Original Research Article

Empirical analysis on the development of ecological agriculture under the initiative of "sustainable development"

Abstract

Aims: As a large agricultural country, China is promoting the development of agriculture in the direction of modernization and ecology. Therefore, the comprehensive production capacity of agricultural products is continuously improved, and emerging agriculture is booming. However, there are also problems such as uncoordinated regional development, deterioration of environment and resources and so on. Therefore, it is very important to accurately evaluate and shorten the regional differences in the sustainable development level of ecological agriculture in China.

Study design: In order to shorten the temporal and spatial differences in the development of ecological agriculture, this paper starts with Henan Province, an important grain production area in China, analyzes and studies from point to area, and puts forward targeted measures and policies.

Place and Duration of Study: Zhoukou Henan Province, from December 2018 to January 2020.

Methodology: Starting from 18 cities in Henan Province, this paper constructs a comprehensive evaluation index system including economy, society, ecology and agricultural ecological efficiency calculated by U-EBM model for the first time, and uses the grey weighted clustering model based on improved entropy weight method 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" of grey theory to test the development trend and influence mechanism of regional ecological agriculture.

Results: It is found that the proportion of fixed assets investment in 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. The results of data-driven clustering 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.

Conclusion: It is in line with the actual situation of unbalanced development of ecological agriculture in various regions of Henan Province, and verifies the reliability of the model, which will provide accurate evaluation direction and relevant policy and strategic deployment for the future study of agricultural ecological development.

Key words: ecological agriculture; improved entropy weight method; possibility function; undesirable-EBM; grey weighted clustering

This Research was supported by Natural Science Foundation of Zhejiang Province(No. LY17A010009).

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[Tan Mingjiao et al.,2019].

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. (2010) 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. (2021) 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 eco-agriculture in Hunan Province was not coordinated, and the regional differences were obvious. Lu Shenghan et al. (2020) 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 (2017) 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. (2018) 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. (2020) 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 (2015) 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.(2010), 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 nth DMU: $x=(x_1,x_2,\dots,x_I)\epsilon\Re_+^I$, $y=(y_1,y_2,\dots,y_J)\epsilon\Re_+^J$, $b=(b_1,b_2,\dots,b_L)\epsilon\Re_+^L$.

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

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

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 [Yuan Jiuhe et al., 2013]. On the contrary, the weight is opposite.

(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:

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

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

(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[Ma bingjuan, 2007] 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 grey fixed weight cluster evaluation model is adopted[Liu Sifeng et al., 2014].

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. I, 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. I is as follows:

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

(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. II), 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. II, there are:

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

(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. III), $f_j^k(\cdot)$ 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. III, there are:

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

(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. VI), 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. IV, there are:

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

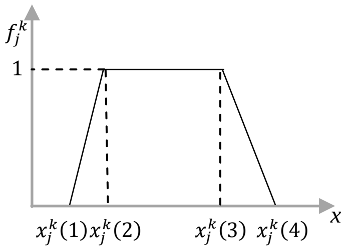

Fig. I typical possibility function

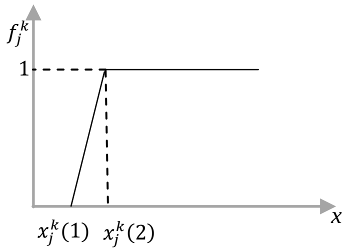

Fig. II upper limit measure possibility function

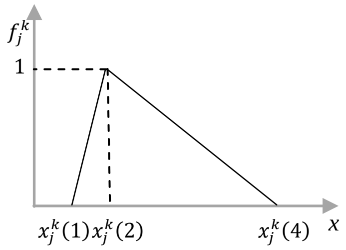

Fig. III moderate measure possibility function

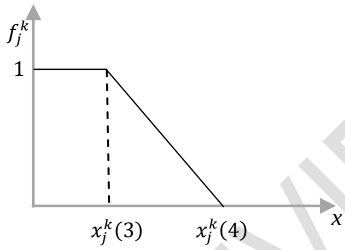

Fig. IV lower limit measure possibility function

(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 $\delta_i^{k^*} = \max_{1 \le k \le s}\{\delta_i^k\}$, 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.

3. Empirical Analysis

3.1 Indicator selection and data source

Based on the needs and realities of sustainable development of ecological agriculture in Henan Province, and drawing lessons from the existing research results, [13-16], following 10 principles, namely, according to local conditions, the combination of key and comprehensive, scientific and practical and advanced nature, and the combination of traditional methods and modern methods, 10 indicators were selected from economic, social 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 index selection of input-output system, follow the principle of industrial ecology, that is, on the premise of minimizing social resource consumption and ecological environment damage, in order to obtain higher economic output, and use the existing research results [Chen Jie et.al.,2021;Li Beige et.al.,2021;Tian Jie,2021;Zhang Xin,2021] for reference to select relevant indicators. 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, CO_2 emission data can be obtained from ceads database, while the relevant data of agricultural SO_2, 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.

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

Level 1 indicator	Level 2 indicator	Level 3 indicator	Indicato
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	+
	Ecological benefits	Pesticide application rate X_6	−
		Fertilizer application discount X_7	−
		Agriplastic film usage X_8	−
		Percentage of forest cover X_9	+
	Ecological efficiency	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
	Ideal output	Gross industrial product	million yuan
Output	Nonideal output	Industrial environmental pollution index	Relative comprehensive index calculated from CO_2, SO_2, smoke and dust, wastewater and general solid waste

3.2 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.

3.2.1 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.

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

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

3.2.2 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:

$$f_1^1(x_1)=\begin{cases}0\,, & x\le 14701,\\ \dfrac{x-14701}{17424-14701}, & x\in(14701,17424),\\ 1\quad, & x\ge 17424.\end{cases}$$

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

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

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

$$f_1^3(x_3)=\begin{cases}1\,, & x\le 11978,\\ \dfrac{x-14701}{17424-14701}, & x\in(14701,17424),\\ 0\quad, & x\ge 14701.\end{cases}$$

(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:

$$\delta_1^3=\sum_{j=1}^{9} f_j^3(x_{1j})\eta_j = f_1^3(x_{11})\eta_1 + f_2^3(x_{12})\eta_2 + f_3^2(x_{13})\eta_3 + f_4^2(x_{14})\eta_4 + f_5^2(x_{15})\eta_5$$

$$+f_6^2(x_{16})\eta_6 + f_7^2(x_{17})\eta_7 + f_8^2(x_{18})\eta_8 + f_9^2(x_{19})\eta_9 + f_{10}^3(x_{310})\eta_{10} = 0.2943\,.$$

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

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

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. V).

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

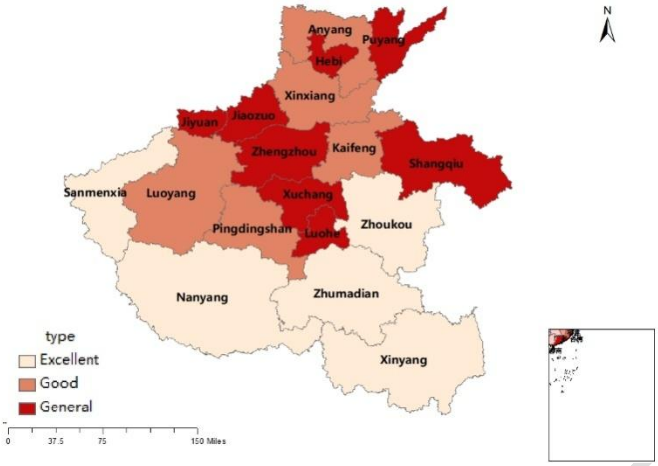

Fig. V Distribution of ecological agriculture development level

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 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[Kang Leilei et al., 2017].

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 mechanizationX_5 and serious damage to agricultural ecological environment[Ding Yi et al., 2013], and the development level of ecological agriculture is relatively weak compared with other cities in Henan province.

4. Conclusions and suggestions

4.1 Conclusion

In this paper, the entropy weight method is used to objectively determine the weight of each evaluation index, and the mathematical logic idea is used to scientifically and objectively determine the weight of each evaluation index, and then the gray fixed weight clustering method is combined, the possibility function can well reflect the mutual connection between the internal information of the same index and make full use of the advantages, and can well solve the fuzzy information existing in the comprehensive evaluation of ecological agriculture fuzzy Multiobjective Decision Making, problems with different dimensions of evaluation indexes[Zhou Guiping, 2018]; Finally, the clustering results show that there are significant differences in the development level of agriculture in 18 cities in Henan province, which are roughly divided into three gray shade scale, namely: excellent areas: nanyang city, Xinyang city, Zhumadian city, Sanmenxia city, Zhoukou city; good areas: Anyang city, Luoyang city, Pingdingshan city, Xinxiang city, Kaifeng City; general areas:Luohe city, Xuchang city, Zhengzhou city, Hebi city, Jiaozuo city, Puyang city, Shangqiu city, Jiyuan City.

4.2 Suggestions

In order to further promote the sustainable development of ecological agriculture in Henan province, the following suggestions are put forward:

First, improving farm mechanization level, the key element of developing ecological agriculture is to improve the farm mechanization level of the region. Therefore, to improve the development level of ecological agriculture, on the one hand, in order to implement the agricultural machinery support and preferential policies to farmers themselves, the government should establish a supervision mechanism after the policies are issued to make relevant preferential policies transparent[Zhang Liye,2016]. On the other hand, according to the geographical advantages of their own regions and the situation of agricultural production, local governments have increased their investment in different agricultural machinery to improve the popularization rate of agricultural mechanization.

Second, improving the construction of agricultural infrastructure and the small per capita water resources are the factors restricting the development of ecological agriculture in some areas of Henan province. Solving such problems, developing new agricultural machinery with environmental protection and high efficiency, infrastructure construction such as water conservancy is particularly important. Therefore, the local agricultural department first invests in the expansion project of facility agriculture to expand the production scale of ecological agriculture[Yang Ruizhen et al., 2016]; Secondly, it strengthens the construction of road facilities in ecological agricultural areas, improves the construction of infrastructure such as farmland water conservancy, the government and agricultural departments should promote modern water conservancy irrigation technology to local agricultural producers to solve the disadvantages of traditional agricultural irrigation methods, as well as the implementation of agricultural input pollution and livestock waste comprehensive prevention and control demonstration area construction in key water source protection areas, thus improving the utilization efficiency of water resources while protecting water resources.

Third, reducing the use of plastic film, pesticide and fertilizer, one of the reasons for the low ecological benefits of most cities in Henan province is the extensive use of plastic film, fertilizer and pesticide. To solve this problem, we can take the following measures: On the one hand, through legal channels, local government departments plus-sized control over the production and sale of inferior fertilizers and highly toxic pesticides. On the other hand, for the use of plastic films, they have vigorously promoted recycling, it is not recommended to change one season, thus reducing the amount of film. In addition, the government can also cooperate with biological companies to use advanced scientific and technological products and agricultural technologies to physically support agriculture and reduce dependence on chemical products.

References

Tan Mingjiao and Feng Weilin: theoretical analysis and enlightenment of China's Ecological Agriculture Development, Regional Economic Review, No.1, 2019.

Zheng Jun, Shi Jianmin. Construction of ecological agriculture competitiveness evaluation index system based on AHP [J]. Chinese Journal of eco-agriculture, 2010,18(05):1087-1092.

Zhao Yaping, Liu Yanhong, Li Hui, Zhou Tian yunzi. Research on Performance Evaluation of ecological agriculture in Hunan province based on principal component analysis [J]. Rural economy and science and technology, 2021,32(03):189-191.

Lu Shengyi, Zhu founded, Zhou Jianxin, Tian Shichao, Wang Yanru, Chang Jun. Ecological benefit evaluation of land consolidation from the perspective of ecological landscape [J]. Soil and Water Conservation Research, 2020,27(05):311-317.

Lin Dongping, Zhang Haifeng. Benefit analysis of ecological agriculture in China based on fuzzy mathematics [J]. Jiangsu Agricultural Sciences, 2017,45(14):277-280.

Feng Yajuan, Qi Qiao, Han Jiabin. Temporal and spatial evolution and driving factors of agricultural ecological efficiency in China [J]. Soil and Water Conservation Bulletin, 2018,38(06):254-262.

Ren Yongtai, Yu Haoran, Liu Hui, Wang Huiying. Evaluation of eco-agricultural economic competitiveness based on factor analysis and gray correlation-taking Heilongjiang province as an example [J]. Ecological economy, 2020,36(12):85-92+153.

Li Lianjun. Comparative study on the development level of modern agriculture in Jiangxi based on factor analysis-data from 11 prefecture-level cities in Jiangxi province [J]. Special Zone Economy, 2015,{4}(02):74-76.

Tone Kaoru, Tsutsui Miki. An epsilon-based measure of efficiency in DEA – A third pole of technical efficiency[J]. European Journal of Operational Research,2010,207(3):

Yuan Jiuhe, Qi Chunjie. Dynamic evaluation of agricultural sustainable development ability in Hunan province based on entropy method [J]. Resources and Environment in Yangtze River basin, 2013,22(02):152-157.

Ma bingjuan. Research on Evaluation method of atmospheric environmental quality based on improved gray clustering method [D]. Zhengzhou University, 2007.

Liu Sifeng, Fang Zhigeng, Yang Yingjie. Two-stage gray comprehensive measure decision model and improvement of triangular whitening weight function [J]. control and decision, 2014,1232-1238.

Chen Jie, Wang Jianmin, Fan Yuhuan. Study on temporal and spatial differences and influencing factors of industrial ecological efficiency in the Yangtze River economic belt [J]. Journal of Henan University of Science and Technology (SOCIAL SCIENCE EDITION), 2021,39 (05): 39-46.

Li Beige, Hu Zhiqiang, Miao Changhong. Spatial differentiation characteristics and influencing factors of industrial ecological efficiency in the Yellow River Basin [J].Geographical research, 2021,40 (08): 2156-2169.

Tian Jie. Ecological efficiency evaluation of China's industrial system -- from the perspective of industrial chain [J]. Statistics and decision making, 2021,37 (15): 96-99.

Zhang Xin. Study on industrial ecological efficiency of 9 cities in Dawan District, Guangdong, Hong Kong and Macao Based on DEA Malmquist model [J]. Strait science, technology and industry, 2021,34 (05): 24-30.

Hou Youxin, Zhang Kerong, Xu Yasong, Jiang Wulin. Evaluation of modern ecological agriculture development level in Fuyang city based on entropy method [J]. Anhui Agricultural Science, 2021,49(08):227-230.

Zhao Yaping, Liu Yanhong, Li Hui, Zhou Tian YUNZI. Research on Performance Evaluation of ecological agriculture in Hunan province based on principal component analysis [J]. Rural economy and science and technology, 2021,32(03):189-191.

Kang Leilei, Wang Qiong. Skyscraper fire safety evaluation based on DEA and gray clustering [J]. Industrial safety and environmental protection, 2017,43(07):29-33+37.

Ding Yi, Liu Yonghong, Cao Shengxian. Research on urban air quality evaluation based on fuzzy-gray clustering method [J]. Environmental Science & Technology, 2013,36(S2):374-379.

Zhou Guiping. Study on coupling of eco-agriculture and eco-tourism in Jiangsu province [J]. China's agricultural resources and zoning, 2018,39(04):226-231.

Zhang Liye. Comprehensive benefit evaluation of sustainable development of modern agriculture in Henan province [J]. China's agricultural resources and zoning, 2016,37(10):95-100

Yang Ruizhen, Chen Yinjun: development trends and tasks of modern ecological agriculture in China, China's agricultural resources and zoning, No. 5, 2017.