



Empirical Analysis on the Development of Ecological Agriculture under the Initiative of "Sustainable Development"

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Authors' contributions

This work was carried out in collaboration among all authors. Author HY Selection of topics, writing of papers, application of methods and analysis of data results of the manuscript. Author YY fund support, methodological guidance and writing revision of the manuscript. Author ZM Data collection of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

As a large agricultural country, China is promoting the development of agriculture in the direction of modernization and ecology. There are still some problems in the process of vigorous and coordinated development of regional resources. In order to narrow the temporal and spatial differences in the development of ecological agriculture and solve relevant development problems, this study puts forward targeted measures and policies from 18 cities in Henan Province, an important grain producing area in China. The comprehensive evaluation index system including economy, society, environmental and ecology calculated by U-EBM model is constructed for the first time, and the grey weighted clustering model based on improved entropy weight method is used to analyze and evaluate the overall development of ecological agriculture in each city for the first time. This method provides a new evaluation angle, and uses the idea of "less data and grey information" in grey theory to test the development trend and influence mechanism of regional ecological agriculture. It is found that fixed asset investment accounts for a large proportion in water-saving irrigation rate, total power of agricultural machinery and ecological agriculture efficiency, which is the key factor affecting the sustainable development of ecological agriculture. The results of data-driven clustering show that there are significant differences in the development of eco agriculture in various

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regions of Henan Province, which can be roughly divided into three gray levels. The model conforms to the actual situation of unbalanced development of ecological agriculture in various regions of Henan Province, verifies the reliability of the model, and provides accurate evaluation direction and relevant policies and strategic deployment for the research of agricultural ecological development in the future.

Keywords: Ecological agriculture; improved entropy weight method; possibility function; undesirable-EBM; grey weighted clustering.

1. INTRODUCTION

With the sound of the horn of sustainable development, great changes have taken place in social development in recent years. As a large agricultural country, China is constantly updating and optimizing the industry in the face of the strategic deployment of national and social sustainable development. In such an environment, China learns from foreign modern agricultural development ideas to reduce resource waste and environmental pollution caused by agricultural production. Combine the essence of traditional agriculture with modern agriculture, and vigorously develop the ecological development of economic, social and ecological coordination. As a major agricultural province, the rural reform in Henan province has been steadily advancing, and facing many impact problems brought by traditional agriculture while benefiting the public in recent years, agricultural reform is urgent, and the construction of ecological agriculture is a major measure to realize agricultural reform. Ecological agriculture is the unity of the three benefits of economy, society and ecology, that is, the combination of traditional agricultural experience and modern scientific and technological achievements, through artificial design of ecological engineering, to coordinate the contradiction between development and environment, resource utilization and protection, and form a virtuous cycle of ecology and economy [1].

The concept of ecological agriculture in China has been formed for 40 years, and the theoretical research has gradually matured. At present, domestic scholars mainly use AHP, fuzzy mathematics, BP neural network, principal component analysis and grey system to evaluate the development of ecological agriculture. Zheng Jun et al. [2] constructed the index system of ecological agriculture competitiveness, and combined with the analytic hierarchy process (AHP) to comprehensively evaluate the competitiveness of ecological agriculture. The results showed that the main factor affecting the

competitiveness of ecological agriculture is the level of agricultural subject. Zhao Yaping et al. [3] based on the relevant data of ecological agriculture development in 14 cities (prefectures) of Hunan Province in 2018, this paper used the principal component analysis method to evaluate the development performance of ecological agriculture in Hunan Province. The results showed that the regional development of ecological agriculture in Hunan Province was not coordinated, and the regional differences were obvious. Lu Shengyi et al. [4] pointed out that the systematic and scientific evaluation of the ecological benefits of land consolidation had a positive impact on agricultural ecological protection and agricultural landscape construction. They combined AHP and BP model to make a systematic and scientific evaluation of the ecological benefits of land consolidation. The evaluation results were consistent with the actual situation, which showed that the method was feasible and effective. Lin Dongping and Zhang Haifeng [5] pointed out that the key index to measure the development of ecological agriculture was benefit. By using fuzzy mathematics multi-level analysis model, the benefit of ecological agriculture in 31 regions of China was calculated and analyzed, and it was found that the development of ecological agriculture benefit in different regions of China was not coordinated and the difference was large. Feng Yajuan et al. [6] discussed the main driving factors of spatiotemporal changes of agricultural ecological efficiency by using grey correlation model, and obtained that the main reason for the improvement of agricultural ecological efficiency is the progress of technology. Based on the data in 2017, Ren Yongtai et al. [7] established the eco-agricultural economic competitiveness system of Heilongjiang Province supported by eight subsystems, constructed the corresponding evaluation index system, combined the entropy weight method with grey correlation analysis, and obtained that the full-time equivalent of agricultural researchers was the core factor, and the agricultural science and education support competitiveness was the core competitiveness.

Li Lianjun [8] used factor analysis method to analyze and compare the development level of modern agriculture in 11 regions of Jiangxi Province. The results showed that: in 2012, the development level of modern agriculture in Jiangxi Province was relatively balanced, and according to the evaluation results, some policy suggestions were put forward for the local government, such as paying attention to ecological environment construction, increasing farmers' income, accelerating the transfer of rural surplus labor force, increasing agricultural capital investment and so on.

Under the background of sustainable development strategy, traditional agriculture, which has been pursuing economy but neglecting ecology, must be reformed, and ecological agriculture is a major measure of agricultural reform. As an important agricultural province in Central China, Henan Province should practice modern agricultural production and reform. In this paper, the entropy weight method and gray fixed-weight clustering model are combined to build an index system in line with the development of ecological agriculture in Henan Province, evaluate the development of ecological agriculture in various cities of Henan Province, analyze the causes of the problems, and then put forward targeted suggestions, so as to achieve a certain role in promoting the balanced development of ecological agriculture in Henan Province.

2. RESEARCH METHODS

2.1 Calculation Method of Agricultural Ecological Efficiency

In the calculation of agricultural ecological efficiency in the index system, this paper draws lessons from the EBM (epsilon based measure) model with variable return to scale proposed by Tone et al. [9], that is, it overcomes the shortcomings of single radial model and non radial model, and brings the characteristics of radial and non radial changes into the same framework, which makes the calculation results more accurate and can effectively make up for the shortcomings of traditional models. Based on this, this paper adopts the undesirable EBM model which can deal with unexpected output. This model can be expressed as assuming that the DMU set is $o = \{1, 2, \dots, N\}$, each DMU has I inputs, J expected outputs and L unexpected outputs. The analysis considers the following three vectors: the input, expected output and

unexpected output of the n th DMU: $x = (x_1, x_2, \dots, x_I) \in \mathbb{R}_+^I$, $y = (y_1, y_2, \dots, y_J) \in \mathbb{R}_+^J$, $b = (b_1, b_2, \dots, b_L) \in \mathbb{R}_+^L$.

$$\xi = \min \frac{\theta - \varepsilon_x \sum_{i=1}^m \frac{w_i^- s_i^-}{x_{ik}}}{\varphi + \varepsilon_y \sum_{j=1}^J \frac{w_j^+ s_j^+}{y_{jk}} + \varepsilon_b \sum_{l=1}^L \frac{w_l^- s_l^-}{b_{lk}}} \quad (1)$$

$$\text{s.t.} \begin{cases} x_{ik} = \sum_{n=1}^N \lambda_n x_{in} + s_i^-, i = 1, 2, \dots, I; \\ y_{jk}^g = \sum_{n=1}^N \lambda_n y_{jn} - s_j^+, j = 1, 2, \dots, J; \\ y_{lk}^b = \sum_{n=1}^N \lambda_n b_{ln} + s_l^-, l = 1, 2, \dots, L; \\ \lambda_n \geq 0, s_i^- \geq 0, s_j^+ \geq 0, s_l^- \geq 0, n = 1, \dots, N. \end{cases} \quad (2)$$

where, (x_n, y_n, b_n) represents the value of each decision-making unit, $(x\lambda, y\lambda, b\lambda)$ represents the leading edge, s_i^x, s_j^+, s_l^{b-} represents the relaxation value, that is, the distance between the input or output and the frontier, ξ indicates the resulting efficiency

2.2 Entropy Weight Method

The basic idea of entropy weight method is to determine the objective weight according to the variability of indicators. If an indicator has a larger information entropy weight, it means that the value of the indicator has a smaller degree of variation, and the output information is also lower, so it plays a smaller role in the comprehensive evaluation. At this time, the indicator corresponds to a smaller weight [10]. On the contrary, the weight is opposite.

2.2.1 Calculate the information entropy of evaluation index

According to the standardized matrix, let x_{ij} is the value of the j -th evaluation index of the i -th object, E_j is the information entropy of the j -th evaluation index and n is the number of evaluation objects, then the information of the j -th evaluation index is:

$$E_j = -\frac{1}{\ln(n)} \sum_{i=1}^n f_{ij} \ln(f_{ij}), f_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}}. \quad (3)$$

If $f_{ij} = 0$, then define $\lim_{f_{ij} \rightarrow 0} f_{ij} \ln(f_{ij}) = 0$, where $i = 1, 2, \dots, n; j = 1, 2, \dots, m$.

2.2.2 Calculate the entropy weight of evaluation index

If η_j is the entropy weight of the j -th evaluation index and m is the number of evaluation indexes,

then the entropy weight of the j -th evaluation index is:

$$\eta_j = \frac{1 - E_j}{m - \sum_{j=1}^m E_j}, i = 1, 2, \dots, n; j = 1, 2, \dots, m. \tag{4}$$

2.3 Gray Clustering Model

The concept of gray clustering was first proposed by Professor Deng Julong [11] in 1985, and was defined as: there are n clustering objects, m clustering indexes, s different gray classes, according to the gray correlation matrix or Possibility function of sample value x_{ij} ($i = 1, 2, \dots, n; j = 1, 2, \dots, m$), the i -th observation object is classified into the k -th ($k = 1, 2, \dots, s$) gray category. When divided by clustering objects, gray clustering consists of gray relational clustering and gray clustering based on possibility function. In this paper, gray clustering is carried out by using the possibility function. Gray clustering based on possibility function is mainly used to judge the categories of observed objects, thus achieving the effect of "teaching students in accordance with their aptitude". It consists of three parts: gray variable-weight clustering evaluation model, gray fixed-weight clustering evaluation model and gray clustering evaluation model based on mixed possibility function, the gray variable weight clustering is applicable to the situation where the meaning and dimension of the index are the same. This paper will empirically analyze the development status of ecological agriculture in Henan Province. Due to the different significance and dimensions of the indicators involved in this paper, and the great difference in values, the gray fixed weight cluster evaluation model is adopted [12].

The steps to build the gray weighted clustering evaluation model are as follows:

- (1) The values of n objects with respect to index j are divided into s Grey classes, which are called the j -th index subclasses. The possibility function of k subclass of j index is denoted as $f_j^k(\cdot)$.
- (2) If the probability function $f_j^k(\cdot)$ of the k subclass of the j index is the typical probability function shown in Fig. 1, then $x_j^k(1), x_j^k(2), x_j^k(3)$ and $x_j^k(4)$ is called the turning point of $f_j^k(\cdot)$.The typical probability

function is recorded as $f_j^k[x_j^k(1), x_j^k(2), x_j^k(3), x_j^k(4)]$, The possibility function shown in Fig. 1 is as follows:

$$f_j^k(x) = \begin{cases} 0, & x \notin [x_j^k(1), x_j^k(4)], \\ \frac{x - x_j^k(1)}{x_j^k(2) - x_j^k(1)}, & x \in [x_j^k(1), x_j^k(2)], \\ 1, & x \in [x_j^k(2), x_j^k(3)], \\ \frac{x_j^k(4) - x}{x_j^k(4) - x_j^k(3)}, & x \in [x_j^k(3), x_j^k(4)]. \end{cases} \tag{5}$$

- (3) If the probability function $f_j^k(\cdot)$ does not have the third and fourth turning points $x_j^k(3), x_j^k(4)$ (as shown in Fig. 2), it is called $f_j^k(\cdot)$ as the upper limit measure probability function, which is recorded as $f_j^k[x_j^k(1), x_j^k(2), -, -]$.For the upper limit measure possibility function shown in Fig. 2, there are:

$$f_j^k(x) = \begin{cases} 0, & x \leq x_j^k(1), \\ \frac{x - x_j^k(1)}{x_j^k(2) - x_j^k(1)}, & x \in (x_j^k(1), x_j^k(2)), \\ 1, & x \geq x_j^k(2). \end{cases} \tag{6}$$

- (4) If the second and third turning points $x_j^k(2)$ and $x_j^k(3)$ of the possibility function $f_j^k(\cdot)$ coincide (as shown in Fig. 3), $f_j^k(\cdot)$ is called the moderate measure possibility function, which is recorded as $f_j^k[x_j^k(1), x_j^k(2), -, x_j^k(4)]$.For the possibility function of the moderate limit measure shown in Fig. 3, there are:

$$f_j^k(x) = \begin{cases} 0, & x \notin [x_j^k(1), x_j^k(4)], \\ \frac{x - x_j^k(1)}{x_j^k(2) - x_j^k(1)}, & x \in (x_j^k(1), x_j^k(2)), \\ \frac{x_j^k(4) - x}{x_j^k(4) - x_j^k(2)}, & x \in [x_j^k(2), x_j^k(4)]. \end{cases} \tag{7}$$

- (5) If the possibility function $f_j^k(\cdot)$ does not have the first and second turning points $x_j^k(1), x_j^k(2)$ (as shown in Fig. 4), then $f_j^k(\cdot)$ is called the lower limit measure possibility function, which is recorded as $f_j^k[-, -, x_j^k(3), x_j^k(4)]$.For the lower limit measure possibility function shown in Fig. 4, there are:

$$f_j^k(x) = \begin{cases} 0, & x \notin [0, x_j^k(4)], \\ 1, & x \in [0, x_j^k(3)], \\ \frac{x_j^k(4)-x}{x_j^k(4)-x_j^k(3)}, & x \in (x_j^k(3), x_j^k(4)]. \end{cases} \quad (8)$$

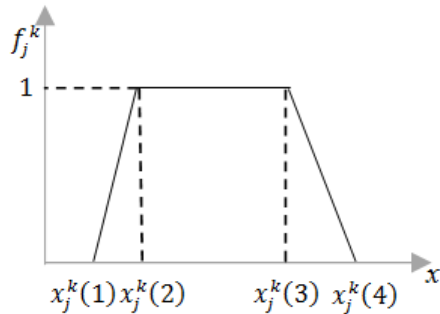


Fig. 1. typical possibility function

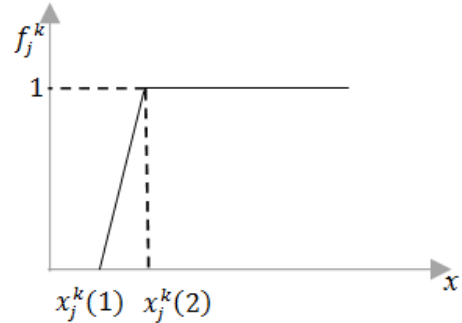


Fig. 2. upper limit measure possibility function

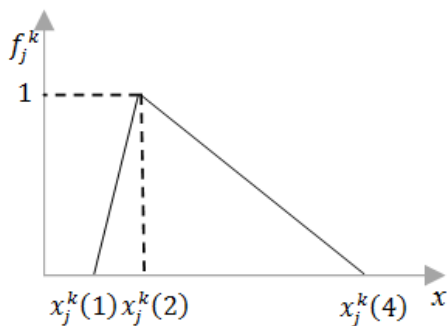


Fig. 3. moderate measure possibility function

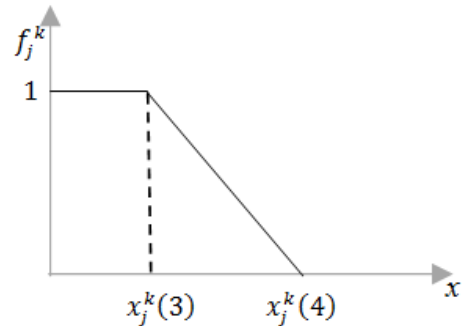


Fig. 4. lower limit measure possibility function

(6) If the weight η_j^k of the k subclass of the j indicator has nothing to do with k , that is, for any $k_1, k_2 \in \{1, 2, \dots, s\}$, there is always $\eta_j^{k_1} = \eta_j^{k_2}$, then the superscript k of η_j^k can be omitted and recorded as η_j , and it is said that $\delta_i^k = \sum_{j=1}^m f_j^k(x_{ij})\eta_j$ is the gray fixed-weight clustering coefficient of object i belonging to k gray class, where $j = 1, 2, \dots, m; k = 1, 2, \dots, s$.

Clustering objects are classified according to the value of gray fixed-weight clustering coefficient, which is called gray fixed-weight clustering. Gray fixed-weight clustering can be performed as follows:

(1) Give the probability function $f_j^k(\cdot)$ of the k subclass of the j indicator, where $j =$

$1, 2, \dots, m; k = 1, 2, \dots, s$.

(2) Determine the clustering weight η_j of each index according to the conclusion of qualitative analysis.

(3) According to the probability function $f_j^k(\cdot)$ and clustering weight η_j obtained from (1) and (2), we can calculate the gray fixed-weight clustering coefficient $\delta_i^k = \sum_{j=1}^m f_j^k(x_{ij})\eta_j$, where $i = 1, 2, \dots, n; j = 1, 2, \dots, m; k = 1, 2, \dots, s$.

(4) From $\delta_i^{k*} = \max_{1 \leq k \leq s} \{\delta_i^k\}$, it is judged that object i belongs to gray class k ; When multiple objects belong to k gray class, according to the size of the comprehensive clustering coefficient, the advantages and

disadvantages and ranking of each object belonging to the gray class k can be further determined.

2.4 Empirical Analysis

2.4.1 Indicator selection and data source

Based on the needs and realities of sustainable development of ecological agriculture in Henan Province, and drawing on the existing research results [13-16], following the principles of adjusting measures to local conditions, integrating key and comprehensive, combining scientific and practical with advanced nature, and combining traditional methods with modern methods,, 10 indicators were selected from economic, social, environmental and ecological benefits respectively. The evaluation index system for the development level of ecological agriculture in Henan Province is established (see Table 1). As for the innovation index in the ecological benefit, the agricultural ecological efficiency is calculated by the u-ebm model. The index selection of its input-output system follows the principle of industrial ecology, that is, on the premise of minimizing the consumption of social resources and the destruction of ecological environment, in order to obtain higher economic output, and draw lessons from the existing research resultsto obtain relevant indicators [17-20]. In this paper, energy consumption, the number of agricultural employees and agricultural fixed investment are selected as energy, labor and capital inputs respectively. The gross agricultural product is an ideal output, while the agricultural environmental pollution index constructed by entropy weight method is

regarded as a non ideal output. The input-output system is shown in Table 2.

The relevant data of the agricultural sector comes from the statistical yearbook of Henan Province. The data of each sub sector are summarized to obtain the corresponding index data. In addition, CO₂ emission data can be obtained from CEADS database, while the relevant data of agricultural SO₂, agricultural wastewater, agricultural smoke and dust emission and agricultural general solid waste generation are from Henan environmental statistical yearbook and relevant statistical yearbooks of various cities.

2.4.2 Build gray fixed-weight clustering model based on entropy weight method

The steps of constructing grey fixed-clustering model based on entropy weight method are as follows: firstly, the weight of each index is obtained by entropy weight method; Secondly, the weight data is combined with the grey clustering decision model to obtain the comprehensive clustering coefficient; Finally, the data is used to cluster and analyze the development status of ecological agriculture in prefecture-level cities.

2.4.2.1 Determine index weight

The entropy weight method is used to determine the weight, so that the weight of each index is more close to the actual requirements through rigorous logical solution of mathematical methods.

Table 1. Evaluation index system of ecological agriculture development level in Henan province

Level 1 indicator	Level 2 indicator	Level 3 indicator	Indicator significance
Development level of ecological agriculture	Economic benefits	Per capita disposable income of farmers X_1	+
		Proportion of investment in fixed assets of agriculture, forestry, animal husbandry and fishery X_2	+
	Social benefits	Water resources per capita X_3	+
		Ratio of effective irrigation area to cultivated land area X_4	+
		Total power of agricultural machinery X_5	+
	Environmental benefits	Pesticide application rate X_6	-
		Fertilizer application discount X_7	-
		Agriplastic film usage X_8	-
	Ecological benefits	Percentage of forest cover X_9	+
		Agricultural ecological efficiency X_{10}	+

Table 2. Construction of input-output system

Target layer	Criterion layer	Index layer	Indicator description
Investment	Energy input	Industrial energy consumption	10000 tons of standard coal
	Labor input	Average number of industrial employees	ten thousand people
	Capital investment	Industrial fixed assets investment	million yuan
Output	Ideal output	Gross industrial product	million yuan
	Nonideal output	Industrial environmental pollution index	Relative comprehensive index calculated from CO ₂ , SO ₂ , smoke and dust, wastewater and general solid waste

By using Matlab 2016b software and using formulas (3) and (4), the evaluation weight sets of the index is obtained:

$$\eta = (\eta_1, \eta_2, \eta_3, \eta_4, \eta_5, \eta_6, \eta_7, \eta_8, \eta_9, \eta_{10}) = (0.1014, 0.1769, 0.0845, 0.1340, 0.1285, 0.0769, 0.0531, 0.0367, 0.0576, 0.1504).$$

2.4.2.2 Application of gray weighted clustering evaluation

(1) Determine the possibility function of each index

Since the idea of establishing the possibility function of each index is consistent, this article mainly expounds the evaluation index of per capita disposable income of rural residents. In this paper, we use the average value of relevant parameter values of index information x and standard deviation δ to obtain the three turning points of Possibility function $\bar{x} - \delta, \bar{x}, \bar{x} + \delta$. The average value \bar{x} of per capita disposable income of rural residents is 14701, the standard deviation δ is 2722.89, and the corresponding three turning points are 11978, 14701 and 17424 respectively. The gray scale of the index is divided into three levels: "excellent", "good" and "general". According to the turning point data, the probability function of the per capita disposable income index of rural residents under the corresponding level is respectively:

$$f_1^1[14701, 17424, -, -], f_1^2[11978, 14701, -, 17424], f_1^3[-, -, 11978, 14701].$$

For the upper limit measure function $f_1^1(x_1)$, the possibility function is:

$$f_1^1(x_1) = \begin{cases} 0, & x \leq 14701, \\ \frac{x - 14701}{17424 - 14701}, & x \in (14701, 17424), \\ 1, & x \geq 17424. \end{cases}$$

For the moderate measure function $f_1^2(x_2)$, the possibility function is:

$$f_1^2(x_2) = \begin{cases} 0, & x \notin (11978, 17424), \\ \frac{x - 11978}{14701 - 11978}, & x \in [11978, 14701), \\ 1, & x = 14701, \\ \frac{17424 - x}{17424 - 14701}, & x \in (14701, 17424]. \end{cases}$$

For the lower limit measure function $f_1^3(x_2)$, the probability function is:

$$f_1^3(x_3) = \begin{cases} 1, & x \leq 11978, \\ \frac{x - 14701}{17424 - 14701}, & x \in (14701, 17424), \\ 0, & x \geq 14701. \end{cases}$$

(2) Determine the weight of each indicator

In the previous gray weighted clustering analysis, the determination of weight usually uses empirical thought and subjective weighting method. Although this weighting method has its scientific features, however, sometimes the facts are distorted, resulting in untrue evaluation results. Therefore, this paper uses entropy weight method to determine the weight, and scientifically determines the weight of each index through strict logic of mathematical methods, so the obtained weight is closer to the actual requirements. The evaluation weight set of the indicator is:

$$\eta = (\eta_1, \eta_2, \eta_3, \eta_4, \eta_5, \eta_6, \eta_7, \eta_8, \eta_9, \eta_{10}) = (0.1014, 0.1769, 0.0845, 0.1340, 0.1285, 0.0769, 0.0531, 0.0367, 0.0576, 0.1504).$$

(3) Comprehensive gray weighted clustering coefficient for calculating the development level of ecological agriculture

According to the calculated probability function $f_j^k(\cdot)$ and weight η_j of each clustering index, the weighted clustering coefficient of each clustering object is calculated. For Zhengzhou city, the weighted clustering coefficient under its optimal measurement is:

$$\delta_1^1 = \sum_{j=1}^9 f_j^1(x_{1j})\eta_j = f_1^1(x_{11})\eta_1 + f_2^1(x_{12})\eta_2 + f_3^1(x_{13})\eta_3 + f_4^1(x_{14})\eta_4 + f_5^1(x_{15})\eta_5 + f_6^1(x_{16})\eta_6 + f_7^1(x_{17})\eta_7 + f_8^1(x_{18})\eta_8 + f_9^1(x_{19})\eta_9 + f_{10}^1(x_{110})\eta_{10} = 0.3798.$$

The weighted clustering coefficient of its benign measure is:

$$\delta_1^2 = \sum_{j=1}^9 f_j^2(x_{1j})\eta_j = f_1^2(x_{11})\eta_1 + f_2^2(x_{12})\eta_2 + f_3^2(x_{13})\eta_3 + f_4^2(x_{14})\eta_4 + f_5^2(x_{15})\eta_5 + f_6^2(x_{16})\eta_6 + f_7^2(x_{17})\eta_7 + f_8^2(x_{18})\eta_8 + f_9^2(x_{19})\eta_9 + f_{10}^2(x_{210})\eta_{10} = 0.3259.$$

The weighted clustering coefficients of the differential measures is:

$$\delta_1^3 = \sum_{j=1}^9 f_j^3(x_{1j})\eta_j = f_1^3(x_{11})\eta_1 + f_2^3(x_{12})\eta_2 + f_3^3(x_{13})\eta_3 + f_4^3(x_{14})\eta_4 + f_5^3(x_{15})\eta_5 + f_6^3(x_{16})\eta_6 + f_7^3(x_{17})\eta_7 + f_8^3(x_{18})\eta_8 + f_9^3(x_{19})\eta_9 + f_{10}^3(x_{310})\eta_{10} = 0.2943.$$

Similarly, we can also obtain the calculation results of weighted clustering coefficients of different cities under three gray shade scale (see Table 3).

According to the gray fixed weight clustering model based on entropy weight method, the size of fixed weight clustering coefficient is obtained, and the development level of ecological agriculture in 18 cities in Henan province is clustered and divided into 3 types of regions, the results are shown in Table 4. Using ArcGIS software to draw development level distribution map (Fig. 5).

According to the development level distribution map, we can clearly see that the development level of ecological agriculture in Henan Province is unbalanced, and find out the existing problems. Here, we use the analysis of the development status of ecological agriculture in different cities under the same gray level conditions to solve the reasons for the imbalance. First, sort the group with "excellent" development level and analyze the results. First, Nanyang is ranked first, with a score of 0.7504 under the optimal measurement. This area is dominated by agricultural industry, its total power

Table 3. Calculation results of weighted clustering coefficient

City	excellent	good	general
Zhengzhou	0.226	0.2525	0.5215
Kaifeng	0.0251	0.5017	0.4732
Luoyang	0.2339	0.5946	0.1715
Pingdingshan	0.1708	0.5761	0.2531
Anyang	0.0745	0.7462	0.1794
Hebi	0.2073	0.2953	0.4974
Xinxiang	0.2263	0.5069	0.2668
Jiaozuo	0.2650	0.2514	0.4836
Puyang	0.1189	0.4195	0.4616
Xuchang	0.2211	0.2473	0.5316
Luohe	0.0316	0.2648	0.7036
Sanmenxia	0.4239	0.2406	0.3355
Nanyang	0.7504	0.1717	0.0779
Shangqiu	0.2864	0.2588	0.4548
Xinyang	0.4970	0.2959	0.2071
Zhoukou	0.3659	0.2731	0.3610
Zhumadian	0.4543	0.3026	0.2431
Jiyuan	0.2698	0.3112	0.4190

Table 4. Evaluation results of ecological agriculture development level of prefecture-level cities in Henan province in 2019

Evaluation of ecological agriculture development level	City
Development level (excellent)	Sanmenxia, Nanyang , Xinyang Zhoukou, Zhumadian
Development level (good)	Kaifeng, Luoyang, Pingdingshan Anyang, Xinxiang
Development level (general)	Zhengzhou, Hebi, Jiaozuo, Puyang Xuchang, Luohe, Shangqiu, Jiyuan

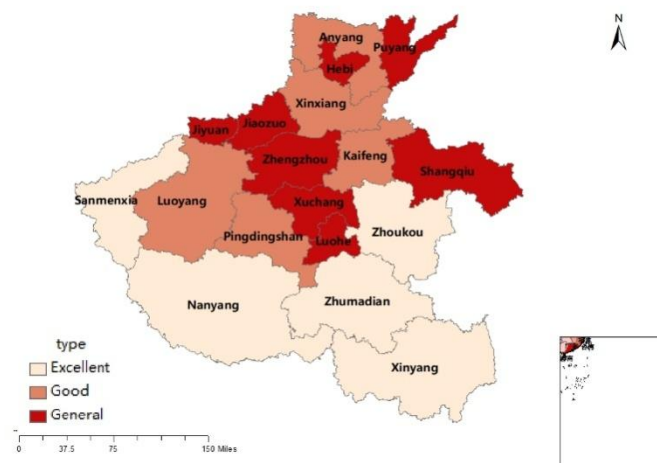


Fig. 5. Distribution of ecological agriculture development level

of agricultural machinery X_5 ranks first in the whole province, with balanced development of economic, social and ecological benefits and generally high, but the agriplastic film usage X_8 in this region is the highest, this will have a negative impact on the ecological environment.

The second place is Xinyang, which is rich in water resources and has the highest per capita water resources X_3 in the whole province, but the effective irrigation area accounts for the lowest proportion of irrigation area X_4 , the problems of ecological benefits have a constraint on the

comprehensive level of ecological agriculture in the city; However, Zhumadian, Sanmenxia and Zhoukou ranked 3-5th in the province in turn. These areas have good geographical advantages, with sufficient labor resources, they all belong to traditional agricultural development areas, and their fertilizer application amount X_7 is the top three in the whole province, which is closely related to the destruction of agricultural ecological environment, it also has some checks and balances on the development of ecological agriculture, restricting the sustainable development of agriculture [21].

Secondly, the cities under the "good" level of development are sorted according to the order of development level from good to bad, namely Anyang, Luoyang, Pingdingshan, Xinxiang and Kaifeng. The development of ecological agriculture in these areas has certain common points, and the development of economy, society and ecology are relatively good. However, each region has not made good use of its own advantages of regional development, and its own advantages should be clearly defined, on this basis, seize the advantages, and then make ecological agriculture better integrate development and sustainable development.

Finally, Luohe city ranked first with a coefficient of 0.7036 in the prefecture under the "general" gray shade scale. The per capita disposable income of rural residents X_1 in this city is relatively high, but the investment proportion of fixed assets of agriculture, forestry, animal husbandry and fishery X_2 is relatively low, and the industrial structure is single, this is contrary to the improvement of economic benefits. In addition to the low usage of pesticides, other indicators of ecological benefits are generally higher, which damages the natural environment. In terms of social benefits, water resources deficiency, however, the proportion of effective irrigation area is not high, and the infrastructure needs to be improved. However, Xuchang, which ranks second, has developed well in terms of social benefits. The proportion of effective irrigation area to cultivated land area X_4 is only lower than Hebi, while the development of other aspects needs to be improved. As for the third-place Zhengzhou, the region's economy is the leader of Henan province, with the highest per capita disposable income of rural residents X_1 , the lowest proportion of investment in fixed assets of agriculture, forestry, animal husbandry and fishery X_2 , and the least amount of per capita water resources X_3 , the ecological aspect is also

too inclined to develop in the direction of environmental damage, which will not be conducive to the sustainable development of ecological agriculture; Regarding Hebi city, Jiaozuo city, Puyang city, Shangqiu and Jiyuan, such areas all have problems such as low total power of agricultural mechanization X_5 and serious damage to agricultural ecological environment [22] and the development level of ecological agriculture is relatively weak compared with other cities in Henan province.

3. RESULTS AND DISCUSSION

3.1 Results

In order to accurately reveal the current situation and impact mechanism of agricultural ecological development in Henan Province, based on the data of 18 prefecture level cities in Henan Province in 2019, this paper first uses an EBM model with unexpected output to calculate the agricultural ecological efficiency of Henan Province, creatively constructs a comprehensive evaluation index system, and uses the grey theory to sort out the current situation of agricultural ecological development in Henan Province from the spatial dimension, Then, the factors affecting the development of agricultural ecology are revealed by improving the entropy weight method. Through discussion and research, this paper can draw the following conclusions: it is found that the proportion of fixed assets investment in agriculture, forestry, animal husbandry and fishery, water-saving irrigation rate, total power of agricultural machinery and ecological agriculture efficiency account for a large proportion, which are the key factors affecting the sustainable development of ecological agriculture; On the basis of calculating the weight, when establishing the clustering model, it is different from the previous clustering methods. Here, the grey weighted clustering method is combined. The construction basis of this method is the expression of the possibility function, which can cross combine and utilize the information within the index, so as to solve the information fuzziness and index inconsistency in the evaluation problem [23]; Finally, the clustering results show that there are significant differences in the development of ecological agriculture in various regions of Henan Province, which can be roughly divided into three gray levels: dominant region, good region and backward region.

3.2 Discussion

In the long run, in order to better develop ecological agriculture in Henan Province, narrow regional differences, and realize the effective utilization of resources and sustainable agricultural production, all regions can start from the following aspects. Firstly, increase agricultural investment. According to the analysis, the key element of developing ecological agriculture is to pay attention to the agricultural investment in the region. Therefore, on the one hand, in order to implement the agricultural support and preferential policies into the hands of farmers, the government should establish a supervision mechanism after the policy is issued and make the information about preferential policies transparent. On the other hand, local governments increase investment in different industries according to their geographical advantages and agricultural production conditions, enrich industrial development and reduce the problem of industrial simplification [24]. Secondly, scientific and technological innovation drives the level of agricultural infrastructure construction and mechanization. The low rate of water-saving irrigation and the low popularization rate of agricultural mechanization are also factors restricting the development of ecological agriculture in some areas of Henan Province. To solve such problems, it is particularly important to develop new and efficient agricultural mechanization and water infrastructure. Therefore, the first is to strengthen the construction of road facilities in ecological agricultural areas, and strengthen and improve the construction of farmland, water conservancy and other infrastructure; Secondly, in order to implement the implemented agricultural machinery support and preferential policies into the hands of farmers, the government should establish a supervision mechanism after the policy is issued, make the relevant preferential policy information transparent, promote agricultural mechanization driven by science and technology, increase investment in different agricultural machinery, and then improve the popularization rate of Agricultural Mechanization[25]. Finally, the government issued relevant policies to urge relevant agricultural departments to promote modern water resources irrigation technology to local farmers, so as to solve the disadvantages of traditional agricultural irrigation methods, and implement the construction of comprehensive prevention and control demonstration area of agricultural input pollution and livestock and

poultry waste in key water source protection areas, so as to improve the utilization efficiency of water resources while protecting water resources. Finally, reduce the use of plastic films, pesticides and chemical fertilizers. One of the reasons for the low ecological benefits of most cities in Henan Province is the large use of plastic films, chemical fertilizers and pesticides. In view of this problem, we can take the following measures: on the one hand, local government departments increase the control of the production and sales of low-quality fertilizers and highly toxic pesticides through legal means; On the other hand, for the use of plastic film, vigorously promote recycling, do not advocate changing every season, so as to reduce the amount of film. In addition, the government can also cooperate with biological companies to use advanced scientific and technological products and agricultural technology to physically support agriculture and reduce dependence on chemical products.

4. CONCLUSION

Based on the development of traditional agriculture and conforming to the requirements of the times, ecological agriculture is an efficient, modern, intelligent and scientific agriculture with coordinated development of economy, society and ecology. When discussing the development of ecological agriculture in Henan, a large agricultural province, this paper constructs a comprehensive evaluation index system of economic, social and ecological development. Under the condition of less data and poor information, the grey weighted cluster evaluation model is selected. The final evaluation result is compared with the ranking of modern agriculture in Henan Province in 2019, and its error is small. The results show that the model can objectively evaluate the development status of ecological agriculture in this area. In the future, combined with the development of other regions, adjust the selection of indicators, and apply the model to the evaluation of ecological agriculture in China and regional regions, so as to provide theoretical support for the policies of relevant government departments, so as to promote the high-quality and balanced development of China's agriculture.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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