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Assessment of Agricultural Environmental Pollution Based on Fuzzy Comprehensive Evaluation: Case Study of the Yangtze River Economic Belt in China

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ABSTRACT

The Yangtze River Economic Belt is an important production area of grains, oil, livestock, and aquatic products across three regions in China; thus, its agricultural environment is of particular importance. However, the agricultural environment of the Yangtze River Economic Belt has been polluted for a long time by three industrial wastes, agricultural fertilizers, pesticides, and livestock wastes. Although effort to prevent and control pollution has been increased in recent years, the situation remains severe. The assessment of agricultural environmental pollution was explored by using fuzzy comprehensive evaluation and the data from the 11 provinces and cities in the Yangtze River Economic Belt in the period of 2008-2016. The results show that agricultural environmental pollution in the Yangtze River Economic Belt is at a serious level on the basis of research on the current situation of such pollution, the use of relevant environmental pollution index data of the provinces and cities in the region from 2007 to 2016, and the performance of fuzzy comprehensive evaluation. Countermeasures to improve agricultural environmental pollution in the Yangtze River Economic Belt are proposed. They include strengthening the control of pollution caused by the three industrial wastes, pesticides, chemical fertilizers, and livestock) and the environmental education of farmers through various forms.

INTRODUCTION

The Yangtze River Economic Belt encompasses 11 provinces and cities, namely, Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Yunnan, and Guizhou. It covers an area of approximately 2.05 million km^2, with a population and gross domestic product (GDP) of more than 40% of the entire country. It is the economic and activity centres of China; it also supports the sustainable development of the nation. After years of development and construction, the traditional mode of economic development has still not fundamentally changed, and the situation of the ecological environment remains serious. In July 2017, the Ministry of Environmental Protection, in cooperation with the National Development and Reform Commission and the Ministry of Water Resources, formulated a plan for the protection of the ecological environment of the Yangtze River Economic Belt. This plan mandated that all economic activities involving the Yangtze River should be conducted on the premise of not damaging the ecological environment. Protection must be extensively implemented and large-scale developments should be avoided. In October 2018, the National Development and Reform Commission, the Ministry of Ecological Environment, the Ministry of Agriculture and Rural Areas, the Ministry of Housing and Urban Rural Development, and the Ministry of Water Resources jointly issued a notice presenting the guidelines for accelerating the treatment of agricultural non-point source pollution in the Yangtze River Economic Belt. The guidelines clearly proposed specific objectives in treating farmland, livestock breeding, and rural residential environment pollution. In recent years, the 11 provinces and cities in the Yangtze River Economic Belt have considered the restoration of the ecological environment of the Yangtze River an overwhelming task. They have made progress and achievements in pollution control and ecological restoration, exerting coordinated effort in the upper, middle, and lower reaches of the river, to implement major conservation projects. However, the state of pollution prevention and control in the Yangtze River Economic Belt remains discouraging. Hundreds of thousands of chemical enterprises are found along the Yangtze River. The total discharge of major pollutants exceeds the environmental capacity, and the environmental protection measures of some enterprises are insufficient. In addition, agricultural pollution and rural non-point source pollution remain serious due to the intensity of resource development, unreasonable production and management mode, and huge historical debts. The Yangtze River Economic Belt is a major production area of grains, oil, livestock, and aquatic products in China. It plays an important role in agricultural production safety. To further

implement precise measures, the government must strive to achieve detailed pollution prevention and control strategies, quantitatively evaluate the agricultural environmental pollution situation in the Yangtze River Economic Belt, and implement targeted pollution prevention and control. Improving the agricultural environment in the Yangtze River Economic Belt and promoting the sustainable development of the region are highly significant.

PAST STUDIES

Many scholars have studied the agricultural environment from different perspectives. Lu et al. identified the total amount of ecological resources, pollution damage, economic development, and environmental protection as major factors that affect the agricultural ecological environment (Lu et al. 2012). Han demonstrated that the overall efficiency of agricultural environmental technology is low in China, and environmental pollution causes a large degree of efficiency loss (Han 2013). On the basis of data from China's comprehensive social survey, the research of Chang showed that residents' cognition of agricultural environmental pollution is high (Chang 2015). Liang et al. reported that ecological environment problems caused by the agricultural production of farmers primarily include ecological environment damage caused by the direct development and utilization of agricultural resources, pollution caused by agricultural production (e.g., large-scale use of chemical fertilizers, pesticides, and plastic films), land pollution caused by sewage irrigation, crop straw burning, or waste pollution. However, for countries in different stages of development, agricultural ecological environment problems caused by farmers' agricultural production behaviour also vary (Liang et al. 2016). The major problem in developing countries is that the environmental cost of farmers in agricultural production is excessively high, causing a series of ecological environmental problems, such as the degradation of natural resources, food pollution, soil pollution, and rural water pollution. In developed countries, environmental problems caused by agricultural production are also serious. The primary reason is the excessive use of pollution causes, such as pesticides and fertilizers (Meijl et al. 2006). Zhang et al. indicated that factors that affect agricultural environmental pollution mostly include the large-scale discharge of three industrial wastes, dry and wet deposition, large-scale use of pesticides and chemical fertilizers, unreasonable use of agricultural films, and pollution from aquaculture waste (Zhang et al. 2017). Wang W. et al. showed that the relationship and interaction among society, economy, resources, and environment in the Yangtze River Economic Belt are continuously being strengthened, and the degree of development consistency and coordination is constantly being improved. In the coordinated development of society, economy, resources, and environment in the Yangtze River Economic Belt, we should focus on the contradiction among economic development, resource consumption, and environmental pollution (Wang et al. 2019). Shi demonstrated that the use of pesticides and other agricultural chemicals has a negative impact on soil fertility and quality (Shi 2011). In addition, the influences of the family structure, cultural level and ability, economic behaviour, and characteristics of farmers, along with the endowment of cultivated land resources in the agricultural environment, have been the focus of scholars (Hao et al. 2011, Tambo et al. 2012, Gorman et al. 2001, Li et al. 2016).

In summary, the major influencing factors of the agricultural environment include the three wastes discharged from industrial production, chemical fertilizer and pesticide pollution from agricultural production, livestock and poultry pollution from the breeding industry, and the environmental awareness of farmers.

RESEARCH METHODS

Data Collection

Based on the current research situation, this study uses the major influencing factors of the agricultural environment as the database: the three wastes discharged from industrial production, chemical fertilizer and pesticide pollution from agricultural production, and related indexes in the discharge of livestock sewage from the breeding industry. The key indicators are industrial wastewater discharge, industrial SO_2 discharge, industrial smoke (powder) dust discharge, agricultural fertilizer application, pesticide use, agricultural film use, and animal husbandry wastes (no such statistical data are available, replaced with animal husbandry output value). The data are mostly obtained from the 11 provinces and cities in the Yangtze River Economic Belt in the period of 2008-2016 from the China Urban Statistical Yearbook and the China Rural Statistical Yearbook.

Construction of Fuzzy Comprehensive Evaluation Model

The evaluation factor set of agricultural environmental pollution in the Yangtze River Economic Belt is $U = (u_1, u_2, u_n)$; u_i indicates the i-th evaluation factor, i = 1, 2, …, n. This study can be defined as $U = (u_1, u_2, u_3, u_4, u_5, u_6, u_7)$, i.e., U = [industrial wastewater discharge, industrial SO_2 discharge, industrial smoke (powder) dust discharge, agricultural fertilizer application, pesticide use, agricultural film use, animal husbandry output value].

The evaluation of agricultural environmental pollution in the Yangtze River Economic Belt is set as $V = (v_1, v_2, …,$

v_m); v_j indicates the evaluation standard, j = 1, 2, …, m. This study considers five grades: v = (very serious, more serious, general, light, very light).

The weight distribution set of the model is set as A = (a_1, a_2, …, a_n), where $a_i > 0$, and $\sum_{i=1}^{n} a_i = 1$; a_i represents the weight of the i-th factor, which reflects a trade-off of each factor. In accordance with the characteristics of the agricultural environmental pollution assessment in the Yangtze River Economic Belt, the weight distribution set of each assessment factor in this study is determined using the Delphi method, i.e., A = (0.2, 0.1, 0.1, 0.2, 0.2, 0.1, 0.1).

The relationship between the evaluation factors and the evaluation grades can be described by a fuzzy relation matrix R from U to V.

$$R = \left(r_{ij}\right)_{m\times n} \begin{pmatrix} r_{11} & r_{12} & & r_{1m} \\ r_{21} & r_{22} & & r_{2m} \\ & & & \\ r_{n1} & r_{n2} & & r_{nm} \end{pmatrix} \quad \ldots(1)$$

The element r_{ij} (i = 1, 2, …, n; j = 1, 2, …, m) indicates the possibility of making the j-th evaluation from the perspective of the i-th factor. Fixed I, (r_{i1}, r_{i2}, r_{im}) is the fuzzy subset of the single-factor evaluation for the evaluation object from the i-th factor.

A fuzzy comprehensive evaluation problem is to transform a fuzzy set A in the evaluation factor set U into a fuzzy set B in the evaluation set V through the fuzzy relation R, i.e., to establish a fuzzy comprehensive evaluation model: B = A × R = (b_1, b_2, …, b_m). By using this fuzzy evaluation model, an M-dimensional fuzzy row vector can be obtained. After normalization, the values of each vector in the vector indicate the corresponding evaluation grades (v_1, v_2, ..., v_m).

Given that B is still an M-dimensional vector; thus, if we provide another evaluation score column vector C = (c_1, c_2, c_m)^T, then the agricultural environmental pollution in the Yangtze River Economic Belt will become a clear algebraic value Q by calculating Q = B × C. Accordingly, evaluators can obtain the evaluation results intuitively and quickly.

Fuzzy Comprehensive Evaluation Model Evaluation

This study evaluates the agricultural environmental pollution in the Yangtze River Economic Belt by using the fuzzy comprehensive evaluation model. Nine experts are recruited to form a group that will evaluate each factor in the evaluation factor set U. On the basis of their assessment, a single-factor evaluation table is established (Table 1).

From Table 1, the fuzzy relation matrix R is established as follows:

$$R = \begin{pmatrix} 2/9 & 4/9 & 3/9 & 0 & 0 \\ 1/9 & 3/9 & 3/9 & 1/9 & 1/9 \\ 2/9 & 2/9 & 2/9 & 2/9 & 1/9 \\ 3/9 & 3/9 & 2/9 & 1/9 & 0 \\ 2/9 & 3/9 & 3/9 & 1/9 & 0 \\ 1/9 & 4/9 & 2/9 & 1/9 & 1/9 \\ 1/9 & 3/9 & 2/9 & 2/9 & 1/9 \end{pmatrix} \quad \ldots(2)$$

By using the established fuzzy comprehensive evaluation model, we can obtain

$$B = A \times R = (0.2, 0.1, 0.1, 0.2, 0.2, 0.1, 0.1) \begin{pmatrix} 0.22 & 0.45 & 0.33 & 0 & 0 \\ 0.11 & 0.34 & 0.33 & 0.11 & 0.11 \\ 0.22 & 0.22 & 0.22 & 0.23 & 0.11 \\ 0.33 & 0.34 & 0.22 & 0.11 & 0 \\ 0.22 & 0.34 & 0.33 & 0.11 & 0 \\ 0.11 & 0.45 & 0.22 & 0.11 & 0.11 \\ 0.11 & 0.34 & 0.22 & 0.22 & 0.11 \end{pmatrix}$$
$$= (0.231, 0.361, 0.275, 0.111, 0.044) \quad \ldots(3)$$

The calculation result B=(0.231, 0.361, 0.275, 0.111, 0.044) shows that 23.1% of the respondents believe that agricultural environmental pollution in the Yangtze River Economic Belt is "very serious," 36.1% consider it "serious," 27.5% think it is "general," 11.1% regard it as "light," and 4.4% believe it is "very light."

Given the evaluation score column vector C, let C = (100, 80, 60, 40, 20)^T. Then, the final score value of agricultural environmental pollution in the Yangtze River Economic Belt is Q = B×C = (0.231, 0.361, 0.275, 0.111, 0.044) (100, 80, 60, 40, 20)^T = 73.8.

From the preceding calculation, agricultural environmental pollution in the Yangtze River Economic Belt is at a serious level. Further measures should be taken to improve the agricultural environment in the region.

RESULT ANALYSIS AND DISCUSSION

In accordance with the research results, the state of agricultural environmental pollution in the Yangtze River Economic Belt is serious, requiring strict implementation of relevant policies issued by the state, joint management, and coordinated governance.

First, the treatment of pollution from the three industrial wastes should be strengthened. To ensure a clean environment for agricultural production, all provinces and cities

in the Yangtze River Economic Belt should strengthen law enforcement and eliminate industrial projects and machinery/equipment that cause serious pollution during operation and production in accordance with relevant national environmental protection system standards, prohibiting the spread of heavy industrial pollution to rural areas. Simultaneously, supervision should be strengthened, particularly the emission reduction of industrial enterprises in the rural economic industry along the Yangtze River. Strict regulations on pollutant emission supervision should be formulated in accordance with relevant laws and regulations and the actual local situation. The total amount of pollutants discharged by industrial enterprises must be strictly controlled.

Second, the prevention and control of pesticide and chemical fertilizer pollution should be strengthened. The key to controlling pesticide pollution is to reduce the use of pesticides as much as possible and to actively explore the use of comprehensive treatment measures. In the prevention and control of diseases and insect pests, physical, agricultural, biological, and chemical pesticide control methods should be effectively combined to minimize the use of pesticides and reduce the degree of environmental pollution. Simultaneously, new pesticides with low toxicity, low residue, and high efficiency should be actively developed, and their usage guidance must be strengthened. In addition, the supervision of the pesticide market should be reinforced, the use of drugs should be standardized, and farmers should strictly abide by the scope and standards of pesticide use. While strengthening the prevention and control of chemical fertilizer and pesticide pollution, the government must also reinforce propaganda and technical training for standardized and rational use of chemical fertilizers, guiding farmers to apply chemical fertilizers scientifically, reasonably, and effectively.

Third, the prevention and control of livestock waste pollution should be strengthened. In the process of prevention and control, the pollution-free, resource-based, and reduction principles should be adhered to. The excrement in breeding houses should be cleaned immediately, washed after cleaning, and disinfected after washing. The collected excrement should be treated in a centralized manner. Anaerobic fermentation can be applied. On the one hand, this process can save energy; on the other hand, it can lead to the development of biogas industry projects in rural areas. The collected excrement can also be fermented into an organic fertilizer, which can be used in combination with chemical fertilizers to improve agricultural production efficiency.

Fourth, the environmental education of farmers should be strengthened through various forms. Through basic education, mass media, street publicity, and the explanation and guidance of technical personnel, publicity and education regarding the agricultural environment and its protection are implemented in a simple and convenient manner. Farmers are actively guided to participate in daily environmental protection activities. In combination with activities, such as poverty alleviation through science and technology, bringing literature and art to the countryside, and organizing an environmental protection day and other important activities, and in cooperation with social organizations and associations, such as trade unions and science and technology associations, we will vigorously conduct activities that will bring environmental protection knowledge to the countryside and educate the rural population. Through text circulation, organization personnel can prepare environmental protection brochures and posters that are related to rural life and easy to understand. Accordingly, the majority of farmers can understand environmental pollution and its serious consequences in rural areas. Farmers will be educated to pay attention to environmental protection in their daily life.

CONCLUSION

This study evaluated the current situation of agricultural environmental pollution in the Yangtze River Economic Belt in accordance with the major factors of such pollution, namely, industrial wastewater discharge, industrial SO_2 discharge, industrial smoke (dust) discharge, agricultural chemical fertilizer application, pesticide use, agricultural film use, and animal husbandry and breeding wastes. Agricultural environmental pollution in the Yangtze River Economic Belt was quantitatively evaluated based on the relevant data from the region and the fuzzy comprehensive evaluation method. We attempted to quantify qualitative analysis problems as much as possible. We drew the conclusion that agricultural environmental pollution in the Yangtze River Economic Belt is at a serious level. The countermeasures were proposed to improve the state of agricultural environmental pollution in the region.

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