices, agricultural production can reduce environmental impacts, unlock greater production potential, promote more responsible resource management, and contribute to a sustainable future. The SI serves as a valuable resource for enhancing knowledge and guiding the implementation of sustainable management and tillage practices in agriculture.

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