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Analyzing Barriers for Developing a Sustainable Circular Economy in Agriculture in China Using Grey-DEMATEL Approach

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Abstract: The agricultural economy, as an integral branch of the global economy, covering the whole supply chain of agricultural production including cultivation, processing, distribution and consumption, is of great importance to realizing a sustainable circular economy and ecological development. As a traditional agricultural country, China has experienced a series of problems such as a serious waste of resources and a fragile ecological environment during its agricultural economic development. With the background of "the Belt and Road Initiative", major progress has been witnessed in both ecological development and agricultural circular economy in China. However, the development of circular agriculture in China has to deal with barriers from different stakeholders. This research identifies critical barriers for the government, farmers, and the enterprises to develop circular agriculture. The causal factors, effect factors, and the center of factors are identified and the correlation between the barriers is described using the Gray-DEMATEL method. Based on the analysis results, several policy suggestions are proposed for the government. This paper provides a feasible framework for decision-making to support the development of a sustainable circular economy in agriculture in China.

Keywords: agriculture; sustainable circular economy; the belt and road; gray-DEMATEL

1. Introduction

Since the 21st century, global problems such as climate change, natural resources shortage, and environmental pollution have been deteriorated [1]. There is an urgent need to come up with a solution to alleviate the contradiction among resources, environment, and economic development mode [2]. The circular economy, a responsible development mode for different industries, has drawn much attention [3]. In order to promote the circular development of the agricultural economy, some countries in Europe, America and Asia, such as China, have increased their input in agricultural circular economy to strengthen their activities centering on green and environmental protection economy. From a global perspective, future progress in the agricultural circular economy will require governments to be forward-looking in policy formulation, which will also lead to significant changes in technology, markets and industrial processes. For example, the European Commission for Industry and academia in Europe has stressed that bioeconomic progress requires a coherent and strategic policy approach. Bioenergy in the European Union (EU) for the period 2013–2020 is seen as an important driver of biochemistry and economic development, not only within the EU but also in North America and Mercosur [4]. According to the European Community, Europe's circular economy market currently exceeds 2 trillion euros, providing 22 million jobs in different sectors such as agriculture, forestry, food, chemicals and bioenergy, accounting for about 9% of the EU workforce. These figures not only highlight the economic growth and job creation of the existing circular economy in the European economy and society, but also enable the EU to play an active role in areas such as greenhouse gas emission reduction, renewable energy use and agricultural policy greening.

To promote the development of agricultural economy cycle, developed countries from European and American have formulated a series of laws and regulations. For example, the United States as early as in 1990, has issued a "pollution prevention law:, making clear provisions for the development of sustainable agriculture. In the 2002 farm security and rural investment act, the legislation to implement land fallow, wetland protection, environmental quality incentive to provide a subsidy, at the same time, increase investment in science and technology of agriculture circular economy research, and publicity [5]. In Europe, the UK has spent 4%–5% of the EU Common Agricultural Policy Fund on agricultural environmental protection since 1993. Meanwhile, it has provided 1.40 pounds of subsidy to farmers since 2006 to help agriculture achieve all-round development [6]. In Germany, a "green ecological agriculture" plan was introduced in September 2001, and has made severe restrictions on exogenous substances pollution or damage to the ecological environment caused by improper operation. In agricultural production, the plan has made a clear requirement on the technology of antibiotics, transfer funds, easy to let the chemical fertilizers and chemical synthesis in addition to the use of pesticides and consumption.

The Chinese "13th five-year plan" has put forward that China will continue to conserve resources and protect the environment, accelerate efforts to build a resource-conserving and environment-friendly society, pursue green, circular and low-carbon development, create a new pattern of modernization featuring harmonious development between human beings and nature, and promote ecological progress and other basic state policies [7]. The Chinese government will promote green development, accelerate the establishment of green production and consumption, accelerate the establishment of a legal system and policy guidance for green production and consumption, and establish a sound economic system featuring green, low-carbon and circular development. Under the background of "One Belt and One Road", green technology cooperation under the principle of comparative advantage and benefit-sharing can be carried out among countries along the Belt and Road [8]. Through "One Belt and One Road" financial organizations such as Asian Infrastructure Investment Bank, a green technology innovation fund can be set up to mainly support the research and development, promotion and achievement transformation of green, environmental protection and practical technologies. China will focus on supporting the research, development and promotion of new technologies in the fields of green energy, environmental governance, ecological restoration, energy conservation and emission reduction, green buildings, and green infrastructure, and actively promote the innovation, cross-border transfer and transformation of "One Belt and One Road" green technologies.

As the largest developing economy, China has been consistently investing in agriculture activities to promote the development of a circular agriculture. In the 13th Five-Year Development Plan, China committed to save resources and protect the environment over the next five years. According to the President Jinping Xi, China has been devoted to achieving a green, recycling, and low-carbon economy, in such a way to promote the development of ecological civilization and realize a new mode of modernization that supports the harmonious development between human and nature [9]. Given the background of "the Belt and Road" project, China can achieve green technology cooperation through the principle of comparative advantage and benefit sharing along the "the Belt and Road" path [10]. Through "the Belt and Road" financial organizations such as the Asian Investment Bank, a Green Technology Innovation Fund can be established to support the development, promotion, and transformation of practical green technologies.

Henan is the largest agricultural province in China, and its agricultural output value holds an important position in the national economy [11]. Henan holds arable land resources of nearly 8000 hectares, accounting for 6.2% of the total in China. With the rich arable land, Henan has developed the largest grain production base in China. Henan contributes more than 40 million tons of grain annually, ranking first in grain output in China for many years. However, long-term high-intensity agricultural production has caused a series of problems [12,13], such as serious resources wastes, a fragile ecological environment, and the continued deterioration of agri-ecosystems. According to the Environmental Monitoring Center, 70% of the surface water resources in Henan Province fail to meet the national water standard, especially some heavily polluted water sources could not be used in irrigation. Therefore, it sees an urgent and necessarily need to promote the development of a circular agriculture in Henan [14]. Besides, achieving a sustainable circular economy in Henan is also of great importance to China's objective of achieving a high quality, efficient, and low-carbon economy.

Based on the practical situation of Chinese agriculture, this paper firstly identifies three critical stakeholders in circular agriculture development, which are the government, farmers, and agricultural enterprises. Secondly, we invited personnel and investigated them to collect the typical barriers in developing circular agriculture, respectively. Then using the Gray-DEMATEL method, this paper identifies the causal factors, effect factors, the center of factors, and the relationship between factors by analyzing the barrier factors. We collected the data in Henan province. The result provides a scientific basis for decision-making to promote a sustainable circular economy in China.

The remainder of this paper is organized as follows—Section 2 is the literature for related studies of agricultural circular economy for three aspects. Section 3 identifies the barriers of agricultural circular economy from the government, farmers and enterprises. Section 4 is the Gray-DEMATEL introduction. Section 5 is the case study using the Gray-DEMATEL. Section 6 is the conclusions and suggestions of this study.

2. Literature Review

The literature review is divided into three subsections, corresponding to the three aspects of the current agricultural circular economy research. The first subsection explores the development strategy and mode of an agricultural circular economy. The second subsection provides a broad overview of the current study and the efficiency of the agricultural circular economy. The third subsection discusses the barriers to an agricultural circular economy.

2.1. Development Strategy and Mode of an Agricultural Circular Economy

There are many studies in recent years that explore the development strategy and mode of an agricultural circular economy. Wu X et al. [15] established a sustainable integrated agricultural model (SIAM) based on agricultural production technology, which is helpful to evaluate the development status of an agricultural circular economy in Northwest China. The result shows that SIAM should be widely supported because it can improve the efficiency of resource utilization and environmental performance. Chen L et al. [16] conducted a further study on China's sustainable biogas model, taking the Beijing Deqingyuan biogas project as an example. They believe that developing biomass energy is an important way to reduce the use of fossil fuels and greenhouse gases and promote the development of ecological agriculture and a circular economy. Through the theoretical analysis of the content and principles of a circular economy, Han J and He X [17] summarized the basic concept of an agricultural circular economy. They emphasized that the development of a circular economy is a fundamental way to achieve agricultural sustainable development in China. To promote an agricultural circular economy, they argued that the government needs to increase publicity to raise people's awareness of environmental protection and promote the formation of ecological values and the concepts of green consumption. Xi H [18] identified three kinds of agricultural circular economic modes including the family cycle, rural cycle, and eco-agricultural cycle after analyzing the agricultural environmental pollution and comprehensive agricultural ability in Yunnan Province. Miao L [19] explored the development status of the agricultural circular economy and existing problems in the Yangling Demonstration Zone. Some suggestions are provided in this study, such as strengthening scientific and technological support and improving the policy system to promote the development of an agricultural circular economy. You H [20] developed an evaluation index system to measure agricultural circular economy development in Yunnan Province. He noted that the area of cultivated fields was decreasing, the overall level of the agricultural circular economy was low, and it was being insufficiently promoted. In view of these problems, he put forward measures to promote the progress of agricultural technology, improve the agricultural service system, and so on.

2.2. Evaluation of the Efficiency of the Regional Agricultural Circular Economy

Some researchers have explored methods to measure the efficiency of the agricultural circular economy. Hu Q [21] assessed the resource efficiency, environmental efficiency, and ecological efficiency of the agricultural circular economy in Jilin Province by selecting eight indicators such as gross agricultural output and energy consumption. The author offers four suggestions to improve the efficiency of the agricultural circular economy: reduce the amount of material needed for agricultural production and improve resource utilization efficiency; develop a cycle production mode combining agriculture and livestock; improve the incentive mechanism for the development of an agricultural circular economy; and broaden financing channels. Qin X et al. [22] evaluated agro-ecological compensation and the efficiency of the agricultural circular economy in the northern area of Jiangsu. Improving the compensation mechanism for ecological agriculture contributes to promoting the better development of a circular economy. Based on the relationship between agricultural technology, industry, and organization, Lu P [23] developed a system to evaluate the efficiency of the regional agricultural circular economy. The evaluation system is used to analyze the practice mode, influence factors, and efficiency of circular agriculture in Pinghu City, Zhejiang Province. Wang Y [24] constructed a circular economy efficiency evaluation model by means of data envelopment analysis, cluster analysis, and regression analysis. This model was used to analyze the economic efficiency of recycling in three provinces in Northeast China. Factors that promoted and restricted the efficiency of the circular economy for these provinces were determined, and counter measures such as deepening the reform of government policies were proposed to improve its efficiency. Li F et al. [25] used a system dynamics model (SD model) to evaluate the ecological and economic effects of circular agriculture in Anding District, Dingxi City in China. The results show that a circular economy can not only greatly enhance economic benefits but also provide significant ecological benefits such as reducing water consumption, reducing fertilizer use, eliminating animal waste and urine pollution, and reducing fossil energy consumption and CO_2 emissions.

2.3. Barriers to the Agricultural Circular Economy

Some researchers [26,27] have discussed the concepts and limitations of the agricultural circular economy. Comparing the similarities and differences in the concepts of a circular economy, a green economy, and a bio-economy, they found that the assumptions and strategies for the three were different but that these concepts shared common economic, environmental, and social goals. Wang B et al. [28] verified that the utilization efficiency of traditional agricultural waste recycling was low. They concluded that technological innovations, people's motivation, costs, and environmental policies were the factors influencing agricultural waste recycling. He K et al. [29] divided the factors that affected farmers' willingness to recycle waste into economic and non-economic factors, such as people's age, attitude, family income, and income sources. They found that setting the compensation in a range of 1.08%–0.31% of the average annual household income would encourage farmers to recycle agricultural waste.

In summary, research on the agricultural circular economy has achieved rich findings, and some studies have explored the factors that restrict the development of the agricultural circular economy. However, analysis of the relationship among the various influencing factors and identification of the key influencing factors are lacking. Therefore, this article will focus on the constraints of circular agriculture development and the relationship between the various factors.

This study includes seven sections. Section 1 introduces the policy and current status of agricultural development and emphasizes the importance of developing circular agriculture in Henan

Province. Section 2 reviews the domestic and foreign literature on the development of an agricultural circular economy. Our examination of the existing literature reveals that it lacks an analysis of the relationships between the various influencing factors.

Based on the stakeholders, Section 3 identifies and summarizes the factors restricting the development of an agricultural circular economy based on the literature and interviews. Section 4 introduces the Gray-DEMATEL method and illustrates its application in this article. In Section 5, we conducted a case study, analyzing the different semantics provided by experts and making a sensitivity analysis. Finally, Section 6 summarizes the research findings and offers some suggestions.

3. Identification of The Barriers

Based on stakeholder theory [30], the main stakeholders promoting the development of an agricultural circular economy are the government, farmers, and businesses.

3.1. Barriers from The Government

The government should create a policy environment that promotes the development of an agricultural recycling economy. However, the system of policies and regulations in the six central provinces in terms of the agricultural circular economy is imperfect [31]. The current policy lacks specific and enforceable standards [32], for example, the system to optimize the allocation of resources and their operation, management and evaluation is inadequate. The administrative mechanism of the government departments is deficient, and the boundary of power and responsibility between departments is unclear [19]. To be more specific, the coordination among government departments is weak, and policies and measures are insufficiently integrated. Local governments seek a more cost-effective economy [33] and their awareness of environmental protection is limited. In other words, most local government officials neglect the development of agricultural circular economy.

Yao Y [34] noted that the development of an agricultural circular economy requires substantial funds, and its returns are slow to appear. In promoting the development of circular agriculture, the government should provide sufficient financial support, such as preferential policies, financial support policies, and a complementary subsidy mechanism. However, at present, the government lacks science-based preferential policies and subsidies [22,35], which leads to a large funding gap for the development of an agricultural recycling economy. Meanwhile, some local governments do not think highly of financial policies [32]. These governments unilaterally pursue GDP and invest in other industries, deforming the economic models. The government lacks corresponding financial subsidies for the financial sector, and the types of green financial products offered are relatively simple [36]. Further, there are limited channels through which farmers and businesses can make and receive loans. Without insufficient capital investment, a complete infrastructure for the development of the circular economy in agriculture will not materialize. The mechanization of many types of facilities is also not widely popularized [37], which also restricts the development of an agricultural circular economy.

Li F [31] noted that the development of an agricultural circular economy in the central region of China reflected a low level of science and technology. The development of agricultural circular economy was hindered by the low degree of agricultural informatization and the lack of flexibility in the promotion of technology [38]. The western region and other underdeveloped areas should make full use of the advantages of "the Belt and Road" initiative and actively cooperate with regions along the route [39]. Introducing advanced technology and attracting green business investment are conducive to the development of a circular economy. Shan Y [10] discussed cooperation between Fujian and Taiwan in agriculture. She emphasized that the future development of agriculture should seize the opportunity presented by "the Belt and Road Initiative". She offers some specific measures, including the development of agricultural e-commerce, the expansion of agricultural cooperation, and the strengthening of financial support. Based on the discussion above, we can identify the following barriers:

B1: Relevant policies and regulations are imperfect.

B2: The administrative mechanism is imperfect.
B3: Scientific preferential policies and financial subsidies are lacking.
B4: The government places less emphasis on financial policy.
B5: Existing infrastructure is weak.
B6: The promotion of "the Belt and Road" green technology is slow.
B7: Local officials have weak environmental awareness.

3.2. Barriers From Farmers

Farmers who are business operators or ordinary participants play a key role in the development of a sustainable circular economy in agriculture. Although the agricultural circular economy has been under development for many years, the general public does not understand the actual concept [19,40]. Farmers' weak awareness of environmental protection directly leads to a lack of initiative. The development of an agricultural circular economy requires substantial labor, but with the development of urbanization, many young people leave for work, resulting in a labor shortage in the countryside [31,41]. Furthermore, an agricultural circular economy requires not only a simple primary labor force but also a high-level workforce with relevant professional knowledge and skills. At present, with no opportunity to receive professional technical training, farmers have limited professional knowledge and skills [18,37,42]. Zhou S et al. [36] emphasized that the government needs to prioritize financial policies for an agricultural recycling economy. Meanwhile, farmers and enterprises need to have a deep understanding of the corresponding green finance policies. Given the lack of funds, the development of circular agriculture is limited. Therefore, several barriers can be identified:

B8: Farmers have weak environmental awareness.
B9: Farmers have limited professional knowledge and skills.
B10: Farmers do not make good use of the green financial policy.

3.3. Barriers From Enterprises

Excellent enterprises play a leading role in the agricultural circular economy: they can develop industrialized and sustainable agriculture. Li F [31] argued that the costs of developing an agricultural circular economy were obviously high, and the value of externalizing natural resources and eco-environmental costs are not reflected. In production processes, technological innovation and promotion contribute to improving efficiency and enlarging the scale of the circular economy [23]. The big data in agricultural production is of great importance to improving the yields and quality of agri-products [43]. However, enterprises lack the ability to develop scientific and technological innovation, and the overall level of science and technology in circular agriculture is still relatively weak in China. Further, the low degree of agricultural information technology restricts the promotion of technology [22]. In addition, it is important to foster an organizational form that supports the application and promotion of technology [28]. In general, given a lack of outstanding enterprises acting as leaders, the development of an agricultural circular economy remains at a small scale, the industrialization level is low, and the mode of operations is backward [44].

During the process of developing an agricultural circular economy, there is an agricultural structural surplus and difficulty selling agriculture production. Low quality agricultural products create a backlog, while there is a strong demand for high quality agricultural products [18]. The processing of agricultural products in enterprises is still at a low stage, and production earns little value-added profit. Thus, companies should pay more attention to product design, process improvement, and plant construction [28]. In addition, with insufficient brand awareness of green products, companies find it difficult to open the market [19]. As a result, the development of an agricultural circular economy is blocked. Based on the above, we identify the following barriers:

B11: Agricultural production costs remain high.
B12: Product design and production processes are behind.

B13: Enterprises display weak technology innovation.
B14: The organizational mechanism is backward.
B15: Small-scale agriculture has low industrialization.
B16: An imbalance between market supply and demand exists.

4. Gray-Dematel Method

The gray number was first proposed by Deng Julong in 1982 [45]. By adopting the gray number interval, a more flexible decision model can be constructed to make the decision-making result more realistic. The DEMATEL method was proposed by the Bastille National Laboratory in the United States and applies graph theory and matrix theory to analyze system factors. The direct influence matrix is constructed through the logical relationship between the various factors in the system. The center and the degree of each factor are calculated to analyze whether that factor is a causal factor or an effect factor. The traditional DEMATEL method is over-determined when experts give their scores, but this is not often the case in reality. To solve this problem, this paper uses the gray number fuzzy method to establish a flexible mathematical decision model. The gray number allows the model to quantitatively reveal the combined impact of various influencing factors while also clarifying the analysis, avoiding ambiguity, and better approximating reality. Thus, in this paper, the gray number is effectively combined with the DEMATEL method, and they are used to analyze the factors that affect the recycling of agriculture. The main steps are as follows:

Step 1. Identify barriers and questionnaire design

First, through field research and the literature review, the barriers that affect the development of an agricultural circular economy are determined based on the perspective of stakeholders. The specific barriers are shown in Table 1.

Step 2: Establish the initial matrix

Invite k experts who are familiar with the development of an agricultural circular economy to compare factors i in the relation matrix with factors j. According to Xia X et al. and Alraeeini M et al. [46,47], we use a 5-level scale with the following scale items—[0, 0] = No influence, [0, 0.25] = Very low influence, [0.25, 0.5] = Low influence, [0.5, 0.75] = High influence and [0.75, 1] = Very high influence. The gray linguistic scales for the experts' assessments are defined in Table 2; refer to Table 2 for the semantic variables of the k experts to obtain the initial matrix A of the correlation.

Given the different experiences of the experts, there will be differences in their understanding of the barriers to the development of an agricultural circular economy. Thus, the weight given to each expert is different. According to Antarciuc E et al. and Wang W et al. [48,49], the semantic variables given by the different experts are shown in Table 3.

Table 1. The barriers to developing an agricultural circular economy.

Objects	Barriers	Explanation	References
Government	B1: Relevant policies and regulations are imperfect	The system of policies, laws, and regulations in the agricultural circular economy has not yet been established, and there is no specific and enforceable code	(Li F, 2013; Qin X & Zhao C, 2015)
	B2: The administrative mechanism is imperfect	Administrative departments have unclear powers and functions. The coordination among administrative departments is not strong, and policies and measures are insufficiently integrated	(Miao L, 2015)
	B3: Scientific preferential policies and financial subsidies are lacking	The government lacks scientific preferential policies and subsidy systems, and the capital gap is large. Given the lack of funds, the enthusiasm of enterprises and farmers to develop circular agriculture is frustrated	(Qin X et al., 2017; Chen Q & Liu T, 2017; Zhou S et al., 2017)
	B4: The government places less emphasis on financial policy	Financial policy receives insufficient attention from the government. At present, the types of green financial products are few, and the main financing channels for the agricultural circular economy are limited	Yao Y, 2016; Qin X & Zhao C, 2015
Government	B5: Existing infrastructure is weak	Existing infrastructure is weak and the mechanization of various types of facilities has not been popularized. This keeps the scale of circular agriculture small, and specialization is in the initial stage	(Dong H & Zhang F, 2015; Cao J et al., 2014)
	B6: The promotion of "the Belt and Road" green technology is slow	The promotion mechanism for "the Belt and Road" green technology is not flexible. New technologies in the fields of green energy, environmental governance, ecological restoration, emission reduction, and so forth, fail to receive strong support for the necessary research, development, and popularization	(Shan Y, 2015; Huang M & Yao D, 2017)
	B7: Local officials have weak environmental awareness	Local government officials lack awareness of environmental protection. They neglect the development of ecological agriculture and focus on the pursuit of GDP in their regions	(Wang H and Zhai H, 2016)
Farmers	B8: Farmers have weak environmental awareness	Lacking awareness of environmental protection, farmers do not understand the core concepts of an agricultural circular economy. They focus more on short-term economic benefits	(Miao L, 2015; Che H et al., 2014)
	B9: Farmers have limited professional knowledge and skills	Many farmers have not received higher education. Lacking the opportunity to gain professional and technical training, they have limited knowledge and interest in technology for circular agriculture	(Dong H & Zhang F, 2015; Xi H, 2011)
	B10: Farmers do not make good use of the green financial policy	Lacking understanding of the policies related to green finance, farmers have limited financing channels. Thus, they do not have sufficient funds to develop circular agriculture	(Zhou S et al., 2017)

Table 1. *Cont.*

Objects	Barriers	Explanation	References
Enterprises	B11: Agricultural production costs remain high	There are significant cost barriers to the process of agricultural economic development, such as raw material prices. The value of externalizing natural resources and eco-environmental costs in an agricultural circular economy have not been fully reflected	(Li F, 2013)
	B12: Product design and production processes are behind	The product design and production processes are behind at many companies, resulting in low-quality products and the single development of agricultural circular economy	(Wang B et al., 2016)
	B13: Enterprises display weak technology innovation	Enterprises lack independent innovation capability. Given their backward production technology, they may produce secondary pollution in the production process	(Lu P, 2016; Qin X et al., 2017)
Enterprises	B14: The organizational mechanism is backward	It is critical to foster organizational forms that match the technology application and promotion. However, most enterprises have not realized the importance of organizational innovation	(Wang B et al., 2016)
	B15: Small-scale agriculture has low industrialization	When continuing with small-scale development, it is hard to generate a cluster effect and achieve high industrialization. With the low level of agricultural informatization, the promotion of new technologies is constrained	(Chen C, 2015)
	B16: An imbalance between market supply and demand exists	For many companies, there is an ample quantity of agricultural products, but their quality is poor. In addition, brand awareness of green products and market development are lacking, resulting in low profits	(Xi H, 2011; Miao L, 2015)

Table 2. The gray linguistic scale for the respondents' assessments.

Linguistic Terms	Grey Numbers
No influence (N)	[0, 0]
Very low influence (VL)	[0, 0.25]
Low influence (L)	[0.25, 0.5]
High influence (H)	[0.5, 0.75]
Very high influence (VH)	[0.75, 1]

Table 3. Linguistic scale for the importance weight of the evaluators.

Linguistic Variable	Grey Values
Very low influence	[0, 0.3]
Low influence	[0.3, 0.5]
Medium influence	[0.4, 0.7]
High influence	[0.5, 0.9]
Very high influence	[0.7, 1]

Step 3: The clarity of the initial matrix

The gray number is

$$\otimes x_{ij}^{k} = [\underline{\otimes} x_{ij}^{k}, \ \overline{\otimes} x_{ij}^{k}]. \tag{1}$$

Formula (1) can be clarified by the converting fuzzy data into crisp scores (CFCS) method [50], including three short steps.

Step 3a: Standardize

$$\begin{aligned} \underline{\otimes}\overline{x}_{ij}^{k} &= (\underline{\otimes} x_{ij}^{k} - \min \underline{\otimes} x_{ij}^{k}) / \Delta_{\min}^{\max} \\ \overline{\otimes}\overline{x}_{ij}^{k} &= (\overline{\otimes} x_{ij}^{k} - \min \underline{\otimes} x_{ij}^{k}) / \Delta_{\min}^{\max}. \end{aligned} \tag{2}$$

Among them $\Delta_{\min}^{\max} = \max \overline{\otimes} x_{ij}^{k} - \min \underline{\otimes} x_{ij}^{k}$

Step 3b: Standardize clear value

$$Y_{ij}^{k} = \frac{\underline{\otimes}\overline{x}_{ij}^{k}(1 - \underline{\otimes}\overline{x}_{ij}^{k}) + \overline{\otimes}\overline{x}_{ij}^{k} \times \overline{\otimes}\overline{x}_{ij}^{k}}{1 - \underline{\otimes}\overline{x}_{ij}^{k} + \overline{\otimes}\overline{x}_{ij}^{k}}. \tag{3}$$

Step 3c: Calculate clear value

$$z_{ij}^{k} = \min \underline{\otimes} x_{ij}^{k} + Y_{ij}^{k} \Delta_{\min}^{\max}. \tag{4}$$

Using formulas (2), (3), and (4) to clear the matrix, matrix B was obtained.

Step 4: Normalize the matrix with the following two steps to obtain the normalized matrix

$$k = \frac{1}{\max\limits_{1 \le i \le n} \sum\limits_{j=1}^{n} b_{ij}}, \quad i, j = 1, 2, \cdots, n \tag{5}$$

$$X{=}k * B \tag{6}$$

Step 5: Establish a comprehensive impact matrix

$$M{=}X(1 - X)^{-1}. \tag{7}$$

Step 6: Calculate the cause E_i and center P_i of each barrier

In the comprehensive impact matrix, Equations (8) and (9) are used to calculate the cause E_i and center P_i of each barrier. When cause $E_i > 0$, it indicates that the element has a great influence on other factors, and it is then called a causal factor. In contrast, if it is affected by other factors, it is called an effect factor. The sum of the elements R_i in T is the comprehensive influence value of barrier i on other barriers and is called a causal factor. The sum of the column elements D_j refers to the comprehensive impact of barrier j on other barriers and is called the affected degree.

$$E_i = \{R_i - C_j | i = j\} \tag{8}$$

$$P_i = \{R_i + C_j | i = j\}. \tag{9}$$

Among them $R_i = \sum\limits_{j=1}^{n} t_{ij} \quad \forall i, C_j = \sum\limits_{i=1}^{n} t_{ij} \quad \forall j.$

5. Case Study

5.1. Gray-Dematel Analysis

A total of 10 enterprises implementing circular agriculture in China were surveyed through questionnaires and business visits. Ultimately, the deputy general managers of two outstanding enterprises in Henan Province were selected as representatives to complete the questionnaire. In addition, a farmer named Li Wei and a representative of the Bureau of Animal Husbandry in Henan completed the questionnaire.

Formed in 2007, Henan Dengzhou Huang Zhi Animal Husbandry Company developed circular agriculture when establishing its first pig farm. It used biogas to generate electricity and planted 100 hectares of vegetables around the farm. Currently, Huangzhi Animal Husbandry Company has built 9 pig farms and created an agricultural circular economy development model featuring clean energy production and utilization, organic vegetable cultivation, aquatic product breeding, the deep processing of livestock and poultry products and transportation. Its product market covers more than 20 cities across the country.

Henan New Dammam Co., Ltd. was established in 1998 and is headquartered in the high-tech zone of Zhengzhou City, Henan Province. It is a comprehensive farming and animal husbandry group integrating pig breeding, pig production, circular agriculture, engineering research and development, food safety, and consulting services. New Dammam actively cooperates with foreign research institutes and outstanding enterprises and has introduced high-end technology and management. Currently, it takes the livestock husbandry industry, the environmental protection industry, and the agriculture industry as its three pillars, and it has developed a circular agriculture model that includes the company, the farming districts, and the farmers. It has cooperated with 1400–2000 farmers to operate pig farms, and the annual number of pigs slaughtered will reach 100–150 million.

The Bureau of Animal Husbandry in Henan is a government department for being in charge of the development of agricultural circular economy. It is appropriate to choose an expert from this department. In May 2017, a research team including Chengqi Wang, Director of the Bureau of Animal Husbandry of Henan Province, conducted a field visit to New Dammam Co., Ltd. to examine its circular economy model of zero discharge treatment, planting, and breeding of manure. They conducted in-depth discussions with the company's leaders in wastewater treatment. They learned that New Dammam aimed to build an industry chain that would combine planting and breeding with "all-ecological, full circulation and full chain". The research team expressed their strong support for this model. Therefore, Chengqi Wang, the Director of the Bureau of Animal Husbandry, was chosen to complete the survey questionnaire.

Li Wei, a farmer from Yuanyang County in Henan Xinxiang, was selected as a representative to fill out the questionnaire. She has operated several farms since 2009. In 2014, Li Wei succeeded in exploring the mode of the agricultural circular economy with the help of Kawasaki Hiroto, an expert from Japan.

The four experts mentioned above work in different economic and political environments and have different understandings of the constraints to developing a circular economy. According to Xia X et al. and Alraeeini M et al. [46,49], different weights are given to their responses based on their work experience, as shown in Table 4.

The specific steps taken to combine the theory of gray number systems and the DEMATEL method to effectively analyze the factors restricting the development of an agricultural circular economy are as follows:

Table 4. Expert weights.

Stakeholders	Grey Numbers
Bureau of Animal Husbandry in Henan	[0.7, 1]
Henan Dengzhou Huang Zhi Animal Husbandry Company	[0.4, 0.7]
Henan New Dammam Co., Ltd.	[0.4, 0.7]
Farmer-Li Wei	[0.3, 0.5]

Step 1: Questionnaire design and data collection

Based on Table 1, we designed a questionnaire on the constraints of developing an agricultural circular economy and collected four questionnaires completed by four experts as mentioned above.

Expert 1: Chengqi Wang started his work in July 1983 and is a member of the Agricultural Department Party and Director of the Bureau of Animal Husbandry in Henan. In May 2017, he conducted in-depth research into several companies that had implemented an agricultural circular economy in Henan. He has a deep understanding of the development of agricultural circular economy.

Expert 2: This deputy general manager works at Henan Dengzhou Huang Zhi Animal Husbandry Company. He has been responsible for planning the development of circular agriculture since 2007. With the growth of the company, he has accumulated rich experience in developing an agricultural circular economy model.

Expert 3: This deputy general manager works at Henan New Dammam Co., Ltd. Since 2009, he has been responsible for exploring the innovations of a sustainable breeding model and has a deep understanding of the establishment of a three-dimensional circular agriculture system.

Expert 4: This farmer, Li Wei, has managed her own farm since 2009. Currently, she operates several farms based on a circular agriculture model.

Step 2: Establish the initial matrix

Using the weighting values of Experts 1, 2, 3, and 4 in Table 4 and the pair-comparison values from Tables 5–8, an overall direct-relation of matrix A can be calculated, as shown in Table 9.

Step 3: Calculate the normalized matrix

The normalized direct-relation matrix (X) is determined by expressions (5) and (6). The matrix is shown in Table 10.

Step 4: Establish the comprehensive impact matrix

Determine the total direct-relationship matrix (M) by expression (7), which is shown in Table 11.

Step 5: Calculate the cause E_i and center P_i of each barrier.

Use formula (8) and (9) to obtain the degree of cause and the degree of center, as shown in Table 12; take the center and the reason as the abscissa and the ordinate, respectively, and construct a Cartesian coordinate system; further, draw the reason driving the factor restricting the agricultural circular economy development as shown in Figure 1. To further describe the relationship between the various restrictive factors in developing an agricultural circular economy, the initial value is taken as $\theta = 0.103$ based on the mean and standard deviation in the comprehensive impact matrix.

Step 6: Develop overall DEMATEL prominence-causal graphs and analyze the results

Overall DEMATEL prominence-causal relationship diagram is developed to aggregate the four experts, as shown in Figure 1.

Table 5. Direct-relation matrix for an agricultural circular economy by Expert 1.

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16
B1: Relevant policies and regulations are imperfect.	0	4	4	2	3	3	3	3	1	1	0	0	2	2	1	3
B2: The administrative mechanism is imperfect.	1	0	4	3	2	2	2	1	0	2	1	1	2	1	1	1
B3: Scientific preferential policies and financial subsidies are lacking.	1	1	0	1	3	3	2	3	2	1	2	1	3	2	3	0
B4: The government places less emphasis on financial policy.	2	1	4	0	3	3	2	1	1	4	1	2	2	1	2	0
B5: Existing infrastructure is weak.	0	0	0	1	0	4	1	2	3	2	1	2	1	0	3	4
B6: The promotion of "the Belt and Road" green technology is slow.	0	2	2	0	1	0	1	2	4	1	1	1	0	1	4	3
B7: Local officials have weak environmental awareness.	3	3	3	1	4	4	0	3	3	3	2	3	2	3	3	2
B8: Farmers have weak environmental awareness.	0	1	1	2	1	4	3	0	3	2	2	2	3	2	1	1
B9: Farmers have limited professional knowledge and skills.	0	0	2	1	2	3	1	4	0	2	4	4	1	4	4	3
B10: Farmers do not make good use of the green financial policy.	0	0	1	1	1	4	1	3	3	0	2	1	0	2	3	0
B11: Agricultural production costs remain high.	1	0	1	0	3	3	2	1	3	2	0	3	1	0	0	0
B12: Product design and production processes are behind.	0	0	2	2	3	3	3	4	0	0	4	0	2	2	2	0
B13: Enterprises display weak technology innovation.	0	0	2	0	1	1	3	3	2	0	3	4	0	2	3	0
B14: The organizational mechanism is backward.	1	2	2	3	2	2	1	2	2	0	3	3	1	0	1	1
B15: Small-scale agriculture has low industrialization.	0	1	1	2	1	2	2	3	1	2	4	3	1	1	0	2
B16: An imbalance between market supply and demand exists.	0	0	0	1	1	1	0	0	0	0	1	1	3	3	2	0

Note: 0 = no influence, 1 = low influence, 2 = medium influence, 3 = high influence, 4 = very high influence.

Table 6. Direct-relation matrix for an agricultural circular economy by Expert 2.

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16
B1: Relevant policies and regulations are imperfect.	0	3	2	3	4	2	4	2	0	0	1	0	1	2	1	4
B2: The administrative mechanism is imperfect.	2	0	4	2	2	3	2	2	1	2	2	2	3	1	2	1
B3: Scientific preferential policies and financial subsidies are lacking.	3	2	0	1	3	3	1	4	4	2	2	1	4	3	2	1
B4: The government places less emphasis on financial policy.	2	1	4	0	3	3	1	0	0	4	2	3	1	0	3	2
B5: Existing infrastructure is weak.	1	1	2	0	0	3	0	3	3	1	0	3	1	1	2	3
B6: The promotion of "the Belt and Road" green technology is slow.	0	3	2	1	0	0	2	3	3	0	2	1	1	2	3	4
B7: Local officials have weak environmental awareness.	4	4	3	2	3	4	0	4	2	4	3	4	3	4	3	3
B8: Farmers have weak environmental awareness.	0	1	0	1	0	3	1	0	4	1	2	1	2	3	0	0
B9: Farmers have limited professional knowledge and skills.	1	0	2	1	2	4	2	3	0	2	4	4	1	4	4	2
B10: Farmers do not make good use of the green financial policy.	1	1	0	2	1	3	1	4	3	0	2	1	0	2	3	1
B11: Agricultural production costs remain high.	1	1	1	0	3	3	3	1	3	3	0	3	1	0	0	1
B12: Product design and production processes are behind.	2	0	2	2	3	3	2	4	1	1	4	0	2	1	1	1
B13: Enterprises display weak technology innovation.	1	1	2	0	1	1	3	3	3	0	2	4	0	3	2	0
B14: The organizational mechanism is backward.	1	3	2	3	2	2	2	2	3	1	4	3	1	0	2	2
B15: Small-scale agriculture has low industrialization.	0	2	1	2	1	2	2	3	0	4	3	3	2	1	0	1
B16: An imbalance between market supply and demand exists.	1	1	0	1	1	1	1	0	1	0	2	1	3	4	2	0

Note: 0 = no influence, 1 = low influence, 2 = medium influence, 3 = high influence, 4 = very high influence.

Table 7. Direct-relation matrix for an agricultural circular economy by Expert 3.

Barriers	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**
B1: Relevant policies and regulations are imperfect.	0	4	3	2	3	3	3	3	1	1	0	0	2	2	1	3
B2: The administrative mechanism is imperfect.	1	0	2	3	2	2	2	1	0	2	1	1	2	1	1	1
B3: Scientific preferential policies and financial subsidies are lacking.	1	1	0	1	4	4	2	4	2	1	2	1	4	2	4	1
B4: The government places less emphasis on financial policy.	3	2	4	0	4	4	2	1	1	4	1	3	2	1	2	1
B5: Existing infrastructure is weak.	1	1	0	1	0	4	1	2	4	2	2	3	1	0	2	4
B6: The promotion of "the Belt and Road" green technology is slow.	1	1	2	0	1	0	1	2	3	1	1	1	0	1	4	2
B7: Local officials have weak environmental awareness.	3	4	3	1	4	4	0	4	4	4	2	4	2	4	4	2
B8: Farmers have weak environmental awareness.	1	2	1	2	1	4	2	0	2	1	2	2	2	2	1	1
B9: Farmers have limited professional knowledge and skills.	0	1	2	1	2	2	1	4	0	2	3	4	1	3	3	2
B10: Farmers do not make good use of the green financial policy.	1	0	1	1	1	4	1	2	2	0	2	2	0	2	2	0
B11: Agricultural production costs remain high.	1	1	1	0	2	2	2	1	2	2	0	1	1	0	0	0
B12: Product design and production processes are behind.	2	0	1	3	3	4	3	3	0	0	3	0	2	2	2	0
B13: Enterprises display weak technology innovation.	1	1	2	0	1	1	3	4	2	0	4	3	0	2	3	0
B14: The organizational mechanism is backward.	0	2	3	3	4	2	1	2	2	1	3	4	1	0	1	1
B15: Small-scale agriculture has low industrialization.	1	0	1	2	2	2	2	3	1	2	2	3	1	1	0	2
B16: An imbalance between market supply and demand exists.	0	1	0	1	1	1	1	0	1	0	1	1	3	2	2	0

Note: 0 = no influence, 1 = low influence, 2 = medium influence, 3 = high influence, 4 = very high influence.

Table 8. Direct-relation matrix for an agricultural circular economy by Expert 4.

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16
B1: Relevant policies and regulations are imperfect.	0	3	4	2	3	3	2	3	0	1	0	0	1	1	2	2
B2: The administrative mechanism is imperfect.	1	0	2	2	3	2	2	2	1	2	0	1	1	1	2	1
B3: Scientific preferential policies and financial subsidies are lacking.	1	1	0	1	4	3	1	4	2	1	2	1	4	2	3	1
B4: The government places less emphasis on financial policy.	2	2	4	0	3	2	2	2	0	4	1	2	2	0	2	0
B5: Existing infrastructure is weak.	0	0	1	0	0	4	1	2	3	1	3	2	1	0	2	3
B6: The promotion of "the Belt and Road" green technology is slow.	0	0	1	1	1	0	1	2	4	1	3	3	2	1	3	4
B7: Local officials have weak environmental awareness.	4	3	3	2	4	4	0	2	2	3	2	3	2	2	4	3
B8: Farmers have weak environmental awareness.	0	1	1	0	0	2	1	0	4	4	2	1	1	2	1	1
B9: Farmers have limited professional knowledge and skills.	0	0	2	1	1	3	1	3	0	2	4	2	1	2	3	2
B10: Farmers do not make good use of the green financial policy.	0	0	1	1	1	0	2	3	3	0	2	0	0	1	2	0
B11: Agricultural production costs remain high.	2	0	1	0	1	2	3	2	3	2	0	2	2	0	3	1
B12: Product design and production processes are behind.	2	0	1	2	2	2	2	2	0	0	4	0	2	1	2	2
B13: Enterprises display weak technology innovation.	1	0	2	0	2	2	3	2	2	0	3	4	0	1	2	1
B14: The organizational mechanism is backward.	0	1	2	2	1	2	1	2	1	0	2	3	2	0	2	1
B15: Small-scale agriculture has low industrialization.	1	0	1	2	2	3	2	3	1	2	3	2	2	1	0	1
B16: An imbalance between market supply and demand exists.	0	0	0	1	0	1	1	0	0	0	1	1	3	2	3	0

Note: 0 = no influence, 1 = low influence, 2 = medium influence, 3 = high influence, 4 = very high influence.

Table 9. Overall crisp direct-relationships.

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16
B1	0.000	0.872	0.770	0.304	0.710	0.590	0.571	0.590	0.038	0.040	0.010	0.000	0.229	0.337	0.062	0.698
B2	0.101	0.000	0.806	0.430	0.362	0.410	0.280	0.110	0.012	0.350	0.108	0.110	0.349	0.049	0.122	0.050
B3	0.161	0.110	0.000	0.037	0.722	0.710	0.211	0.782	0.470	0.110	0.350	0.050	0.691	0.403	0.650	0.022
B4	0.329	0.119	0.950	0.000	0.710	0.698	0.220	0.052	0.038	0.950	0.110	0.470	0.241	0.038	0.410	0.080
B5	0.018	0.020	0.072	0.029	0.000	0.890	0.030	0.410	0.710	0.278	0.124	0.470	0.043	0.010	0.518	0.878
B6	0.008	0.336	0.338	0.009	0.040	0.000	0.100	0.410	0.830	0.040	0.134	0.074	0.024	0.109	0.878	0.662
B7	0.599	0.764	0.650	0.088	0.890	0.950	0.000	0.758	0.638	0.770	0.410	0.770	0.361	0.751	0.722	0.422
B8	0.008	0.110	0.040	0.207	0.038	0.866	0.337	0.000	0.662	0.254	0.350	0.278	0.415	0.403	0.040	0.040
B9	0.010	0.010	0.350	0.037	0.338	0.650	0.100	0.878	0.000	0.350	0.890	0.926	0.043	0.859	0.878	0.518
B10	0.018	0.010	0.040	0.082	0.050	0.852	0.049	0.818	0.590	0.000	0.350	0.108	0.000	0.337	0.578	0.010
B11	0.053	0.020	0.050	0.000	0.566	0.578	0.349	0.062	0.590	0.410	0.000	0.518	0.055	0.000	0.026	0.012
B12	0.137	0.000	0.278	0.304	0.638	0.698	0.451	0.866	0.010	0.010	0.890	0.000	0.301	0.277	0.290	0.024
B13	0.020	0.020	0.350	0.000	0.062	0.062	0.520	0.698	0.410	0.000	0.650	0.890	0.000	0.397	0.578	0.002
B14	0.031	0.398	0.410	0.475	0.458	0.350	0.100	0.350	0.398	0.020	0.698	0.710	0.055	0.000	0.122	0.110
B15	0.010	0.098	0.050	0.259	0.122	0.362	0.280	0.650	0.040	0.470	0.758	0.638	0.115	0.049	0.000	0.278
B16	0.010	0.020	0.000	0.037	0.048	0.050	0.019	0.000	0.020	0.000	0.110	0.050	0.559	0.631	0.362	0.000

Table 9 could be got by using the weighting values of Experts 1, 2, 3, and 4 in Table 4 and the pair-comparison values from Tables 5–8.

Table 10. Normalized direct-relation matrix.

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16
B1	0.000	0.091	0.081	0.032	0.074	0.062	0.060	0.062	0.004	0.004	0.001	0.000	0.024	0.035	0.006	0.073
B2	0.011	0.000	0.084	0.045	0.038	0.043	0.029	0.012	0.001	0.037	0.011	0.012	0.037	0.005	0.013	0.005
B3	0.017	0.011	0.000	0.004	0.076	0.074	0.022	0.082	0.049	0.012	0.037	0.005	0.072	0.042	0.068	0.002
B4	0.034	0.012	0.100	0.000	0.074	0.073	0.023	0.005	0.004	0.100	0.012	0.049	0.025	0.004	0.043	0.008
B5	0.002	0.002	0.008	0.003	0.000	0.093	0.003	0.043	0.074	0.029	0.013	0.049	0.005	0.001	0.054	0.092
B6	0.001	0.035	0.035	0.001	0.004	0.000	0.010	0.043	0.087	0.004	0.014	0.008	0.003	0.011	0.092	0.069
B7	0.063	0.080	0.068	0.009	0.093	0.100	0.000	0.079	0.067	0.081	0.043	0.081	0.038	0.079	0.076	0.044
B8	0.001	0.011	0.004	0.022	0.004	0.091	0.035	0.000	0.069	0.027	0.037	0.029	0.043	0.042	0.004	0.004
B9	0.001	0.001	0.037	0.004	0.035	0.068	0.010	0.092	0.000	0.037	0.093	0.097	0.005	0.090	0.092	0.054
B10	0.002	0.001	0.004	0.009	0.005	0.089	0.005	0.086	0.062	0.000	0.037	0.011	0.000	0.035	0.061	0.001
B11	0.006	0.002	0.005	0.000	0.059	0.061	0.037	0.006	0.062	0.043	0.000	0.054	0.006	0.000	0.003	0.001
B12	0.014	0.000	0.029	0.032	0.067	0.073	0.047	0.091	0.001	0.001	0.093	0.000	0.032	0.029	0.030	0.003
B13	0.002	0.002	0.037	0.000	0.006	0.006	0.054	0.073	0.043	0.000	0.068	0.093	0.000	0.042	0.061	0.000
B14	0.003	0.042	0.043	0.050	0.048	0.037	0.010	0.037	0.042	0.002	0.073	0.074	0.006	0.000	0.013	0.012
B15	0.001	0.010	0.005	0.027	0.013	0.038	0.029	0.068	0.004	0.049	0.079	0.067	0.012	0.005	0.000	0.029
B16	0.001	0.002	0.000	0.004	0.005	0.005	0.002	0.000	0.002	0.000	0.012	0.005	0.059	0.066	0.038	0.000

Table 10 from normalizing direct-relation matrix (X) is determined by expressions (5) and (6).

Table 11. Total-relation matrix.

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16
B1	0.012	0.111	0.116	0.049	0.113	0.127	0.083	0.114	0.054	0.035	0.044	0.044	0.056	0.071	0.059	0.104
B2	0.019	0.013	0.106	0.053	0.066	0.089	0.046	0.053	0.036	0.057	0.041	0.041	0.055	0.028	0.051	0.026
B3	0.024	0.03	0.029	0.019	0.106	0.135	0.048	0.136	0.099	0.039	0.086	0.058	0.092	0.074	0.115	0.036
B4	0.043	0.031	0.125	0.014	0.110	0.138	0.047	0.068	0.054	0.122	0.056	0.087	0.049	0.036	0.096	0.041
B5	0.006	0.014	0.027	0.014	0.023	0.135	0.021	0.085	0.106	0.048	0.053	0.082	0.024	0.032	0.094	0.115
B6	0.006	0.045	0.054	0.013	0.029	0.043	0.028	0.082	0.111	0.026	0.052	0.043	0.022	0.040	0.123	0.088
B7	0.075	0.110	0.120	0.039	0.153	0.206	0.044	0.174	0.143	0.122	0.123	0.152	0.078	0.132	0.154	0.096
B8	0.008	0.027	0.031	0.033	0.034	0.136	0.054	0.046	0.106	0.048	0.076	0.068	0.058	0.070	0.047	0.029
B9	0.010	0.021	0.066	0.025	0.079	0.142	0.042	0.153	0.056	0.067	0.152	0.148	0.033	0.124	0.140	0.084
B10	0.006	0.014	0.024	0.020	0.028	0.131	0.023	0.122	0.096	0.021	0.073	0.046	0.015	0.059	0.093	0.024
B11	0.012	0.014	0.024	0.009	0.082	0.104	0.050	0.048	0.093	0.060	0.033	0.083	0.019	0.024	0.040	0.026
B12	0.024	0.019	0.057	0.045	0.102	0.135	0.072	0.137	0.053	0.031	0.132	0.046	0.053	0.058	0.074	0.033
B13	0.012	0.019	0.062	0.016	0.046	0.069	0.079	0.125	0.083	0.028	0.117	0.136	0.023	0.073	0.098	0.023
B14	0.012	0.054	0.071	0.062	0.084	0.094	0.034	0.082	0.079	0.029	0.111	0.111	0.028	0.026	0.053	0.036
B15	0.009	0.022	0.027	0.038	0.042	0.088	0.049	0.106	0.041	0.071	0.112	0.097	0.030	0.030	0.034	0.047
B16	0.004	0.009	0.012	0.011	0.018	0.023	0.012	0.020	0.017	0.008	0.032	0.027	0.064	0.075	0.052	0.008

Table 11 from Table 10 by expression (7).

Table 12. Degree of prominence and net cause/effect values for an agricultural circular economy.

Barriers	R Sum	D Sum	R+D	R-C
B1	1.194	0.281	1.475	0.913
B2	0.781	0.550	1.331	0.231
B3	1.127	0.950	2.077	0.178
B4	1.118	0.462	1.580	0.656
B5	0.878	1.114	1.992	-0.236
B6	0.805	1.798	2.603	-0.992
B7	1.922	0.734	2.656	1.188
B8	0.869	1.549	2.418	-0.680
B9	1.341	1.226	2.567	0.114
B10	0.793	0.812	1.606	-0.019
B11	0.719	1.292	2.011	-0.573
B12	1.071	1.270	2.341	-0.199
B13	1.011	0.699	1.710	0.312
B14	0.966	0.953	1.919	0.013
B15	0.843	1.324	2.167	-0.482
B16	0.392	0.816	1.209	-0.424

Table 12 from Table 11 by expression (8).

The following conclusions can be drawn from the degree of prominence, the net cause/effect values for an agricultural circular economy (Table 12), and the prominence-causal relationship diagram (Figure 1):

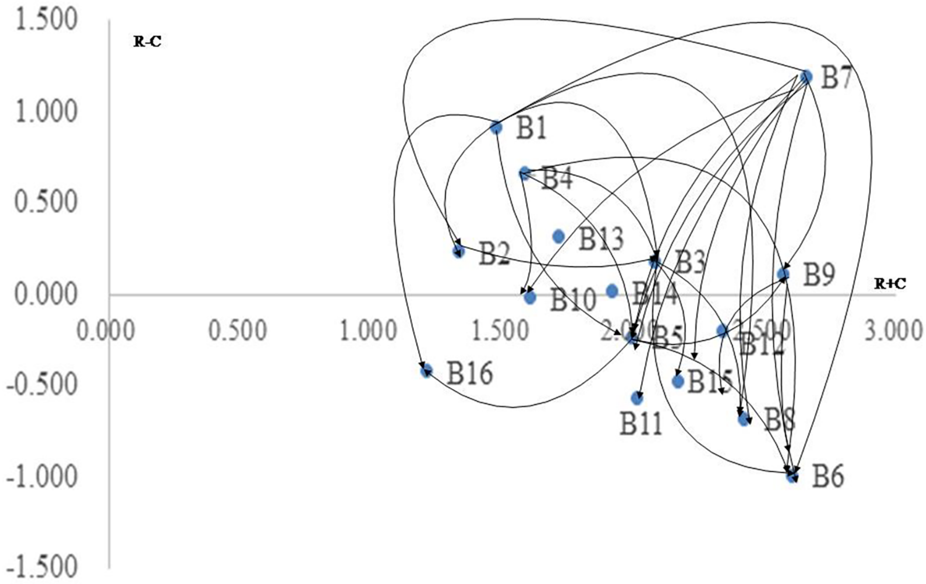

Figure 1. Overall DEMATEL prominence-causal relationship diagram by expressions (8) and (9).

(1) Cause group

According to Figure 1, the causal factors (by expressions (8) and $E_i > 0$) can be sorted as follows—B7 > B1 > B4 > B13 > B2 > B3 > B9 > B14. In these causal factors, B7 (Local officials have weak environmental awareness) is at the top of the cause group, which indicates that B7 is the primary causal factor. The reason could be got from Huang M & Yao D and Chen Q & Liu T [35,39], many local officials are weak in enforcing environmental protection and do not have an in-depth understanding of the concept of the agricultural circular economy; they do not realize the urgency of developing a circular economy for agriculture in the central region; they only focus on the growth of the regional economy and neglect protection of the ecological environment.

Barrier 1 (B1, Relevant policies and regulations are imperfect) is the second causal barrier in developing an agricultural circular economy in Henan. The main reason for this phenomenon is that the existing policies and regulations supporting the agricultural circular economy lack specific and enforceable guidelines, eventually leading to relevant laws and regulations can not be implemented [31,32]. The third barrier is B4 (The government places less emphasis on financial policy). At present, financial policies do not receive sufficient attention from the government, resulting in a single type of green financial product [34]. Meanwhile, there is no corresponding financial subsidy for the financial sector that supports the development of a circular economy [32]. Hence, the financing channels for the agricultural circular economy are limited, and thus its development is being hindered by a lack of funds.

(2) Effect group

Effect factors (by expressions (8) and $E_i > 0$) can be sorted as follows: B10 > B12 > B5 > B16 > B15 > B11 > B8 > B6. The eight factors are influenced by causal factors, which restricts the development of agricultural circular economy in Henan. Among these factors, B10 (farmers do not make good use of the green financial policy) is the most important effect factor. Two causal factors are resulting in B10. One is B4 (The government places less emphasis on financial policy) and the other is B7 (Local officials have weak environmental awareness). Neglecting the development of the agricultural circular economy, local officials have injected funds into other industries in pursuit of more efficient economic growth. In addition, they fail to attach importance to green financial policies, because the local government officials lack awareness of environmental protection. They neglect the development of ecological agriculture and focus on the pursuit of GDP in their regions [33]. As a result, the types of green financial products available are relatively simple: Green funds, green securities, and other products have not been developed. Therefore, the development of an agricultural recycling economy lacks sufficient financial support [35,36].

(3) Correlation between the barriers

The center of factors (by expressions (9)) can be sorted as follows: B7 > B6 > B9 > B8 > B12 > B15 > B3 > B11 > B5 > B14 > B13 > B10 > B4 > B1 > B2 > B16. Barrier 7 demonstrates the highest correlation with the other factors, and barrier 6 is the second most important factor. As seen in Figure 1, B7 (Local officials have weak environmental awareness) results in B2 (The administrative mechanism is imperfect), and B2 contributes to B3 (Scientific preferential policies and financial subsidies are lacking). Two effect factors are influenced by B3, that is, B5 (Existing infrastructure is weak) and B6 (The promotion of the "the Belt and Road" green technology is slow). In summary, with weak awareness of environmental protection, local officials think little about the circular economy in agriculture, and administrative authorities have unclear powers and roles [18,37]. Further, the development of a circular economy in agriculture lacks scientific preferential policies and financial subsidies. Without sufficient funds, the infrastructure needed for agricultural recycling economy is underdeveloped [33,36]. These factors also affect the flexible promotion of the "One Belt, One Road" green technology.

In addition, B7 (Farmers have weak environmental awareness) also leads to B6 and B9 (Farmers have limited professional knowledge and skills). Then, these factors lead to a backward organizational mechanism (B14) [18]. Because organizational mechanisms are not innovative, it leads to high agricultural production costs (B11). Having high costs and no profit, the promotion of "the Belt and Road" green technology is slow (B6) [37]. Due to the lack of funding and technical support, the scale of development for the agricultural circular economy is limited (B15). To be more specific, farmers and enterprises do not receive sufficient support from the government, which dampens their enthusiasm. Furthermore, with the lack of innovation in the overall organizational structure of enterprises and farmers, the cost of agricultural production remains high [33]. The promotion of "he Belt and Road" green technology is limited, as well. Consequently, it is difficult to develop a circular economy with the lack of sufficient technical and financial support.

5.2. Sensitivity Analysis

Sensitivity analysis, which is usually performed for the evaluator with the highest weight, tests the robustness of the obtained results. In this paper, according to Xia X et al. and Wang W et al. [46,49], we change the weight of expert 1 for the sensitivity analysis. The cause and effect diagraph of each weight is shown in Figures 2–4.

Overall, the influencing factors have not changed substantially. The most important causal factor, effect factor, and the center of factors are still B7, B10, and B7, respectively. If the weight of expert 1 changes from [0.7, 1] to [0.3, 0.5], the effect of factor B10 is slightly different. Its trend as an effect factor is more obvious. This slight deviation occurs in the effect factors, but the final sensitivity analysis results are consistent with the overall prominence-causal relationship diagraph, as shown in Figure 1.

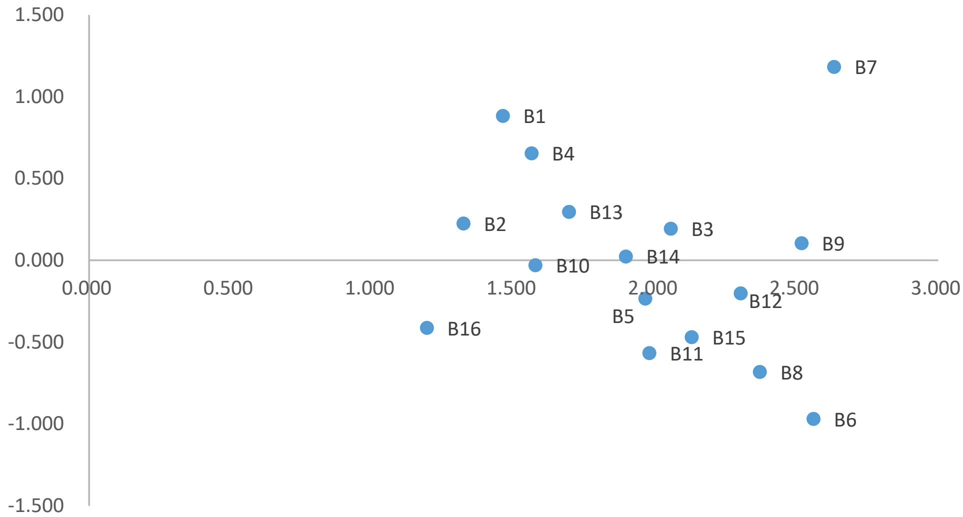

Figure 2. Overall DEMATEL prominence-causal relationship diagram ([0.5, 0.9]).

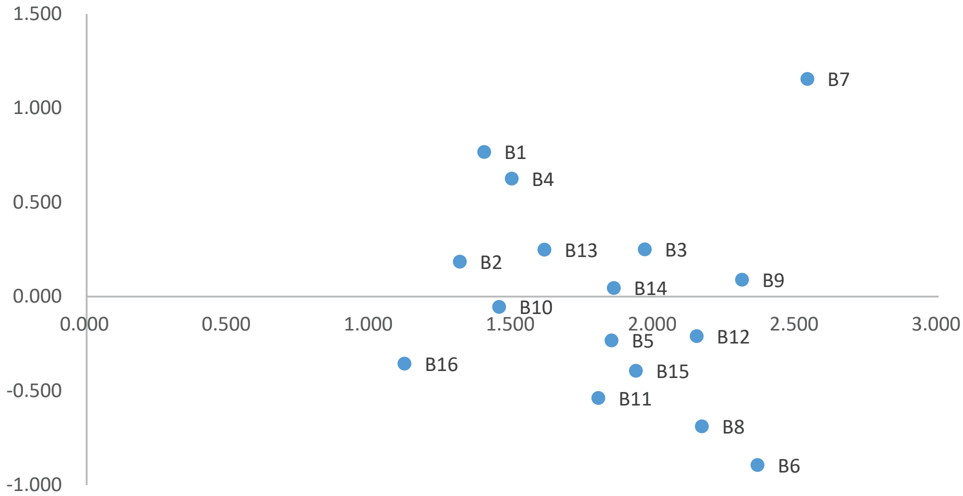

Figure 3. Overall DEMATEL prominence-causal relationship diagram ([0.4, 0.7]).

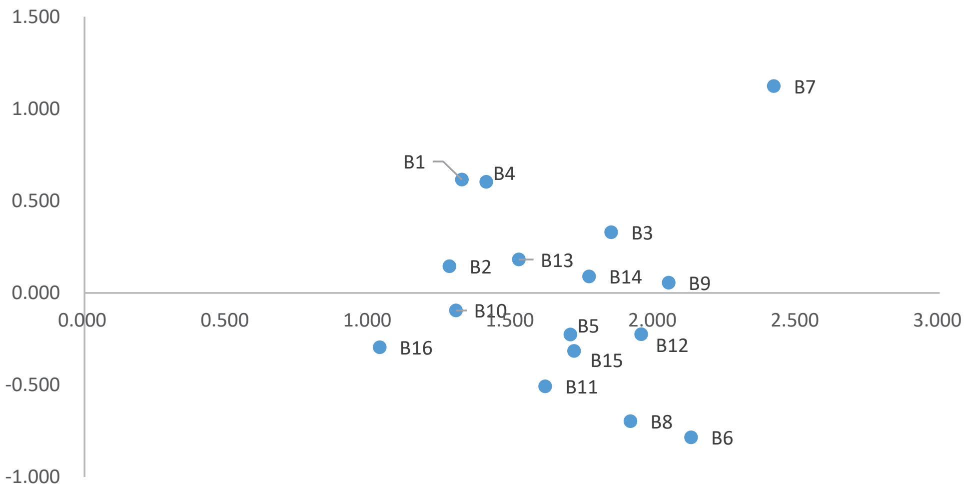

Figure 4. Overall DEMATEL prominence-causal relationship diagram ([0.2, 0.4]).

6. Conclusions and Suggestions

Developing a sustainable circular economy in agriculture is essential in contemporary sustainable environments. Based on studies addressing the development of an agricultural circular economy in China and abroad, we designed a questionnaire about the restricted factors. Four experts were invited to complete the questionnaire. Then, we used the gray number-DEMATEL method to analyze these barriers and identified the causal factors, effect factors and center of factors. Ultimately, several conclusions and suggestions are given, as follows.

- B7 (Local officials have weak environmental awareness) is the primary causal factor. Many local officials neglect the development of ecological agriculture while focusing on short-term economic indicators. They are not active in implementing eco-cycling agriculture projects [19], and they do not pay much attention to scientific preferential policies and financial subsidies. As a result, many areas lack a good policy environment and good infrastructure for implementing circular agriculture [51]. Therefore, the local governments need to raise their environmental awareness and pay more attention to the development of the agricultural circular economy. In the meantime, the financial subsidy mechanism and green finance policy should be improved to stimulate the enthusiasm of farmers and enterprises for developing circular agriculture.
- B10 (Farmers do not make good use of the green financial policy) is the most important effect factor. Two causal factors are resulting in B10. Local officials have weak environmental awareness, and the government does not attach much importance to financial policies, including green finance policy. With local officials' weak awareness of environmental protection, few funds are investing in the circular agriculture industry. Furthermore, farmers have difficulty understanding the existing green finance policy [36,38]. The development of an agricultural circular economy lacks adequate financial support. Therefore, the government needs to perfect the mechanism for developing green finance policy and to provide financial subsidies to financial institutions that support the development of recycling agriculture [36]. In a word, it is important to broaden the financing channels for farmers and enterprises.
- B7 (Local officials have weak environmental awareness) demonstrates the highest correlation with other factors, and B6 (The promotion of "the Belt and Road" green technology is slow) is the second highest. The innovation and diffusion of green technology are conducive to more agricultural operators adopting circular agriculture technologies [23]. Currently, the mechanism for promoting green technology is not sufficiently flexible. Generally, the government, farmers, and enterprises fail to pay sufficient attention to green technology. In fact, there are other reasons for the promotion of green technology. First, cutting-edge green technologies are in the hands of experts and scholars and cannot be effectively promoted and applied. Second, there is a large gap between economically developed and underdeveloped regions. With the low degree of agricultural informatization, inter-regional sharing of green technology is difficult to achieve [19]. Thus, the government should strongly support R&D and the promotion of new technologies, especially in the fields of green energy, ecological restoration, energy conservation, emission reduction, green infrastructure, environmental management, and so forth [10,52]. It is important to seize the opportunity to develop circular agriculture along "the Belt and Road" path. Making use of the green technology fund provided by "the Belt and Road" financial organizations such as the Asian Investment Bank, companies can establish a platform for sharing green technology. Then, the application and promotion of green technologies can be achieved. In a word, both farmers and companies should pay attention to policy developments such as green technology and green finance. With policy support, they can obtain the necessary technologies and funds for the development of circular agriculture.

This study will help China improve the agricultural circular economy, however, there are still some limitations. Firstly, only relevant experts from Henan Province are selected when filling in the questionnaire. Secondly, Gray-DEMATEL is better than DEMATEL in avoiding objective aspects, however, comparative analysis between the Gray-DEMATEL and DEMATEL is lacked. Thus, in future research, we could analyze barriers for developing a sustainable circular economy through selecting several major agricultural provinces in China in order to put forward corresponding policy recommendations, and ultimately promote the development of Chinese agricultural circular economy.

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