Hindawi
Journal of Sensors
Volume 2022, Article ID 3871406, 12 pages
https://doi.org/10.1155/2022/3871406

Research Article

Analysis of Vegetable Waste Pollution Risk and Resource Potential Based on Geographical Information System and Remote Sensing

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Received 23 November 2021; Revised 28 June 2022; Accepted 2 August 2022; Published 31 August 2022

Academic Editor: Yuan Li

Land resources are an important foundation for human survival and development. In recent years, land resources have experienced rapid industrialization and urbanization. With the expansion of urban construction land and the sharp decline of natural and agricultural landscapes, ecological and social problems have gradually surfaced. Based on the intuitive interpretation of LandsatTM/ETM +/OLI image data from 2016 to 2020, this work created an annual land use reference database. The use of resources and the recovery of nutrients from vegetable waste are necessary measures to achieve sustainable and environmentally friendly agriculture. Collecting and analyzing data from the literature are to determine the risk of vegetable waste pollution and the possibility of resource utilization. The amount of vegetable waste produced and the total amount of nitrogen, total phosphorus, and total potassium pollution in the study area are estimated, and ArcGIS is used to characterize TN (total nitrogen) and TP (total phosphorus). The spatial distribution of TK (total potassium) pollution intensity and pollution risk comprehensive index determines the key areas of vegetable waste nonpoint source pollution control in the region and compares the resource utilization potential of vegetable waste based on the demand for fertilizer. This paper combines the research of the subject; takes cultivated land as the research object; clarifies the main pollutants, contaminated area, content, and distribution of cultivated land; uses factor analysis method to conduct a preliminary study on the causes of heavy metal contaminated soil in the study area; and adopts a source-sink balance model, analyze the cumulative characteristics of soil pollution. Based on geographical information system (GIS) and remote sensing technology, this paper investigates the risk assessment of vegetable waste pollution and discusses the analysis of resource potential.

1. Introduction

The surface system is the material basis for human survival, and land use is one of the most direct landscape symbols. As the most direct manifestation of the interaction between human activities and the natural environment, land use land cover (LULC) has become one of the most important way to understand the regional environmental change [1]. At the same time, it has become the main content of the international geosphere biosphere program and the international human program of global environmental change and is the research hotspot in the current academic circles [2]. With the help of dynamic change model, transfer model, and overlay buffer analysis, this paper analyzes the spatial model and regional differences of LUCC in the study area and selects the indicators of ecological security construction based on P.S.R (pressure-state-response) model and obtains the environmental security assessment results through system assessment and GIS remote sensing analysis [3]. Heavy metal pollution is the research focus of agricultural land pollution; and its harm to soil environmental quality, production, and crop quality has aroused widespread concern [4]. Heavy metal pollution of agricultural land in China is mainly concentrated in the current situation of agricultural land pollution and remediation, and the pollution characteristics are not specified [5]. At present, there are few risk assessment methods and indicators for agricultural soil pollution in China, and the assessment results of soil and plant

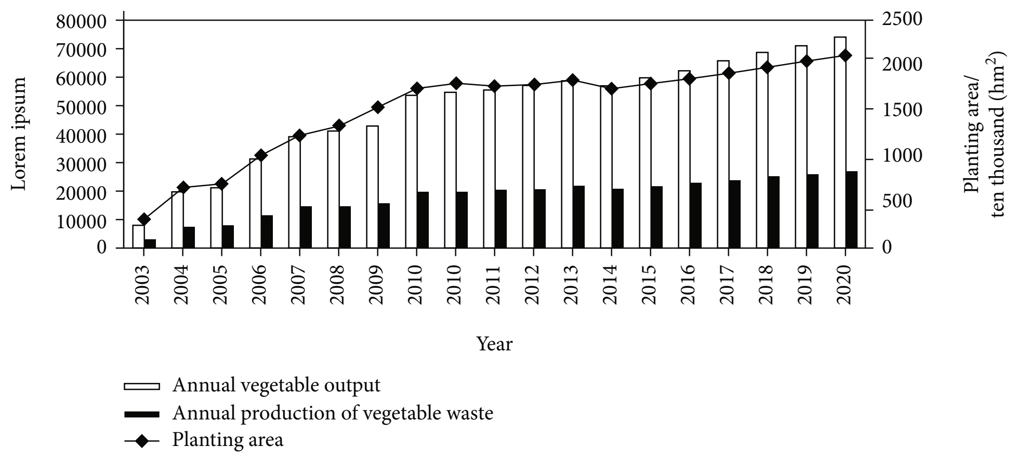

Figure 1: The changing trend of vegetable planting area, annual output, and annual output of vegetable waste in China from 1987 to 2020.

pollution are inconsistent [6]. At the same time, China's vegetable planting area and total output continue to grow. In 2020, China's vegetable planting area will reach 1998.1 million cubic meters, an increase of 23.3% over the 16.201 billion cubic meters in 2013, accounting for 32.6% of the total domestic planting area. With the continuous increase of vegetable production and the continuous improvement of residents' requirements for the quality of vegetables, residents will carry out a large number of screening when selecting vegetables. Finally, the screened vegetables are at risk of being discarded [7]. Therefore, the production of vegetable waste increases sharply, which not only causes waste but also causes a kind of pollution and even challenge to the environment. Based on the existing risk assessment methods of soil heavy metal pollution in agricultural areas, this paper puts forward a set of advanced resource potential analysis and assessment methods, which fully consider the soil and plant pollution and its accumulation trend [8]. The safe treatment and resource utilization of plant waste are the problems to be solved in China. The study area takes the alluvial plains and hilly peninsulas of the Yellow River, Huaihe River, Haihe River, and their tributaries as the research objects. It is one of the important vegetable planting areas in China, with 177 facility vegetable base counties and 68 export vegetable base counties [9]. The vegetable planting intensity is high, and there are vegetable wastes. The risk of nonpoint source pollution caused by the regional vegetable production process is high. In this paper, the source of plant waste, inventory, the advantages and disadvantages of the main treatment methods, and microbial degradation were comprehensively analyzed [10]. It was concluded that composting was the most effective way to realize the rapid utilization of resources [11].

2. Materials and Methods

2.1. Overview of the Study Area. The Yellow River, Huaihe River, Haihe River, and their tributaries alluvial plain, as well as hills and peninsulas are the places to be studied, a total of 58 cities, drainage area: 795000 square kilometers. The soil is mainly brown soil and cinnamon soil with high yield. The soil is rich and deep, and vegetables are planted intensively. From 2016 to 2020, the average annual horticultural output of the study area exceeded 247 million tons, accounting for 31.4% of the total national output.

According to the food and Agriculture Organization of the United Nations, the changing trend of vegetable planting area, annual output, and annual output of vegetable waste in China from 1987 to 2020 is as shown in Figure 1.

2.2. Research Methods

2.2.1. GIS and Remote Sensing. When selecting images, the main considerations are spatial, spectral resolution, image acquisition time, image quality, image cost and availability, and the scope of the research area [12–18]. In order to meet the needs of this study, the remote sensing images used are collected and selected.

Compared with Landsat TM/ETM+, Landsat OLI data has added 2 new bands and readjusted the bands, effectively avoiding atmospheric absorption characteristics [19].

2.2.2. Risk Assessment of Vegetable Waste Pollution

(1) Estimation of Vegetable Waste Production. The horticultural output of each city in the Huanghuaihai region is from the 2010, 2015, and 2020 statistical yearbooks; the area of arable land and fertilizer consumption is taken from the 2020 provincial statistical yearbooks. In previous studies, the production waste coefficients of different types of vegetables are different. This study is based on the calculation method of agricultural nonpoint source pollution and calculates the average vegetable production waste coefficients according to the production weight of different types of vegetables. According to the national vegetable production weight and the waste generation coefficient, total nitrogen, total phosphorus, and total potassium content found in the literature, the calculation equation (1) is as follows:

$$S = \sum_{i=1}^{a=7} P_i \times S_i, \tag{1}$$

Table 1: Vegetable production waste coefficient and TN, TP, and TK content.

Types of vegetables	Representative vegetables	Production waste coefficient	Moisture content	TN content	TP content	TK content
Leafy vegetables	Chinese cabbage	9.8	93.5	2.71	0.35	4.36
Melons and vegetables	Cucumber	2.6	88.3	2.35	0.94	3.42
Roots	Radish	4.3	91.3	4.05	0.45	2.65
Nightshade	Tomato	2.3	84.3	2.14	3.56	4.36
Onions and garlic	Green onions	1.8	91.5	2.32	0.36	3.12
Vegetable beans	Kidney bean	7.7	89.1	2.45	1.12	3.50
Aquatic lettuce	Lotus root	2.2	90.3	2.45	1.12	3.50

where S is the average coefficient of vegetable production waste, n represents the plant species classified by the National Bureau of Statistics of China; P_i represents the proportion of i-type vegetables, and S_i represents the i-type factory production waste coefficient. Similarly, it calculates the average moisture content, TN (total nitrogen), TP (total phosphorus), and TK (total potassium) content of vegetables, as shown in Table 1.

(2) Pollution Risk Assessment. The straw-to-wheat ratio refers to the ratio of the stalk of the crop to the yield of the crop. It is currently a generally accepted method of calculating the number of stalks in China. This study uses the plant waste generation coefficient and yearbook data to calculate the plant waste in the Huanghuaihai area Yield and its TN, TP, and TK content. The pollution intensity of agricultural nonpoint source pollution reflects the degree of agricultural intensification in certain regions and the impact of agricultural activities per unit area on water bodies. The study uses the agricultural non-point source pollution intensity method to estimate the nonpoint source pollution intensity of plant waste and uses ArcGIS to discard plants. The normalization of TN, TP, and TK pollution intensities directly reflects the spatial distribution of nonpoint source pollution of plant waste in 58 prefectures and cities in the study area (see equations (2)–(5)) [20].

$$L_V = Y \times S, \tag{2}$$

$$L_{N/P/K} = Y \times S \times C_{N/P/K}, \tag{3}$$

$$S_V = \frac{L_V}{a \times (1 - m)} \times 10000, \tag{4}$$

$$S_{N/P/K} = \frac{C_{N/P/K}}{a} \times 1000, \tag{5}$$

where L_V is the pollutant load of plant residues, S is the coefficient of production residues, $L_{N/P/K}$ is the pollutant load of TN, TP, and TK in plant residues, and $C_{N/P/K}$ is TN in plant wastes The content of TP, TK, and SV is the pollution intensity of plant waste, $S_{N/P/K}$ is the pollution intensity of TN, TP, and TK; a is the area of cultivated land, and m is the moisture content.

The risk of plant residue pollution is expressed by the pollution index. Due to the large difference in the level of index values, the dispersion of the pollution intensity values TN, TP, and TK is standardized and analyzed, and the standardized values are added with the same weight to obtain the complete pollution index. According to the risk of plant residue pollution, the pollution risk from the spread source is classified, and on this basis, the key control areas are determined. The standard deviation function is as follows [21]:

$$Q_i = \frac{X_i - X_{\min}}{X \min_{\max}}, \tag{6}$$

$$l = \frac{1}{3} \times (Q_N + Q_P + Q_K), \tag{7}$$

where Q_i is the normalized value of the evaluation factor i; X_i is the level value of the evaluation factor i; $X_{\min}$ is the minimum value of the evaluation factor; $X_{\max}$ is the maximum value of the evaluation factor; I is the global pollution index; Q_N, Q_P, and Q_K represent the normalized value of TN, TP, and TK, respectively.

2.3. Resource Utilization Potential. At present, the way to solve the problem of plant waste and pollution in China is still to use chemical fertilizer. In the process of using plant waste and fertilizer, the production of plant waste and the demand for nutrients in chemical fertilizers jointly determine the use of plant residues [22–24]. Therefore, this research uses the generation of plant waste and the demand for chemical fertilizers as the driving force to analyze the resource utilization potential of plant waste in the Huanghuaihai area. According to the statistical data of the yearbooks of the cities in the study area in 2020 [25], the prefecture-level cities are classified, and the regional percentiles of each variable are calculated, as shown in Table 2. The two-dimensional map uses ArcGIS to characterize the resource utilization potential of each city and analyze high-potential areas.

3. Results

3.1. Time Characteristics of Nonpoint Source Pollution Load of Vegetable Waste. Figure 2 shows the results of changes in the pollutant load of vegetable residues, TN, TP, and TK in the study area over time in 2010, 2015, and 2020. In 2020, the pollutant load of vegetable residues in the study

Table 2: Statistics of vegetable waste production and fertilizer consumption in each city in 2020.

Variable	Max	9% quantile	22% quantile	70% quantile	65% quantile	Minimum
Vegetable waste output/10^4t	88.36	53.23	38.84	21.65	12.32	1.36
Fertilizer consumption/10^4t	157.56	104.35	62.15	35.62	24.52	2.42

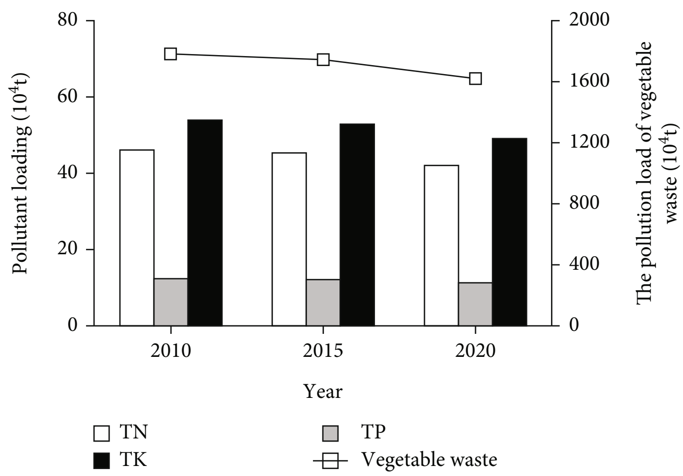

Figure 2: Time characteristics of vegetable waste pollution load.

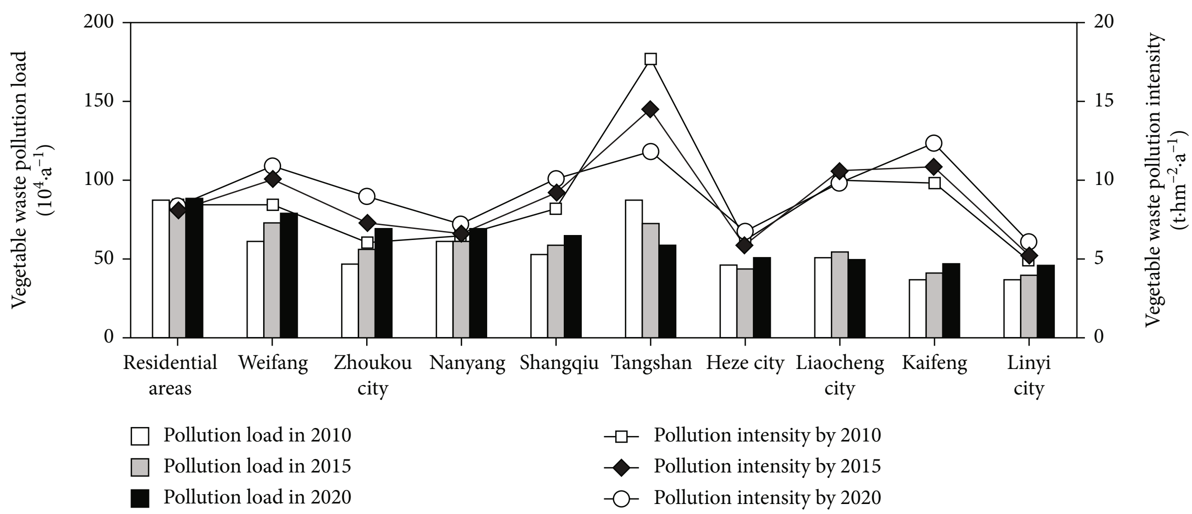

Figure 3: Time characteristics of pollution load and pollution intensity in the top ten cities for vegetable waste production in the study area.

area was 161,800 tons, a decrease of 8.94% compared with 2010 and a decrease of 7.08% in 2015. This may be because with the rapid development of urban-rural integration, the rural population has shown a downward trend, resulting in a decrease in vegetable output, the pollution load of plant residues decreased. In 2017, the total TN pollution load of the plant's waste was 418,800 tons, the total load of TP was 111,800 tons, and the total load of TK was 537,900 tons, which is equivalent to 7.19%, 5.10%, and 25.61 of the reduced fertilizer applications of nitrogen, phosphorus, and potassium in the district that year %.

Sort the pollutant load of plant residues in the study area from high to low, and calculate the pollutant load and pollution intensity of plant residues in 2010, 2015, and 2020. The results are shown in Figure 3. In 2020, the pollution load of plant waste in the city was 590800 tons, which is 18.70% lower than the 726,700 tons in 2015 and 32.96% lower than the 881,200 tons in 2010. Except that the pollutant load of plant waste in 2020 is 883,800 tons, 693,400 tons, and 500,000 tons, which are not much different from 2007 and 2012, the pollutant loads of other cities have increased or decreased to varying degrees.

3.2. Spatial Characteristics of Pollution Load and Pollution Intensity. It can be seen from Table 3 that the average pollution load of plant waste in the Huanghuaihai area is 279,000 tons, with a standard deviation of 205,000 tons. The average pollution load of TN, TP, and TK is 7207.49, 1927.98, and 9274.82, and the standard deviations are 5181.26, 185.97, and 6667.40, respectively. The average pollution intensity

Table 3: Statistics of pollution load and pollution intensity in the study area.

Index	Number of cities	Minimum	Max	Median	Average value	Standard deviation
Pollution load of vegetable waste/(10^4t•a^{-1})	58	1.61	88.45	21.65	27.65	20.45
TN pollution load (t•a^{-1})	58	412.52	22835.42	5568.49	7207.56	5181.65
TP pollution load (t•a^{-1})	58	110.36	6108.13	1489.56	1927.65	1385.76
TK pollution load (t•a^{-1})	58	530.15	29385.46	7165.65	9274.10	6667.43
Pollution intensity of vegetable waste (t•hm^{-2}•a^{-1})	58	2.13	14.85	5.66	6.53	3.45
TN pollution intensity (kg•hm^{-2}•a^{-1})	58	4.64	26.61	32.45	23.46	18.66
TP pollution intensity (kg•hm^{-2}•a^{-1})	58	1.52	9.14	3.45	4.36	2.65
TK pollution intensity (kg•hm^{-2}•a^{-1})	58	6.36	44.65	16.36	19.36	9.55

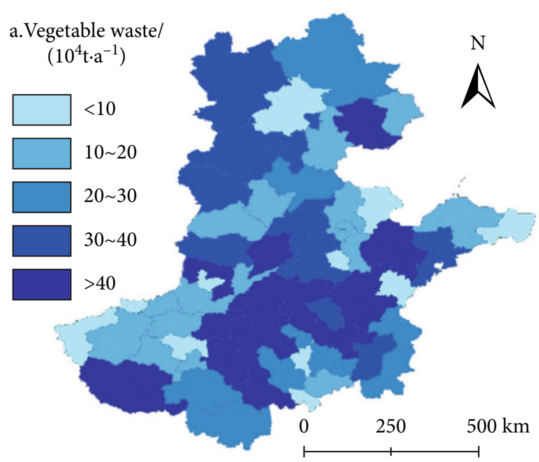

Figure 4: Spatial distribution of vegetable waste pollution load in the study area.

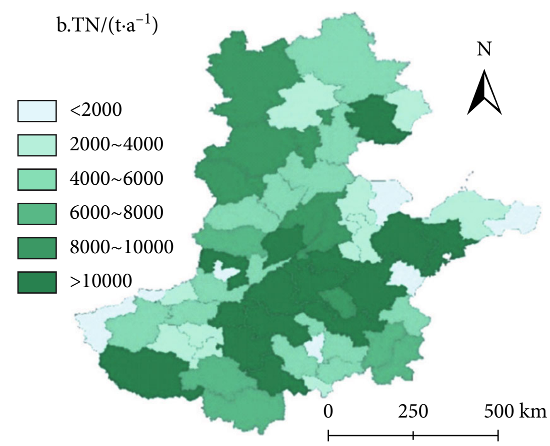

Figure 5: Spatial distribution of TN pollution load in the study area.

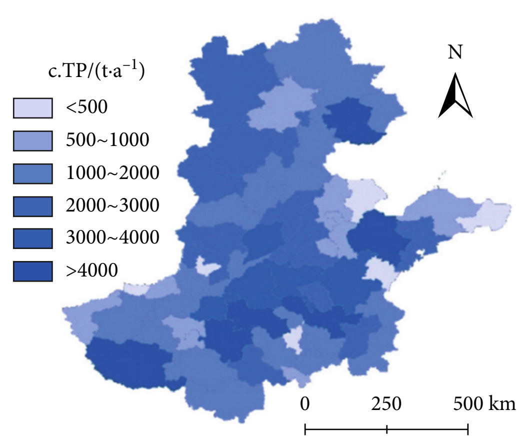

Figure 6: Spatial distribution of TP pollution load in the study area.

of vegetable waste in the prefecture-level cities was 6.45, with a standard deviation of 3.18; the pollution intensities of TN, TP, and TK were 15.15, 4.05, and 19.49; and the standard deviations were 7.48, 2.00, and 9.62, respectively. The pollution load and pollution intensity vary greatly in space.

The spatial distribution of plant residual pollutant load in 58 prefectures and cities in the study area is shown in Figure 4.

The spatial distribution of TN pollution load in 58 prefectures and cities in the study area is shown in Figure 5.

The spatial distribution of TP pollution load in 58 cities in the study area is shown in Figure 6.

The spatial distribution of TK pollution load in 58 prefectures and cities in the study area is shown in Figure 7.

The pollutant load of plant waste in prefecture-level cities in the study area is between 1.6 and 883,900 tons, of which 12 cities have more than 400,000 tons. These cities have large administrative areas and suitable climates. There are 10 cities where the amount of plant waste is less than 100,000 tons, most of which have less arable land and small vegetable planting area. The pollution load TN, TP, and TK of prefecture-level cities in the Huanghuaihai region are 412.45-22 835.46 t, 110.33-6 108.40 t, and 530.75-29 385.38 t, respectively, and their distribution patterns are roughly the same as those of plant residues. TN pollutant load is more than 16000 tons, TP pollutant load greater than 4000 tons, TK pollutant load greater than 19,000 tons, and vegetable waste pollutant load, accounting for 26.44% of the total load of Huanghuaihai.

The spatial distribution characteristics of vegetable waste pollution intensity in 58 prefectures and cities in the study area are shown in Figure 8.

The spatial distribution characteristics of TN pollution intensity in 58 prefectures and cities in the study area are shown in Figure 9.

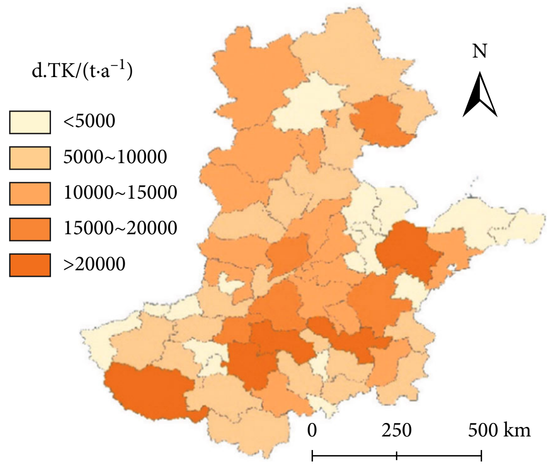

Figure 7: Spatial distribution of TK pollution load in the study area.

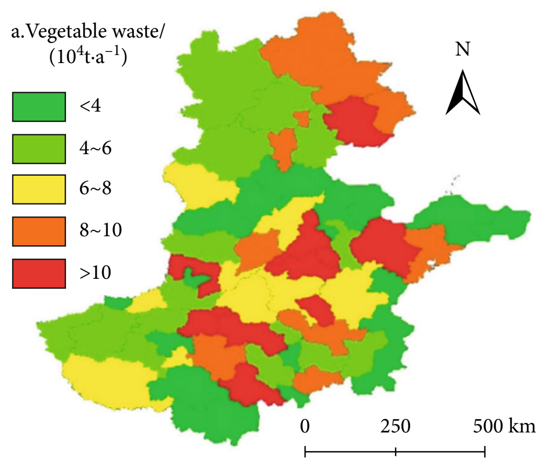

Figure 8: Spatial distribution of vegetable waste pollution intensity in the study area.

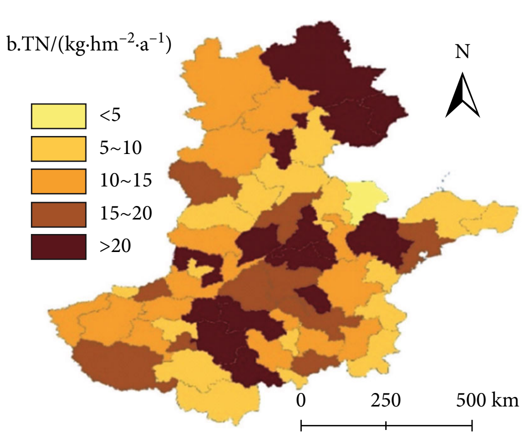

Figure 9: Spatial distribution of TN pollution intensity in the study area.

The spatial distribution characteristics of PT pollution intensity in 58 prefectures and cities in the study area are shown in Figure 10.

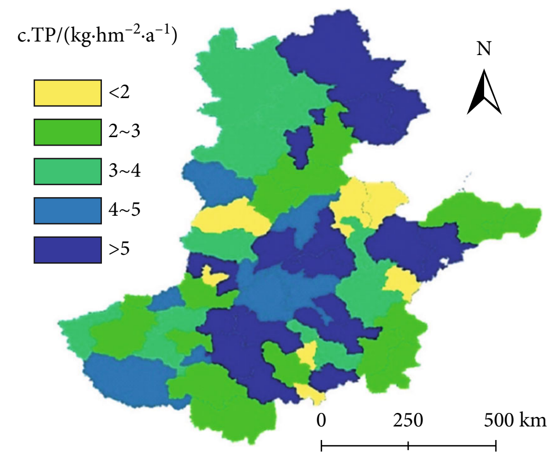

Figure 10: Spatial distribution of TP pollution intensity in the study area.

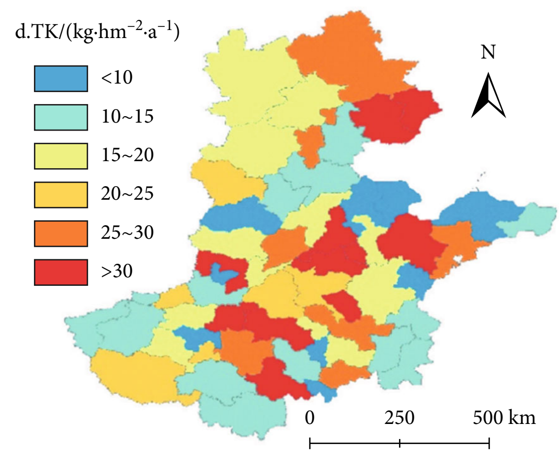

Figure 11: Spatial distribution of TK pollution intensity in the study area.

The spatial distribution characteristics of TK pollution intensity in 58 prefectures and cities in the study area are shown in Figure 11.

The pollution intensity of plant residues in 10 cities exceeded 10 t hm^{-2} a^{-1}, and the pollution intensity of TN, TP, and TK exceeded 23.76, 6.36, and 31.58 kg hm^{-2} a^{-1}. The average urban domestic waste in the study area the pollution intensity is 6.45 t hm^{-2} a^{-1}. In these areas, the area of arable land is relatively small, and the proportion of vegetables grown is relatively high. The pollution intensity in the south and west is relatively high. The pollution intensities of TN, TP, and TK are 4.95 -6.95, 1.32-1.86, and 7.29-8.44 kg hm^{-2} a^{-1}, respectively. It can be seen from the above results that the distribution of TN, TP, and TK pollution intensity of plant residues is relatively consistent, showing the characteristics of greater pollution in the middle and north and lower pollution in the southwest.

3.3. Spatial Analysis of Vegetable Waste Pollution Risk. The pollution risk of plant waste in the study area is more consistent with the spatial distribution of pollution intensity. There

Table 4: Pollution of vegetable waste in areas with high pollution risk.

City	Vegetable waste/ (10^4t·a^{-1})	Pollution load			Pollution intensity				Comprehensive pollution index
		TN/ (10^4t·a^{-1})	TP/ (10^4t·a^{-1})	TK/ (10^4t·a^{-1})	Vegetable waste/ (t·hm^{-2}·a^{-1})	TN/ (kg·hm^{-2}·a^{-1})	TP/ (10^4t·a^{-1})	TK/ (10^4t·a^{-1})	
Zaozhuang	31.65	0.54	1.30	1.65	14.96	34.95	9.36	44.49	1.01
Kaifeng city	46.35	0.12	1.52	1.45	12.45	28.46	7.45	37.27	0.91
Laiwu city	8.13	0.65	0.36	0.36	12.65	28.46	7.45	37.26	0.91
Tangshan	58.03	0.12	1.65	1.52	11.65	27.36	7.35	35.63	0.87
Tai'an city	39.03	0.45	1.34	1.65	11.35	27.16	7.26	35.70	0.87
Jinan city	37.42	0.42	1.85	1.42	11.16	27.04	7.15	34.83	0.85
Anyang	42.36	1.65	1.64	1.36	11.05	26.35	6.95	34.56	0.84
Weifang	78.12	2.46	2.62	2.46	10.59	25.46	6.64	32.62	0.79
Fuyang city	42.65	1.25	1.45	1.52	10.51	24.23	6.58	31.24	0.75
Shangqiu	65.13	1.36	2.13	2.36	10.46	23.64	6.35	30.59	0.74
Qinhuangdao city	15.42	0.34	0.56	0.75	9.26	23.59	6.12	30.09	0.72
Liaocheng	50.36	1.36	1.65	1.68	9.14	22.42	6.10	29.49	0.71
Langfang city	32.10	0.58	1.45	1.63	9.09	22.36	6.01	29.06	0.70
Chengde	21.55	0.36	0.36	0.74	9.02	21.15	5.98	27.54	0.66
Zhoukou city	69.42	1.65	2.31	2.65	8.36	20.13	5.65	26.94	0.64
Qingdao city	39.75	1.52	1.39	1.95	8.12	19.95	5.26	25.46	0.60
Xuzhou	88.35	2.36	0.45	2.48	8.69	19.45	5.21	25.36	0.60
Bengbu	19.30	0.45	2.36	0.64	8.58	19.36	5.35	25.54	0.60

are 18 cities with a comprehensive pollution index greater than 0.5. These cities have a higher risk of plant waste proliferation and pollution. The total pollutant load of plant residues is 7,846,400 tons, which is equivalent to 48.49% of the total load of the entire district, and the average pollution intensity of plant debris is 10.56 t•hm^{-2}•a^{-1}, which is 1.64 times the average pollution intensity of Huanghuaihai Lake (Table 4).

The general pollution index of urban plant waste with the highest pollution risk is 1.00, and the pollutant load of plant waste is 316,200 t•a^{-1}. The pollution loads of TN, TP, and TK are 0.82, 0.22, and 10,500 t•a^{-1}, respectively. The pollution intensity of the residue is 14.73 t•hm^{-2}•a^{-1}, and the pollution intensity of TN, TP, and TK is 14.73 t•hm^{-2}•a^{-1}. The TK is 34.57, 9.25, and 44.48 kg•hm^{-2}•a^{-1}, respectively (Figure 12).

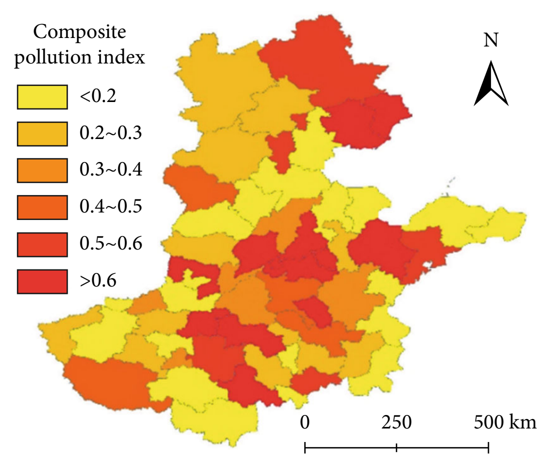

Figure 12: Comprehensive pollution index of vegetable waste in the study area.

3.4. Resource Utilization Potential of Vegetable Waste. Using plant waste as fertilizer can replace some chemical fertilizers. As can be seen from Figure 13, the plant residue output and consumption demand in the study area is up to 25%. There are 11 cities with great resource utilization potential, accounting for 19.00% of the study area. The total amount of chemical fertilizer used in these cities was 11.3771 million tons, accounting for 41.8% of the total application in the region, and the total amount of plant residues was 5,889,700 tons, accounting for 36.40% of the total application in the region. The areas with low resource utilization potential include 8 cities. The yield of plant waste and the demand for chemical fertilizers are at the lowest 25%. According to the 10% quantile of plant waste production and the quantile of chemical fertilizer use, the regions with high resource utilization potential are divided. It can be seen that city has the largest resource utilization potential, and plant production residues and chemical fertilizer use are ranked in the top 10%; B cities, C, D, and E are in the top 10% of fertilizer application, and crop waste production is in the top 25%. Cities F, G, and H are in the top 10% of plant waste generation, and the amount of fertilizer application is in the top 25%. The resource utilization potential is greater than that of I, J, and K cities.

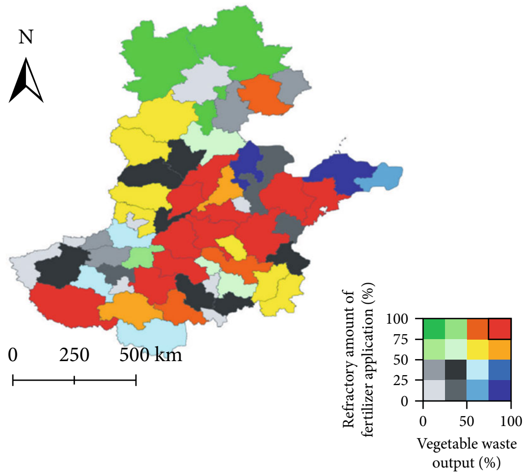

Figure 13: The resource utilization potential of vegetable waste in the study area.

According to the “Annual Report of China Environment Statistics” [26], the agricultural chemical oxygen demand, ammonia nitrogen, total nitrogen, and total phosphorus demand in the study basin accounted for 37.9%, 33.5%, 44.6%, and 44.2% of the top ten basins, respectively. Among them, the total nitrogen emissions they were 765,000 tons, 942,000 tons, and 350,000 tons, respectively. The total phosphorus emissions were 88,000 tons, 115,000 tons, and 39,000 tons, as shown in Table 5. The residual TN and TP pollution loads in the study area are 418,800 tons and 111,800 tons, respectively. If all the TN and TP of the plant residues enter the water body, it is equivalent to 20.3% and 20.3% of the total nitrogen and total phosphorus emissions of the marine basin’s agricultural pollutants 46.2%.

4. Discussion

4.1. Risk Analysis of Vegetable Waste Pollution. As China’s economic structure is an extensive agricultural economy, various agricultural wastes have become the main source of surface water pollution in rural areas. Unlike the stems of edible plants, plant remains have high moisture content, are perishable and smelly, and will pass through the sewage process. Surface runoff pollutes the surface and groundwater through scouring and leakage. The yield and waste coefficients of different types of vegetables vary greatly due to different planting and harvesting methods [27]. Compare the yield and waste coefficients of leafy vegetables, melons, and root vegetables. In the main vegetable production areas, the sown amount of various types of vegetables is relatively stable. The yield and waste coefficients are weighted by the sowing amount of different types of vegetables, which can determine the average vegetable production waste coefficient, which can overcome the difficulty in estimating the amount of vegetable waste caused by the scattered vegetable planting and uneven temporal and spatial distribution to a certain extent.

As the price of chemical fertilizers continues to rise, it is an inevitable trend for the development of modern organic agriculture to replace some chemical fertilizers with agricultural wastes. Studies have shown that the TN, TP, and TK content of plant wastes in the Huanghuaihai area can replace 908,700 tons of urea and superphosphate. Potassium sulfate 254,100 tons, potassium sulfate 1,075,800 tons. For example, after composting vegetables, they contain a lot of cellulose-decomposing bacteria, which can promote the reproduction of beneficial microorganisms in the soil, increase the content of low-molecular organic acids in the soil, and activate and effectively increase soil nutrients.

As a place to absorb organic waste, the carrying capacity of agricultural land depends not only on the nature and fertility of the soil but also on the absorption of grain and straw during harvest. The pollution intensity is the nitrogen and phosphorus nutrient pollution per unit area of the cultivated soil, which reflects pollution risk of plant waste to cultivated soil. It should be noted that the pollution level of plant waste in the 4 cities is relatively high, but the pollution intensity is relatively low. These areas have suitable climate conditions, perfect agricultural production conditions, and high vegetable yields, but the administrative area is large, the area of arable land is large, and the plant waste the pollution intensity is low. The pollution degree of plant waste in these three cities is relatively low, but the pollution intensity is relatively high, which may be related to the vegetable planting area and planting type.

The total amount of plant remains in the study area is 16.1808 million tons, which provides a good prospect for the development and application of vegetable stalks. However, the spatial distribution is wide and the yield of vegetable stalks varies greatly in different regions. Analyzed the plant waste pollution and resource utilization potential of various cities in the Huanghuaihai region. Among them, 11 cities have relatively high utilization potential. According to the natural economic conditions and agricultural development in different regions, the comprehensive utilization technology of plant residues should be promoted to the greatest extent [28]. Realize the reduction, safety, and utilization of plant residue resources.

4.2. Traditional Processing Methods of Vegetable Waste. Vegetables are generally seasonal, short in storage, difficult to transport, and perishable. The highest yield is usually in the high temperature season. In China, due to the current technical limitations, random disposal of plant residues not only causes a huge waste of resources but also it also pollutes the environment [29].

In cities, plant waste accounts for 20% to 50% of urban domestic waste. This part of plant waste is not easy to separate and dispose of separately. It is usually treated as domestic waste. In rural areas and small vegetable distribution centers, the traditional method of disposing of plant waste is mainly field accumulation [30]. Due to the high water content of plant excrement, it accumulates in large amounts in the open air and is extremely perishable and smelly, breeding mosquitoes and flies, and provides good conditions for the reproduction and transmission of pathogenic microorganisms and mineral elements in the washed and infiltrated plants. Then, the surface and groundwater pollution

Table 5: Agricultural pollutant discharge in the Huanghuaihai Basin (10^4t).

Watershed	Cod	Ammonia	Total nitrogen	Total phosphorus
Haihe	154.2	7.5	76.3	8.1
Huaihe	175.6	13.1	94.1	11.4
Yellow River	75.2	3.6	35.4	3.6
Total	405.3	24.5	205.9	24.5
Vegetable waste	—	—	41.30	11.19
Potential contribution rate/%	—	—	20.6	46.5

are caused by surface runoff leakage [31]. For example, in the Dianchi Lake Basin in Yunnan, farmers randomly collect or dispose of plant waste in lakes and rivers, and the nonpoint source pollution caused by them is far greater than that caused by industrial production. In addition, the plant debris will contain a large number of pests and diseases. The accumulated leakage will pollute the soil and affect the growth of subsequent crops. The burning of the construction site will produce a large amount of dense smoke, which not only pollutes the atmospheric environment but also seriously affects the inland waterway traffic and causes haze.

4.3. Comparative Analysis of Resource Utilization. According to statistics [32], the collection rate of plant waste in China is 0.80. Therefore, it is estimated that the amount of plant waste that can be recycled in China in 2021 will be approximately 215 million tons. It is estimated that in 2021, the plant residues nitrogen, phosphorus, and potassium nutrient reserves will be 954.7 thousand tons of nitrogen, 534,600 tons of phosphorus, and 82 million tons of potassium, accounting for 3.99% of the national nitrogen fertilizer consumption. 6.44% of the phosphorus fertilizers use 13.07% of the potassium application. In addition, it also contains 18.8883 million tons of organic matter and medium and trace elements necessary for plant growth.

4.3.1. Resource Utilization Method

(1) Return Directly to the Field. The ratio C/N value of plant residues is relatively low, which is more suitable for direct return to the field than straw cultivated in the field. After returning to the field, it undergoes a fermentation stage to improve the physical and chemical properties of the soil, which improves the quality and yield of the plant. Studies have shown that the average annual return rate of plant waste is 16%, and the generation and return rates of annual residues have a relatively high trend. Studies have shown that direct application of plant residues with microbial agents can significantly increase the yield of Chinese cabbage [33].

(2) Feed Utilization. Studies have shown that normal growing vegetable waste does not contain any other toxic and harmful substances [34]. Except for some tissues that have disease and insect pests, vegetable waste contains a lot of cellulose, which can be used as feed after proper treatment. At present, for the treatment of plant residues in feed, silage technology, ammonia treatment technology and microbial treatment conversion technology are mainly used to process them into microbial protein products. Zhang et al. developed high-quality protein foods with the waste of Chinese cabbage as raw materials and added bran to ferment the solid mixed bacteria together [35]. WGP uses plant waste as the main raw material and bran as the auxiliary material. It uses nonsterile solid fermentation technology to produce single cells. Protein feed, then, the protein content of the product increased by 75%. Studies have shown that plant waste and fishery by-products after fermentation and heat treatment can be used as alternative feed ingredients for pigs. Today, feed production using plant residues as raw materials not only brings huge benefits to the environment but also improves feed quality and reduces feed production costs.

(3) Simple Anaerobic Refining. Studies have shown that trace elements from plant waste can be partially converted into liquid organic fertilizer after 96 days of fermentation and exist in an effective form that plants can use. In addition, the GI value in the original fertilizer solution is as high as 80%, which is less toxic and can be diluted or directly used in farmland. Research on the effects of vegetable waste retting and chemical fertilizers on the yield and quality of rape has shown that the collection of plant residues can significantly increase the yield and quality of canola, but excessive use will inhibit the yield.

(4) Biogasification and Utilization. According to China's agricultural waste resource analysis, plant waste biogasification produces $477.75 \times 109\ m^3$ of biogas per year. Vegetable waste has a high water content and a total solid content of about 10%, which is usually consistent with anaerobic digestion. The ratio of chemical oxygen demand to nitrogen (COD: N) is (100 : 4.:4) ~ (128 : 4). Vegetable by-products are nutritious, and anaerobic fermentation can be carried out without adding nitrogen and nutrient sources. After anaerobic fermentation, not only can produce biogas, but biogas waste and the liquid produced can be used as fertilizer for plants. The use of biogas residue as fertilizer can not only significantly improve crop resistance and inhibit the persistence of soil-borne diseases but also significantly improve the physical and chemical properties of soil and can also be used as a food additive.

However, not all plant wastes are suitable for anaerobic digestion into biogas. The cellulose content in the plant residues is low. The excessively fast hydrolysis rate during anaerobic fermentation leads to the accumulation of volatile acids and the decrease of pH, which leads to the inactivation of methanogens. Inhibiting or even destroying the methane production process, vegetable straw is rich in lignin and cellulose, and its unique high polymerization state can resist microbial degradation and reduce the hydrolysis rate of anaerobic fermentation.

4.4. Mixed Aerobic Composting. Aerobic composting is the process of microbial degradation of organic waste under aerobic conditions to produce biological fertilizers. At present, many studies [36] have shown that aerobic digestion can produce high-quality organic fertilizers by using common composts such as plant residues and crop straws, manure, and plant residues. Compared with chemical fertilizers, compost made of plant waste has the characteristics of comprehensive nutrition and rapid yield increase, which promotes the improvement of crop growth and the quality of agricultural products. It can also increase the content and activity of soil organic matter, improve physical and chemical properties, and eliminate soil hazards. The residue of the substance and the inhibition of the growth of soil pathogens play an important role here. Studies have shown that when plant residues are applied during the cucumber growth period, the temperature of cucumber roots is higher than that of conventional fertilizer, and its maturity time, yield, and output are better than conventional compost. Other studies have shown that the application of compost to alkaline soil can significantly reduce the pH value and EC value of alkaline soil, reduce soil bulk density, increase porosity, and significantly increase soil organic matter content and alkaline soil content.

Composting plant waste in the factory's greenhouse can solve the problem of carbon dioxide deficiency. Using potato vines and other plant wastes and chicken manure to compost in the greenhouse can significantly increase the CO_2 concentration in the greenhouse, and the fermentation product can be used as a high-quality biological fertilizer, not only reaching the original position. Treating harmless plant wastes can also increase the yield and quality of vegetables by adding carbon dioxide gas to fertilizers. Vegetable waste compost is not only a high-quality organic fertilizer, it can also meet the requirements of seedling substrates in terms of compost density, total porosity, water retention holes, and vent holes. It is an environmentally friendly alternative to peat, which is renewable and does not contain onsite pollutants.

4.5. Comparison of Advantages and Disadvantages of Different Resource Utilization Methods. Plant waste has a high resource potential. The most important resource utilization options today is direct return to the field, feed utilization, simple anaerobic recycling, biogas utilization, and mixed aerobic composting. Each resource treatment method has its own advantages and disadvantages. Vegetables have serious pests and diseases. Plant waste contains pests and diseases. Plant wastes are particularly easy to rot during the high temperature period of summer and autumn, which promotes the spread of harmful pathogens. They are returned directly to the field or simply retorted to the field. The field can greatly increase the incidence of plant diseases and insect pests in the next season and even cause a large number of deaths, which affects normal production. Although the fermentation time of surface solid phase fermentation to produce food protein is short, it requires aseptic operation. The reliability requirements are high, and part of the waste has been decomposed in a large amount, which is not suitable for large-scale production and promotion. However, due to the biodegradability and structural strength characteristics of plant waste, biochemical treatment technology is more suitable for treating plant waste, but the biogasification anaerobic fermentation time is long, the cycle treatment volume is small, and the fermentation conditions are demanding. In addition, anaerobic fermentation technology has higher requirements for fermentation equipment, and the scale of the factory is severely restricted. Sewage and garbage treatment will also increase additional costs. Improper treatment will also cause secondary pollution. Aerobic high-temperature compost keeps the compost at high temperature and effectively kills. To kill pathogenic microorganisms, it can also produce high-efficiency organic fertilizers. The nutrient cycle occurs through the absorption of plants. The high-temperature aerobic composting fermentation time is short, and the requirements for processing equipment are low. It is designed according to local conditions, such as terrain and climate. Second, vegetable production in developed countries is highly concentrated, large-scale, and mechanized. Vegetable residues are easy to collect, and most of them are anaerobic fermentation. However, vegetable planting areas in China are relatively scattered, with a large number and wide distribution of plant residues, which are distributed in various concentrated areas. It is very diverse. Therefore, high-temperature aerobic composting is easier to realize the rapid utilization of China's plant waste resources.

5. Conclusion

In the last decades, the process of China's agricultural industrialization is accelerating, the degree of agricultural intensification is rapidly increasing, and agricultural nonpoint source pollution has become increasingly prominent, which has become a major factor in China's water environment security. Pollution from scattered agricultural sources is affected by many factors, such as agricultural production activities, rainfall, topography, soil, and land use, which vary greatly in space. Based on the quantitative study of the spatial distribution of point source pollution and nonpoint source potential pollution, this study established a spatial pollution assessment model and a point source pollution risk assessment spatial model. Then divide the exposure level and risk level, determine the key areas of nonpoint source pollution control, and build a regional classified monitoring technology system to provide research basis for China's agricultural nonpoint source pollution control. In this work, the TCLP method was used to determine the effective content of heavy metals in the soil, and the continuous BCR extraction method was used to determine the content of various chemical forms of heavy metals in the soil. Then, the distribution rules of heavy metals in plant soils in different regions, soil depths, and soil types were studied, and the cumulative risk, pollution risk, ecological risk, and health risk of heavy metal pollution in plant soil were evaluated. Bioavailability of heavy metals in soil. Vegetable soil includes the ability of various vegetable varieties to absorb and accumulate different heavy metals and the correlation between the content of heavy metals in vegetables and the total amount, available state content and content of various chemical forms of heavy metals in soil. Plant waste has a risk of pollution, but it is also an important source of organic materials. It is rich in nutrients and organic matter. After safe resource development and treatment, it can be used as an important source of organic fertilizer, reducing the contribution of chemical fertilizers and the source of straw pollution, which can be effective reduce agricultural production costs. Understanding the quantity and spatial distribution of plant wastes is a prerequisite for reducing agricultural diffusion source pollution in key plant production areas and promoting the utilization of straw resources. However, the complex sources of plant waste, scattered distribution, and diverse migration paths make accurate estimation difficult. Through the comprehensive analysis of this article, thermo-aerobic composting is currently the most suitable solution for resource waste and plant waste pollution in China. However, the thermo-aerobic composting technology for plant waste in China is not yet mature. With high water content, low C/N, microorganisms, pathogens, and high nitrogen content, future research should pay more attention to the development of conditioners and process equipment suitable for composting high-humidity materials to achieve efficient, fast, and safe treatment of plant waste. Thoroughly solve the economic and environmental problems caused by China's plant waste, realize recycling, and minimize safety and factory waste.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Additional Points

Conflicts of Interest

The authors declare that they have no competing interests.

Acknowledgments

This study was funded by Hubei Provincial Department of Education Scientific Research Project "Research on Market Utility and Investment Income Evaluation of Hubei Ecological Resources Capitalization" (Q20192903), Hubei Provincial Department of Education Philosophy and Social Science Research Project "Hubei Natural Resources Capitalization Operation Effect Measurement and Improvement Path Research" (19Q181), and the major project of Hubei Province Humanities and Social Sciences Key Research Base Dabie Mountain Tourism Economy and Culture Research Center "Research on the Poverty Alleviation Effect and Promotion Strategy of the Capitalized Operation of Ecotourism Resources in Dabie Mountain" (201829503).

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