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Impacts of Livestock Manure Resource Utilization on Soil Health and Crop Yield: Mechanisms, Effects, and Future Perspectives

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Abstract: Research on the mechanisms, effects, and future prospects of utilizing livestock manure for soil health and crop yields reveals that appropriate treatment and utilization methods can significantly improve soil structure, increase organic matter content, enhance nutrient supply capacity, and promote soil microbial diversity. These improvements contribute to enhanced soil fertility and ecosystem stability, thereby increasing crop yields and promoting sustainable agricultural development. Studies have investigated technologies such as composting, anaerobic digestion, and biochar, showing that, with proper management and treatment, manure can serve as a valuable agricultural resource. However, challenges including technical and economic feasibility, inadequate policy support, and limited public acceptance persist as significant barriers to widespread adoption. Future efforts should prioritize advancing technological innovation, enhancing policy incentives, and raising public awareness to fully realize the economic and environmental benefits of manure resource utilization.

Keywords: Livestock manure, resource utilization, soil health, sustainable agriculture, environmental benefits

1. Introduction

Livestock farming is an integral part of global agricultural production. However, with the intensification and scaling of this industry, the management of livestock manure is becoming increasingly critical. It is estimated that large quantities of livestock manure are produced globally each year, which not only puts pressure on the ecological environment but also threatens soil health and crop yields. Excess livestock manure may, in some cases, contain heavy metals such as copper and zinc, which can accumulate in the soil, harming soil health. Additionally, antibiotics and other chemicals used in livestock farming often remain in the manure, further exacerbating environmental pollution [1]. While manure can increase soil organic matter content and nutrient availability, excessive application can lead to nutrient imbalances and soil degradation [2]. Despite the potential ecological hazards of livestock manure, it can also be transformed into an important resource if integrated into a circular economy system [3]. Therefore, effectively managing and utilizing livestock manure has become a key challenge for sustainable global agricultural development.

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Studies have shown that applying livestock manure can significantly increase crop yields. For example, the application of chicken manure can effectively enhance the yields of sorghum and wheat [4]. Furthermore, the combined use of livestock manure and chemical fertilizers can further improve crop yields and nutrient use efficiency. For instance, a mixture of 30% poultry manure and 70% chemical fertilizer can improve rice yield and soil properties [5]. However, the effects of livestock manure on crop yields vary depending on management methods and nutrient balance. In some cases, it can increase yields, while in others, improper management may lead to yield reductions or negative impacts [6]. Manure resource utilization can not only reduce environmental pollution but also provide valuable organic fertilizer to the soil, promoting sustainable agricultural development. In-depth research on the impact of livestock manure resource utilization on soil health and crop yields will provide important reference value for its effective management and resource utilization.

This study aims to explore the impact of livestock manure resource utilization on soil health and crop yields. Specifically, the research includes analyzing the effects of different manure treatment methods on soil physical and chemical properties, and how these changes further affect crop growth and yield performance. By delving into these issues, this study seeks to provide a theoretical basis and practical guidance for the rational utilization of livestock manure, contributing to the sustainable development of agriculture.

2. Major Approaches and Technologies for Livestock Manure Resource Utilization

There are various methods for the resource utilization of livestock manure. The main technologies include:

2.1. Composting Technology

Composting is a biochemical process that uses microorganisms to convert degradable organic matter into solid waste into stable humus under controlled conditions [7]. Through composting technology, livestock manure is transformed into organic fertilizer, effectively reducing pathogens and odorous substances while increasing soil organic matter content.

Process: Composting primarily targets solid manure. After preliminary treatment by a solid-liquid separator, it undergoes high-temperature aerobic fermentation for harmless treatment, and then it is used in farmland or for producing organic fertilizer. Fermentation methods include windrow, trough, silo, high (low) rack fermentation beds, and in-situ fermentation beds.

Advantages of this technology: High-temperature aerobic fermentation ensures thorough manure treatment; it increases the added value of manure, and the product can be used for returning to farmland or for sale. Major limitations include: the need for fixed sites and infrastructure; it is more suitable for farms with less wastewater production (such as cow manure, chicken manure, and sheep manure). For places with large amounts of wastewater like water flush manure, additional wastewater treatment systems are required.

2.2. Anaerobic Digestion and Biogas Production

Anaerobic digestion refers to the process where microorganisms decompose organic matter (such as livestock manure, straw, weeds, etc.) under anaerobic conditions, producing combustible mixed gases such as methane and carbon dioxide. Biogas fermentation systems aim to produce energy while achieving comprehensive utilization of biogas, digestate, and biogas residue.[8]

Technological characteristics: It requires a smal.ler footprint, allows for deeper fermentation, and has better nutrient preservation effects, but the technological requirements and costs are relatively high. The main technological advantages include: it effectively treats manure while producing

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renewable energy, providing energy support for agriculture; digestate and biogas residue can be used as fertilizers, further promoting resource recycling.

2.3. Application of Biochar

Biochar is a solid carbonaceous product obtained through the transformation of biomass (such as livestock manure) via pyrolysis or hydrothermal carbonization (HTC) [9]. The production process includes drying treatment, drying livestock manure to a moisture content of less than 15%; carbonization, producing biochar through high-temperature pyrolysis under anaerobic conditions, while thoroughly decomposing antibiotics and resistance genes in the manure. The main technological advantages include improving soil structure, enhancing soil water retention and nutrient supply capacity; and reducing the potential threat of harmful substances in manure to the environment.

2.4. Other Treatment and Transformation Technologies

Other manure resource utilization technologies, such as liquid fertilizer preparation and nutrient recovery, are also under continuous development, further improving the utilization efficiency of manure. Liquid fertilizers: including solution-type and suspension-type fertilizers (such as liquid ammonia, ammonia water, carbonated ammonia water, and mixed fertilizers containing nitrogen, phosphorus, and potassium), which can reduce nutrient loss while meeting the nutritional needs of different crops.

By combining the application of the above technologies, the resource utilization of livestock manure can achieve the dual goals of environmental protection and sustainable agricultural development.

To clearly present the differences and characteristics of the three main technologies for livestock manure resource utilization, they are compared and summarized in terms of raw materials, treatment processes, product characteristics, advantages, and disadvantages, as shown in Table 1.

Table 1: Comparative Analysis of Major Technologies for Livestock Manure Resource Utilization

Item	Raw Material	Treatment Process	Product Characteristics	Advantages	Disadvantages
Composting Technology	Mainly solid manure from livestock farms	Requires solid-liquid separator for preliminary processing, long-term aerobic fermentation	The high-temperature conditions of aerobic fermentation result in thorough manure sanitization, a short fermentation cycle, and the absence of odor.	This method is suitable for farms with low wastewater output, effectively reduces pathogens and odorous substances, and increases organic matter content.	Requires infrastructure, better suited for farms with less wastewater; high wastewater volumes need extra systems[7]

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Table 1: (continued).

Anaerobic Digestion & Biogas Production	Organic matter like animal manure, straw, weeds	Microbial decomposition to produce methane & CO_2 under specific moisture, temperature & anaerobic conditions	Produces renewable energy, biogas, digestate & biogas residue for comprehensive utilization	Manure treatment and energy generation, resource circulation	Higher cost and technology requirements[8]
Application of Biochar	Livestock manure	Drying manure to <15% moisture, followed by anaerobic high temperature pyrolysis	Improves soil structure, water retention, nutrient supply, and decomposes antibiotics and resistance genes	Improves soil properties and fertility [9]	—

3. Mechanisms of Livestock Manure Resource Utilization on Soil Health and Crop Yield

The resource utilization of livestock manure has multiple positive effects on soil health. The main mechanisms include:

3.1. Improving Soil Physical and Chemical Properties

Through composting or the application of biochar, nutrient elements in the soil increase, the aggregate structure is improved, and the soil's aeration and water retention capacity are significantly enhanced, which are beneficial for plant root growth. In addition, beneficial microorganisms in livestock manure multiply in the soil, maintaining soil ecological balance and optimizing soil pH, further improving soil physical properties.

3.2. Increasing Soil Organic Matter Content

Livestock manure is rich in organic matter, which is an important nutrient source for plant growth. Composting, biochar, and other technologies can release nutrients from manure, increase soil organic matter content, and enhance the soil carbon pool, further improving soil fertility.

3.3. Increasing Soil Nutrient Content

Livestock manure can be converted into biogas or biomethane through anaerobic digestion, while the resulting digestate can be used as an organic fertilizer. Manure fertilization technology, through oxidation pond treatment, mixes harmless manure water with irrigation water, realizing the integration of water and fertilizer application. These methods enrich the soil with nutrients such as nitrogen, phosphorus, and potassium, meeting crop growth needs and alleviating manure treatment pressure.

3.4. Promoting Soil Microbial Diversity and Activity

Livestock manure is rich in organic substances such as carbohydrates, proteins, and lignin, which can be decomposed and utilized by multifunctional microorganisms, releasing a large amount of energy

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while removing odors, forming high-efficiency organic fertilizer. Substrate cultivation, utilizing manure as a culture substrate, growing crops, or cultivating microorganisms, effectively utilizes nutrients in the manure and promotes agricultural production and environmental protection. Soil microbial regulation, the application of manure can significantly increase the diversity and activity of soil microorganisms, improve soil bacterial community structure, enhance soil fertilizer and water retention, reduce reliance on chemical fertilizers, and improve the sustainability of planting systems.

3.5. Improving the Crop Root Environment

The rational utilization of livestock manure significantly improves the growth environment of crop roots by optimizing soil physical properties and increasing organic matter and nutrient content. It also promotes soil microbial activity and diversity, thus enhancing root development and nutrient absorption capacity.

3.6. Long-term Effects on Crop Yields

The resource utilization of livestock manure (e.g., biochar) can improve soil health and fertility over the long term, increasing crop yields, especially in soils with insufficient nutrient supply [10]. While manure is beneficial for various soil properties, it's necessary to cautiously assess its long-term impact on some soil attributes.

The above studies show that livestock manure resource utilization can not only improve soil health but also significantly increase crop yields, which is of great significance for agricultural production and environmental protection.

To present the specific effects of livestock manure resource utilization on soil and crops more intuitively and clearly, the relevant influencing factors are sorted and analyzed from multiple dimensions such as soil physical and chemical properties, organic matter and nutrient content, microbial status, crop root environment, and yield, as detailed in Table 2.

Table 2: Summary Table of Influencing Factors of Livestock Manure Resource Utilization on Soil and Crops

Impact on Soil Health	Treatment Method	Raw Material	Influence
Soil physical and chemical properties	Livestock manure	Poultry, cattle and pigs	Increased nutrient elements, enhanced aeration and water retention, maintaining soil pH balance[2]
Soil organic matter content	Composting, Biochar	Poultry	Increased soil organic matter content, enhanced soil carbon pool[11]
Soil nutrient content	Biochar	Poultry	Enriched soil with nutrients such as nitrogen, phosphorus, and potassium[11]
Soil microbial diversity & activity	Livestock manure	Poultry, cattle, and pigs	Increased soil microbial diversity and activity, improved soil bacterial community structure[2]

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Table 2: (continued).

Crop root environment	Combined application	Chicken manure & rice husk	Optimized soil physical properties, increased organic matter and nutrient content, improved crop root environment[12]
Long-term impact on crop yields	Biochar	Biomass	Increased crop yields[10]

4. Environmental Effects of Livestock Manure Resource Utilization

4.1. Reducing Greenhouse Gas Emissions

Livestock manure is a significant source of greenhouse gas emissions, mainly methane and nitrous oxide. Effective resource utilization can significantly reduce greenhouse gas emissions, especially methane and nitrogen oxides. For example, using anaerobic digestion technology to treat livestock manure can convert it into biogas, reducing methane production at the source. Biogas produced using anaerobic digestion technology is considered an effective way to mitigate the impact of greenhouse gas emissions on climate change [13]. In addition, biogas can be used for power generation or heating, further reducing greenhouse gas emissions. At the same time, digestate and biogas residue can be used for agricultural production, improving resource utilization and reducing manure waste.

4.2. Eutrophication Risk and Prevention Measures

Nutrients such as nitrogen and phosphorus in livestock manure are the main causes of water eutrophication. When these nutrients are directly discharged into water bodies without treatment, they cause the rapid proliferation of algae and plankton, consuming oxygen in the water, which in turn deteriorates water quality and leads to eutrophication. Studies have shown that phosphorus runoff is one of the key factors triggering surface water eutrophication [2]. The massive proliferation of algae not only consumes oxygen but also threatens the survival of aquatic life. Therefore, measures need to be taken to control the risk, such as precise fertilization and reasonable crop rotation. Through manure resource utilization, nitrogen and phosphorus emissions can be effectively reduced, protecting the water environment.

4.3. Environmental Impact of Heavy Metal Pollution

Heavy metal pollution in livestock manure mainly comes from elements like copper and zinc in feed additives. These trace elements are added to feed to improve feed utilization, enhance livestock immunity, and improve meat quality. However, livestock have low absorption rates of these heavy metals, with most being excreted in the manure, leading to high heavy metal content in the manure. Countries like the United States, Denmark, and the Netherlands mainly focus on nitrogen and phosphorus content when using livestock manure for returning to farmland, but the limits on heavy metals such as copper and zinc are relatively lenient. Therefore, in order to avoid the threat of heavy metal pollution to ecosystems and human health, it is necessary to strengthen monitoring and management and establish stricter emission standards.

5. Challenges and Bottlenecks of Livestock Manure Resource Utilization in Agriculture

Despite the many benefits of livestock manure resource utilization, it still faces the following challenges and bottlenecks:

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5.1. Technical and Economic Feasibility

Currently, many efficient and low-cost treatment technologies have not been widely adopted. Insufficient capital investment and limited financing channels make it difficult for farmers to achieve large-scale manure resource utilization. In addition, high investment costs, the complexity of operating parameters, manure collection problems, and digestate management issues constrain its development in rural areas of developing countries.[14]

5.2. Constraints of Laws and Policies

Current policies focus more on pollution control and lack incentives for manure resource utilization. Due to a lack of effective regulatory mechanisms, the enforcement of environmental standards in the resource utilization process is insufficient, easily causing environmental pollution problems.

5.3. Social Acceptance and Public Awareness

Some farmers have weak environmental awareness of manure resource utilization and low participation, affecting overall promotion effects. At the same time, some farmers have a low acceptance of manure resource utilization-derived organic fertilizer products, further weakening their enthusiasm.

6. Conclusions and Future Perspectives

In summary, the resource utilization of livestock manure has positive effects on soil health and crop yields, and it is an important means to promote sustainable agricultural development. However, there are still major obstacles such as high operating costs, low benefit ratios, technical failures, and the lack of a functional manure market. To achieve more efficient resource utilization, future efforts need to be strengthened in the following areas:

- Technological Innovation and Industrial Upgrading: Establish a long-term management mechanism to promote in-situ and nearby fertilizer utilization of manure, and promote technological innovation and industrial upgrading. Strengthen the research and development of fertilizer utilization facilities, equipment, and technical models; promote the introduction of new technologies and processes, such as microbial engineering and intelligent management systems; and enhance overall competitiveness and resource utilization efficiency.
- Policy Support and Market Improvement: Enhance policy support, focusing on the practical operational effects of treatment technologies, rather than simple investment subsidies. In addition, support end-users of manure treatment products and provide suitable application machinery and equipment. At the same time, delve into market demands, analyze customer needs, encourage farmers to actively produce farm manure and apply commercial organic fertilizers, increase the utilization rate of organic fertilizers, and promote the marketization of manure treatment products.
- Social Awareness and Public Participation: Increase publicity and education to enhance farmers and the public's environmental awareness and acceptance of manure resource utilization; enhance farmers' enthusiasm for participation; and lay a good social foundation for the promotion of resource utilization.

Future research should focus on the long-term impact assessment of manure resource utilization, as well as the comprehensive analysis of environmental and economic benefits. The exploration of new technology applications, such as microbial engineering, artificial intelligence, and intelligent management systems, should be strengthened to promote the comprehensive development of manure resource utilization.

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References

[1] *Rathnayake D, Schmidt H P, Leifeld J, et al. Biochar from animal manure: A critical assessment on technical feasibility, economic viability, and ecological impact[J]. GCB Bioenergy, 2023, 15(9): 1078-1104.*

[2] *Rayne N, Aula L. Livestock manure and the impacts on soil health: A review[J]. Soil Systems, 2020, 4(4): 64.*

[3] *Hollas C E, Rodrigues H C, Oyadomari V M A, et al. The potential of animal manure management pathways toward a circular economy: A bibliometric analysis[J]. Environmental Science and Pollution Research, 2022, 29(49): 73599-73621.*

[4] *Ibrahim K A, Mohammed A A, Mohamed E A, et al. Effect of Chisel Plough and Chicken Manure on growth and Yield of Sorghum (Sorghum bicolor (L.) Moench)[J]. Research Journal of Pharmaceutical, Biological and ChemicalSciences, 2014, 5(2), 1324.*

[5] *Iqbal A, He L, Ali I, et al. Manure combined with chemical fertilizer increases rice productivity by improving soil health, post-anthesis biomass yield, and nitrogen metabolism[J]. Plos One, 2020, 15(10): e0238934.*

[6] *Antoneli V, Mosele A C, Bednarz J A, et al. Effects of applying liquid swine manure on soil quality and yield production in tropical soybean crops (Paraná, Brazil)[J]. Sustainability, 2019, 11(14): 3898.*

[7] *Park M, Kim J, Hwang Y W, et al. A thematic review on livestock manure treatment strategies focusing on thermochemical conversion[J]. Environmental Science and Pollution Research, 2023, 30(52): 111833-111849.*

[8] *Jiang Y, Zhang Y, Li H. Research progress and analysis on comprehensive utilization of livestock and poultry biogas slurry as agricultural resources[J]. Agriculture, 2023, 13(12): 2216.*

[9] *Liu Z, Wang Z, Tang S, et al. Fabrication, characterization and sorption properties of activated biochar from livestock manure via three different approaches[J]. Resources, Conservation and Recycling, 2021, 168: 105254.*

[10] *Qambrani N A, Rahman M M, Won S, et al. Biochar properties and eco-friendly applications for climate change mitigation, waste management, and wastewater treatment: A review[J]. Renewable and Sustainable Energy Reviews, 2017, 79: 255-273.*

[11] *Kumari R, Malaviya P. Short-term impact of poultry biochar amendments to stimulate antioxidant enzyme activity of wheat (Triticum aestivum L. HD-2967) in response to greywater[J]. Environmental Science and Pollution Research, 2023, 30(32): 78598-78606.*

[12] *Qi X, Qu Z, Zhang J, et al. Applying Different Organic Amendments Optimizes Soil Nitrogen Management and Increases Greenhouse Tomato Yield[J]. Water, Air, & Soil Pollution, 2024, 235(5): 291.*

[13] *Pasqual J C, Bollmann H A, Scott C A, et al. Assessment of collective production of biomethane from livestock waste for urban transportation mobility in Brazil and the United States[J]. Energies, 2018, 11(4): 997.*

[14] *Khoshnevisan B, Duan N, Tsapekos P, et al. A critical review on livestock manure biorefinery technologies: Sustainability, challenges, and future perspectives[J]. Renewable and Sustainable Energy Reviews, 2021, 135: 110033.*