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Advances in recycling and utilization of agricultural wastes in China: Based on environmental risk, crucial pathways, influencing factors, policy mechanism

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Abstract

With the development of agriculture in China, the productions of agricultural wastes increase rapidly. The occurrence of agricultural wastes was unique in the different areas. The agricultural straw and livestock excrement are considered to be potential resources. Improper disposition of agricultural wastes not only result in environmental pollution, but also waste a lot of valuable biomass resources. The recycling and utilization of agricultural wastes are considered to be the important step in environmental protection, energy structure and agricultural development. However, the problem in China's current agricultural waste recycling impeded the achievement of scale ecological functions. The objectives of this study were to illuminate the potential environmental risk, recycling and utilization pathway, influencing factors and policy suggestions in the recycling and utilization progress of agricultural wastes. The survey provided the development mode of industrialization and scale of agricultural waste recycling. The recycling and utilization pathway of agricultural wastes were also analyzed. The crucial suggestions were proposed, such as cultivating new industry, building economy incentive standard, improving laws and regulations, and creating rural market strengthening medium and long-term plans of agricultural waste recycling. The resource consumption, ecological crisis and other issues caused by agricultural wastes were evaluated. It will provide more comprehensive fundamental information for the recycling and utilization of agricultural wastes during the modernization and urbanization of China.

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1. Introduction

In recent years, agricultural wastes have become the important pollution sources, and the problems caused by poultry and animal feces is global attention¹. The random straw burning and livestock excrement in the agricultural country have caused a series of environmental problem. And direct combustion and arbitrary discard even become common ways, a serious threat to China's rural ecological environment and improvement in agricultural production and farmers' living conditions². According to the research at home and abroad showed that all kinds of agricultural wastes, especially poultry, animal feces and crops straw, have a very high nutrition potential and can also improve soils for sustainable production ability³. Therefore, the effective transformation of agricultural waste recycling and utilization was important in the controlling of environment pollution. Besides, facing with the problem, it can also address the serious energy crisis.

China is a traditional agricultural country with considerable amounts of poultry farms, crops and so on. With the development of agriculture in China, the productions of straw and livestock manure increase rapidly. It lacks laws and regulations of agricultural wastes recycling. Therefore, agricultural wastes are a huge resource library. Unfortunately, the systematical evaluation on the resource utilization of agricultural wastes in China must be launched. The agricultural wastes from rapid expansion of animal farms and mushroom industries as well as other agricultural industries enter into environments⁴. Improper disposition of agricultural wastes not only result in environmental pollution, but also waste a lot of valuable biomass resources. However, few researches have been reported on utilization of agricultural wastes to reduce soil consumption^{3,4}. Therefore, the agricultural waste disposal becomes an important aspect during the modernization and urbanization process. However, the crucial resources characteristics, utilization technologies, influence factors and socio-economic assessment on agricultural waste utilization still remain unclear. Therefore, they are urgently tracked and summarized through statistics analysis, experiments, field survey and geographic information. The recycling and utilization of agricultural wastes are considered to be the important step in environmental protection, energy structure and agricultural development.

The objectives of this study were 1) to understand the potential environmental risk of agricultural wastes, 2) to evaluate the recycling and utilization pathway of agricultural wastes, 3) to investigate the influencing factors on the recycling and utilization of agricultural wastes, and 4) to make policy suggestions for the agricultural wastes during the modernization and urbanization process in China.

2. Potential environmental risk and value of agricultural waste

A large number of agriculture wastes have been produced each year in recent years around the world². Agricultural wastes annually increased at an average rate of 5%-10%⁴. The random abandon and unreasonable utilization would also result in air pollution, soil contamination, and so on. The burning of manure and straw will generate a lot of harmful gas, smoke and dust, seriously polluting our air environment^{5,6}. Animal manure also contains many pathogens, parasite eggs, heavy metals and so on. A part of agricultural residues has even been directly discharged into water, leading to serious contamination of aquatic environment. The occurrence of agricultural wastes was unique in the different areas. The resource consumption, ecological crisis and other issues caused by agricultural wastes were illuminated. The potential environmental risk of agricultural waste in China can be evaluated by the amounts, distribution characteristics and sources of agricultural straws, animal excrements and so on.

Due to information and interest differences to agricultural waste recycling, the low efficiency in farmers and extension departments become the main cause. The amount of agricultural straw and animal wastes in China increased steadily⁸. According to the survey data^{8,9}, farmer's input and output index system can be built to illuminate the conversion efficiency of agricultural waste utilization, and deeply explore the regional differences, factors and so on. Furthermore, the innovation capacity can make society to be as a whole coordination. As an example¹⁰, biochar is a relatively stable carbonaceous material converted from organic wastes. More attention and efforts were given to develop technologies on converting agricultural wastes into biochar¹¹. Field experiments were being carried out on

effect of carbon pool to pollution mitigation in farm fields. Meanwhile, the potential effects of biochar application on crop productivity and carbon release in agriculture were carried out. The results showed that the agricultural straw and livestock excrement are considered to be potential resources. Therefore, agricultural waste recycling practices continue to emerge.

The development mode and operation mechanism of agricultural waste recycling can be discussed and elaborated systematically. Meanwhile, the perspective of collaborative innovation can also be explored via farmers, technical departments, professional associations and property management^{12,13}. In accordance with regional agricultural waste recycling input-output, the households and technology department with low efficiency affected the ability of collaborative innovation in agricultural waste recycling. The survey provided can support for the development mode of industrialization and scale of agricultural waste recycling^{14,15}. However, there still exist many problems in China's current agricultural waste recycling modes, which impede the achievement of scale ecological functions. Firstly, it was lack of government functions which play the leading role, such as policy incentives and protection system. Secondly, the limitations of traditional rural history and culture led to limit the value of agricultural waste resource. Thirdly, most of waste recycling objects were demonstration projects without large-scale promotion. Due to the high cost of agricultural waste disposal, the problem of inadequate finance appears as wells as the inferiority of the agricultural waste recycling technology and equipment.

3. Recycling and utilization of agricultural wastes

3.1. Recycling and utilization pathway of agricultural wastes

The recycling and utilization pathway of agricultural wastes were analyzed. There were problems existing in the utilization process of agricultural wastes in China, which included the large quantity and unknown amount of agricultural wastes¹⁶. The disposal and utilization problems focus on the agricultural wastes, backwardness of techniques, lags of agricultural automation, belated policies and social service systems in agricultural waste utilization¹⁷. Straw and manure are raw material resources owing to the rich in nutrients. Burning straw in fields can make 30% of potassium to be only reused, whereas other nutrients rich, such as nitrogen, phosphorus, organic matter and heat, will run off¹⁸. The results indicated that agricultural wastes were utilized in the traditional measures with the low utilization efficiency.

However, in modern agronomic process, the small-scale recycling utilization could not afford the amounts of agricultural waste produced rapidly. In the pre-experiment¹⁹, rice nursery media is formulated by using pig manure, cow excrement, mushroom compost and inorganic minerals. The results showed that the basic media made of 55% organic fertilizers and 45% inorganic minerals for rice seedling growth were more suitable than 100% of pig manure, cow excrement, mushroom compost and inorganic minerals alone. Among media, the medium made of 35% pig manure, 20% cow excrement, 30% vermiculite and 15% perlite, gained the highest biomass and evenness. The seedling quality in media made of 60-70% organic fertilizer was better than the tested commercial media contained more than 80% organic fertilizer. The seedling quality in the media A and B were better than the other media. The media A was made of 30% pig manure, 30% cow excrement, 30% vermiculite and 10% perlite, whereas the media B, which was made of 20% pig manure, 30% cow excrement, 20% vinegar residue compost, 20% vermiculite and 10% perlite. Nitro-humic acid and calcium superphosphate were added into nursery media, respectively. Seedling growth in the media with nitro-humic acid was better than that in the media with calcium superphosphate. Besides, water holding porosity and electric conductivity were well correlated with shoot biomass. The status, as a key indicator, could evaluate the quality of nursery medium which was consisted of the agricultural waste compost. The nonpoint pollution also caused by some big and medium livestock farms. The results showed that the farmers' technical efficiency still has a large space to be promoted. The scale efficiency is also the major cause. The technique, cost and benefits of the waste recourses were still the main problems unsolved^{19,20}. A series of measures were put forward 1) to establish and improve a lot of policies, laws and regulations related to the resourceful utilization and harmless disposal of agricultural wastes, 2) to increase the financial support from different channels and strengthen construction of basic infrastructures in agricultural waste utilization process by building a new countryside, 3) to push forward the industrialization of agricultural waste utilization in order to develop circular economy, 4) to promote the innovative research, demonstration and extension of utilization technologies.

The theory of agriculture waste logistics combined with cyclic economy was explained. The innovations make an ideal partly into the reality via necessary conditions, such as compulsory regulation and policy support, however, it had still be not yet available. Except technical and institutional innovations, the financial subsidies and compulsory regulations should be explored. The recycling mode of agricultural wastes has been taking shape, whereas the development and operation mechanism are not clear. Based on the mode, the concept and detailed operation mechanism of the agricultural waste recycling mode were proposed. They were consisted of the incentive, dynamic, investment and balance mechanism. Therefore, the connotation and operation mechanism must be expounded. Many crucial suggestions were proposed, such as cultivating new industry, building economy incentive standard, improving laws and regulations, and creating rural market strengthening medium and long-term plans of agricultural waste recycling.

3.2. Influencing factors on the recycling and utilization of agricultural wastes

Agricultural wastes had caused environmental pollution, which imperiled sustainable development and human health. Therefore, the influencing factors on the recycling and utilization of agricultural wastes had become the difficult problem in most countries. Agricultural waste recycling becomes not only an important part of promoting the modernization of agriculture, but also the inherent demand of rural ecological civilization construction. The influence factors, consisted of the cost, technology innovation, enthusiasm and environmental measures of agricultural wastes, were discussed^{21,22}. The results implicated that the utilization and efficiency of agricultural wastes were remarkably affected by the local natural geographical environment, encourage policy, population density as well as the industry and agriculture development.

Specifically, the core problem of waste management is innovative eco-agricultural, resource and eco-industrial technology, and especially fostering organization form to match the technology application and promotion. Hence, to enhance the utilization level of ecology carrying capacity is induced and achieved. The pathways for agricultural waste recycling are various, which include the gasification of crops, taking crop stalks as feed, fertilizer or new building materials, and making manure from livestock excrement^{23,24}. The cycling of life wastes is mainly carried out through separate collection of junk in order to achieve effective waste recycling and reuse. Agricultural waste recycling modes can also be divided into two categories, consisted of farmers and enterprises. The influencing factor focused on measuring the farmers' input and output performance. The former mainly includes traditional, straw matrix and base-dyke agriculture mode conducted by farmers in rural areas, while the latter is composed of agriculture-industry and agriculture-tourism mode assisted by enterprises to achieve further extension. Moreover, the latter is the development trend in future, and needs more attention in design and construction. Most of farmers can get a wide perception range of agricultural wastes, and believe agricultural wastes have great potential resource value after they achieves conversion and utilization. The utilization products should be cheaper, commercialized, high quality, diversified and multifunctional.

In fact, the majority of farmers are willing to participate in agricultural waste recycling with a profound understanding on waste resource value and potential, especially the economic and ecological value. In recent years, agricultural waste recycling related concepts have widely spread in countryside with diversified information sources. Manure and agricultural wastes showed that crop straw were mainly used as feed, fertilizer and energy, whereas the manure is mostly used as fertilizer. The phenomena of agricultural waste burning, burying or even discard were common, and only a small amount of crop straw were used into energy processing. However, they are failure owing to the influence of policy environment, economic power, technology and other factors. The major factors have been investigated, such as centralized waste treatment facility, farmers' cooperative organizations and the distance to fairs or markets. Moreover, the industry degree could also have a significant negative impact.

3.3. Recycling and utilization policy of agricultural wastes

In economy and social development of China, agricultural waste generation and emissions were required to be controlled in the whole process. The pollutants from agriculture wastes have four characteristics, including huge quantities, bad qualities, low price and excessive danger²⁵. The pathway of recycling was named the four application

practices, which were biomass energy, fertilizer, feed and biomaterial. However, there are still limited by recycling and utilization policy. The recycling and utilization policy of agricultural wastes were deeply discussed.

In combination with socio-economic status, the diversified strategy and emphases of agricultural waste resources must be presented to develop eco-agriculture and cyc-economy²⁶. However, the status must depend on the policy guidance, technical support and investment priority in order to promote agricultural waste resources. It was significant to expand the scope of environmental sociology, and understand existing problems in agricultural waste recycling and utilization policy, and to provide the crucial policy suggestions in China. This also had more extent significance to the agricultural waste recycling and utilization in the West Sichuan Plain of China. As the welfare characteristic of policy measure, the values of agricultural waste resource can be perceived widely by farmers, which reflect their cognizance and acceptance level²⁷. The results showed that agricultural waste resource can be perceived by most of farmers. There is a slight difference in key factors. People have high value perception to agricultural waste resource. However, the persons are predominantly male and highly educated with the young age, rich technology experience, awareness and enthusiasm of environmental protection, and mainly living by agriculture. To realize the unification and recycling of economic, environmental and social value on agricultural waste resource, it needs government lean to agricultural recycling economy. The government can adopt many measures to their liberating worries, such as strengthen subsidies, encourage participations of agriculture-linked enterprise, cultivate service entities, and so on. Besides, the capital investment can be also enhanced, which is represented as formal and non-formal education. The rural information construction is also accelerated in order to form the mutual learning organization between farmer and government. Besides, market mechanism should full play the role of self-regulation.

To develop economy, save resources, protect environment and build a shared vision of environmental protection and nurture everyone environmental affection, the recycling and utilization policy of agricultural wastes should be improved²⁸. The utilization efficiency of agricultural wastes was low. Regional advantages with certain science and rationality can greatly improve agricultural waste recycling to some extent. In addition, project research showed that the degree of organization and infrastructure construction conducive to enhancing agricultural waste recycling process^{29,30}. Based on government policy, the promotion of organization degree can improve the recycling and utilization efficiency in the agricultural development process and the education level of farmers.

4. Conclusion

The amount of agricultural straw and animal waste in China increased steadily. The occurrence of agricultural wastes was unique in the different areas. The agricultural straw and livestock excrement are considered to be potential resources. However, the potential environmental risk of agricultural waste in China can be evaluated by the amounts, distribution characteristics and sources of agricultural straws, animal excrements and so on. The input and output system should be built to illuminate the conversion efficiency of agricultural waste utilization. The problem in China's current agricultural waste recycling impeded the achievement of scale ecological functions. The technical efficiency still has a large space to be promoted. Besides, the technique, cost and benefits of the waste recourses were still the main problems unsolved. The small-scale recycling utilization could not afford the amounts of agricultural waste produced rapidly in modern agronomic process. The crucial suggestions were proposed, such as cultivating new industry, building economy incentive standard, improving laws and regulations, and creating rural market strengthening medium and long-term plans of agricultural waste recycling. The influencing factors on the recycling and utilization of agricultural wastes had become the difficult problem in most countries. Besides, the recycling and utilization policy of agricultural wastes should be improved via government attention.

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