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Analysis of ecological benefits of agricultural land and design of evaluation strategies

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Abstract: The rational application of farmland resources is the basis of China's social and economic development, and in the context of global low-carbon and sustainable development strategies, the rational allocation of farmland resources and the analysis of ecological benefits are particularly important. In this regard, this study constructs an evaluation strategy for ecological benefit analysis of farmland based on the theory of low carbon economy and the theory of carbon emission from farmland. Firstly, the farmland analysis indexes are determined, including land ecological conditions, land environmental quality and ecological environment at three levels; then the entropy value method and the coefficient of variation method are used to obtain the set weights of each index; finally, the comprehensive index evaluation formula is relied on to obtain the results of farmland eco-efficiency in each region. The experimental data show that the method can effectively improve the accuracy of the evaluation strategy and has a higher practical scope.
Keywords: *Eco-efficiency, Evaluation, Farmland, Weights.*

1. Introduction

Carbon emission from farmland, as a negative output of land economic development, mainly refers to the situation of waste carbon gas emission caused by human activities such as farmland use, including energy consumption activities, land production activities and land preparation activities, etc. According to the analysis of farmland benefits, it can be affirmed that carbon emission from farmland is closely related to the ecological benefits of the land itself, and it also has a certain impact on the ecological balance. In today's world where the contradiction between resource environment and land economic development is intensifying, the excessive carbon emission from farmland application has become one of the core causes of global greenhouse effect and also a key environmental problem brought by rapid economic development. Therefore, as early as the 2009 Global Climate Conference, countries around the world have started to construct carbon emission reduction plans according to their own situations. In fact, with the promotion of carbon tax, carbon trading and other policies, many countries in the world have already started to consciously save energy and reduce emissions, and it can be said that carbon reduction capacity is becoming one of the core factors in the competition of economic development of each country, as well as an important indicator to promote the sustainable development of the global economic environment.[1]

In recent years, China's economic development has entered a high-speed stage, and although it has achieved more remarkable economic development achievements, it has also caused certain land ecological and environmental problems. The traditional resource-dependent economic development

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model can no longer adapt to the development needs of modern society, and it is urgent to build a sustainable development strategy. For the increasingly serious environmental and climate problems, China's government departments are also insisting on vigorously developing a low-carbon economy, based on the concept of sustainable development, and guiding the industries to low carbon emission, low energy consumption and low pollution. Starting from the Fifth Plenary Session of the 18th Party Central Committee, the relevant leading departments have put forward the concept of green development and constructed a series of major decisions on environmental protection starting from energy conservation and emission reduction, striving to fight the battle of environmental protection with all their might.[2] Land is the carrier of human survival activities, and the farmland use carries most of the carbon emissions of the primary industry, including livestock grazing activities and agricultural planting inputs.[3] The land management activities of farmland itself will also directly affect the balance of carbon emission of the ecosystem. It can be seen that the change of land use will dominate the subsequent land carbon emission, and the management of land use itself is also an effective means for the government to achieve macro-control, which has a room for operation that other industries do not have. Based on government functions, it is important to reduce carbon emissions, reduce carbon emission intensity and optimize land structure by rational allocation of land from the development of farmland land use for production and ecological construction. In this regard, this study takes the development of low carbon economy as the starting point and constructs a new evaluation and analysis strategy based on the actual situation of ecological benefits of farmland in China, so as to guide the regions to optimize the macro-control policies and promote the development of low carbon work.[4].

2. Theoretical Analysis of Farmland Use and Ecological Benefits

2.1. Low Carbon Economy Theory

In 2003, low-carbon economy has appeared in the core theory of international energy development, and as the climate and environment information among governments around the world has been enriched, this concept has been extended and become the focus of economic development transformation on a global scale promoted by the United Nations, which also marks the birth and development of the theory of low-carbon economy, for which the economic and environmental development departments of various countries have also launched intense discussions.[5-6]

In essence, low carbon economy can be seen as an elaboration of economic development, a discipline that rationalizes the contradictory relationship between carbon dioxide and economic development through the comprehensive application of economic development theory. In terms of content, low carbon economy theory is about how to promote sustainable development of environment and economy through market and government macro-control and other means. Low carbon emission, on the other hand, is the core of low carbon economic development, and also a key element of low carbon economic development. Generally speaking, carbon productivity is an important indicator to measure the development of low-carbon economy, which mainly refers to the level of economic output corresponding to unit carbon emission, and is used to measure the development of productivity under the low-carbon economic system.[7] In fact, low carbon in a low-carbon economy is not the ultimate goal, but a necessary means for sustainable development strategies. The ultimate goal of low carbon economy is determined by the economic and environmental situation of the country, generally speaking, countries with higher humanities development will also have higher economic levels and should fulfill higher carbon emission reduction responsibilities, while developing countries with heavier economic construction pressure should reduce certain carbon emission responsibilities. [8]

2.2. Theory Of Carbon Emission from Farmland

Agricultural activities are the second largest source body of carbon emissions under the carbon emission structure, accounting for about 30% of the total carbon emissions. Dong Hongmin, an agronomist in China, has focused on analyzing the emission classification of agricultural carbon

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emissions, including animal methane emissions, methane emissions during rice growth, and plant and animal waste and fertilizer management. Through comparative analysis, it can be determined that methane release from agricultural land accounts for more than fifty percent of the national methane emissions. 2021, Tian Yun et al. measured the proportion of agricultural carbon emissions in the northern region of China, and the analysis of experimental data shows that the sources of carbon emissions under agricultural material inputs mainly consist of pesticides, fertilizers, agricultural films, and agricultural diesel fuel. Through the LMDI model diagram, the carbon emission group factors are decomposed, and after expanding the scale to the whole country, it can be determined that agricultural farmland finishing in China has an important influence on domestic carbon emission, so in the future, if we want to achieve reasonable carbon emission as well as sustainable development strategy, we need to balance the ecological benefits of farmland land and total carbon emission. In this regard, this study starts from the evaluation and analysis system of ecological benefits of agricultural land and constructs a complete evaluation strategy for subsequent carbon emission planning operations to achieve a win-win situation for the environment and economy.

3. Farmland Eco-Efficiency Evaluation Index System

3.1. Indicator Selection

The ecological benefits of farmland use are mainly reflected in the impact on the land atmosphere or regional ecosystem in the process of modern agricultural production. With the change of economic development mode, the green low-carbon concept and sustainable development idea have been deeply penetrated into the farmland production, marking the unification of agricultural production and environmental development. The utilization of agricultural land is a complex system, and in order to realize the analysis of its ecological benefits, it is necessary to establish a complete index system under the guidance of basic concepts, combined with actual index functions and relying on a certain hierarchical structure.

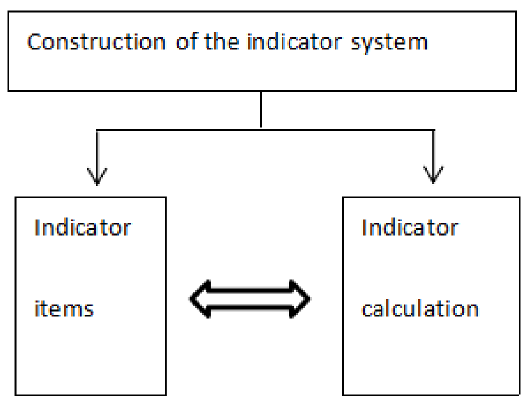

Figure 1.
The idea of constructing the indicator system.

This design divides the land eco-efficiency indicators into three parts: guideline layer, indicator layer and indicator type, where the guideline layer includes the ecological conditions of the land as well as the quality and governance of the ecological environment, and the indicator layer includes specific indicator sequences, while the indicator type is divided into positive and negative indicators.

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Table 1.
Evaluation index system of ecological benefits of farmland use.

Guideline level	Indicator level	Indicator type
Ecological conditions of farmland	Arable land area	Positive
	Green space per capita	Positive
	Farmland population density	Negative
	Farmland coverage	Positive
	Total water resources on farmland	Positive
	Arable land reduction area	Negative
	Agricultural wastewater discharge	Positive
	Agricultural waste gas emissions	Positive
	Agricultural solids	Negative
Eco-environmental quality	Tons of wastewater discharged from farmland	Negative
	Emissions of farmland waste gas	Negative
	Waste emissions	Negative
	Amount of pesticide use per unit of cultivated land	Negative
	Amount of chemical fertilizer used per unit of arable land	Negative
	Average pollution concentration	Negative
	Agricultural waste utilization rate	Positive
	Sewage treatment rate	Positive
Eco-environmental governance	Air quality non-hazardous treatment rate	Positive
	Number of days with air quality above Class II	Positive

To realize the future low carbon economic development, the theoretical system of farmland land eco-efficiency and the determination of indicators should be centered on the eco-resource cycle of efficient utilization, in order to reduce the subsequent problems of quantifying carbon sources and finally realize the combination of farmland land production eco-efficiency and environmental development.

3.2. Analysis of Indicator Selection

The selected indicators are mainly based on the ecological benefit output, including the ecological condition of farmland, ecological environment quality, and ecological environment management.

The ecological conditions of farmland belong to the basic indicators of ecological benefits of the current region, and its good or bad directly affects the level of ecological benefits of farmland land, and also reflects the livability of the environment. Ecological environment quality, on the other hand, belongs to the comprehensive concept of environmental management in a region, including land atmosphere and water environment, etc. Under the influence of current factors, the index system based on agricultural sewage, waste gas and solid pollutant emissions is selected to truly reflect the ecological and environmental development indicators of the region as well as the degree of impact of land benefits. The ecological environment management, on the other hand, mainly represents the local government's attention and investment in the environmental management and protection of farmland, which will directly affect the level of comprehensive ecological benefits under agricultural development.

4. Evaluation of the Ecological Benefits of Agricultural Land Use

4.1. Standardization of Indicators

In order to effectively eliminate the different influences under the index system, the design uses a polar difference algorithm to centralize the above index data, while calibrating the positive and negative directions of the index information.

$$y_i = \begin{cases} (x_i - M_{\min}) / (M_{\max} - M_{\min}) (\text{Positive}) \\ (M_{\max} - x_i) \;/\; (M_{\max} - M_{\min}) \; (\text{negativenegative}) \end{cases} \qquad (1)$$

In the formula, x_i indicates the true value of the indicator; y_i indicates the true value after standardization; i indicates the true number of indicators generally takes the value of 1 to 15, $M_{\min}$ indicates the minimum value in the first indicator, $M_{\max}$ indicates the maximum value.

4.2. Weighting Determination

For the weight determination of the above indicators, a single analysis method obviously has some limitations. In this regard, this study adopts two strategies, the entropy value method and the coefficient of variation method, to determine the final weights of the indicators through comprehensive and integrated weighting. This method can effectively solve the limitations of traditional methods and objectively reflect the influence effect of indicators.

4.2.1. Entropy Method Analysis

The concept of entropy value comes from thermodynamics, while in the field of informatics is generally called the average total amount of information, mainly expressing the degree of randomness or the degree of uncertainty of the randomness experiment. For example, if a random experiment includes P1 to Pn, there will be a finite number of results T that cannot be combined at this time, including T to Tn, whose probability of possible occurrence is P to Pn,then there is the average total information entropy value at this time as follows:

$$E = -\sum_{i=1}^{n} p_i \ln p_i (i = 1, 2, \cdots n) \qquad (2)$$

The larger the entropy value at this point, the smaller the difference from P to Pn,and the higher the uncertainty of the randomized test, and vice versa can be established.

The entropy method is also to determine the weight of each indicator through the idea of entropy value, which can effectively avoid the defects of single weight assignment to a certain extent. For the indicator, the greater the information entropy value, the greater the role of the indicator in the comprehensive evaluation, and the entropy method can be regarded as a new weight assignment strategy constructed by objective evaluation indicators under objective conditions, which has the characteristics of simple operation and objectivity. In this study, the entropy method and the weight assignment process are introduced into the weight analysis, and each indicator is treated as a separate random experimental analysis with the following calculation strategy：

Let the actual indicator value be x_{ij}, then there are i cities under indicator j with indicator share p_{ji} ：

$$p_{ji} = x_{ij} / \sum_{i=1}^{n} x_{ij} \qquad (3)$$

$$e_j = -k\sum_{i=1}^{n} p_{ij} \ln p_{ij} \qquad (4)$$

where, $k = 1/\ln n$, n denotes the number of cities. At this point, the coefficient of variation proportion of each indicator is found:

$$q_j = 1 - e_j \qquad (5)$$

The weights of each indicator can be obtained by normalizing the above formula.

4.2.2. Coefficient of Variation Method

In addition to the entropy value method constructed above, this study also introduces the coefficient of variation method to assist in the weight assignment. The coefficient of variation method is to directly use the values of each term and the subordinate information to obtain the final weights after a series of calculations, which belongs to an objective assignment strategy. This calculation method can reflect the degree of variation or dispersion of the overall unit indicators, and has the advantage of eliminating the influence of the variation of each unit indicator, as well as the influence of the degree of variation of different indicator data. The process is calculated as follows:

The arithmetic mean is first calculated, that is, by summing the data of a single data group and dividing by the amount of data:

$$\overline{x} = \frac{x1 + x2 + \cdots x_n}{n} \qquad (6)$$

Calculate the standard deviation according to equation (6):

$$\sigma = \sqrt{\frac{\sum (x - \overline{x})^2}{n-1}} \qquad (7)$$

The coefficient of variation for each term was calculated as:

$$V_i = \frac{\sigma}{\overline{x}} \qquad (8)$$

Then the weights of each indicator are:

$$W_i = \frac{V_i}{\sum_{i=1}^{n} V_i} \qquad (9)$$

4.3. Calculation of Eco-efficiency Evaluation

The evaluation strategy of agricultural land eco-efficiency is based on the above two calculation methods and adopts the comprehensive index evaluation strategy. The comprehensive index evaluation strategy is to analyze all the results of each element of the system relative to the degree of impact of the target by setting the target impact mile and then constructing multidimensional target indicators, using the method from cause to effect, considering different calculation elements, and finally analyzing all the results of each element of the system relative to the degree of impact of the target. In this data standardization operation, the extreme difference method is used to construct a dimensionless data processing template, and the index weights are determined by combining the above entropy method and the coefficient of variation method, and finally the summation of each index is seen, and the total score is calculated for objective evaluation and analysis of the improvement of target benefits. By synthesizing the ecological benefits brought by land use, the comprehensive score was scored as follows.

$$S = \sum_{j=1}^{m} (w_j \times Y_j) \qquad (10)$$

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In the above formula, S denotes the comprehensive score of land use eco-efficiency currently calculated; w_j denotes the weight of each indicator. According to the index system constructed above, relying on formula (10), the hierarchical results of different indicators and land can be calculated, and then further divided into levels according to the hierarchical results, both the final analysis results of eco-efficiency level can be obtained.

5. Research Analysis

In order to effectively verify whether the above constructed analysis strategy for evaluating the ecological benefits of farmland can achieve a comprehensive evaluation, it is compared with the traditional analysis method, using the past experimental data of Beijing-Tianjin-Hebei region as a blueprint and relying on the database simulation data, two evaluation models are constructed to analyze and evaluate the ecological benefits of the surrounding land, with specific parameters designed as the standard deviation of the standard line and the standard deviation comparison of the experimental factors.

According to the land eco-efficiency evaluation system of Beijing-Tianjin-Hebei region, after calculating the corresponding data evaluation results of each layer according to formula (10), further analysis and evaluation can determine the evaluation level of land use production efficiency of 13 municipalities in Beijing-Tianjin-Hebei region. Details can be seen in the following table.

Table 2.
Simulation Evaluation Table of Eco-efficiency Level in Beijing-Tianjin-Hebei Region for Experimental Use

Region	Overall score	Eco-efficiency analysis
Zhangjiakou	0.758	Areas with high ecological benefits
Beijing	0.687	
Chengde	0.665	
Tianjin	0.504	Areas with average ecological benefits
Qinhuangdao	0.485	
Tangshan	0.455	
Handan	0.421	
Shijiazhuang	0.404	
Cangzhou	0.403	
Langfang	0.365	Areas with weak ecological benefits
Shape	0.355	
Baoding	0.322	
Hengshui	0.175	Areas with low ecological benefits

Note: The table data are simulated data for experiments (based on real data) for experimental reference.

Based on the content of the above chart, it can be determined that throughout the Beijing-Tianjin-Hebei region, the level of land use eco-efficiency shows a trend of higher north-south than central, and can be specifically divided into four eco-efficiency base ratings.

The correlation of the experimental data is further measured by distributing the standard deviation and the factorial standard deviation. Standard deviation is a measure of data accuracy in the field of economics, and requires third-party software to label the index parameters and generate standard lines to compare the degree of deviation of experimental data. This proposed evaluation strategy is labeled as an experimental group, while the comparison group data is constructed to obtain the comparison results.

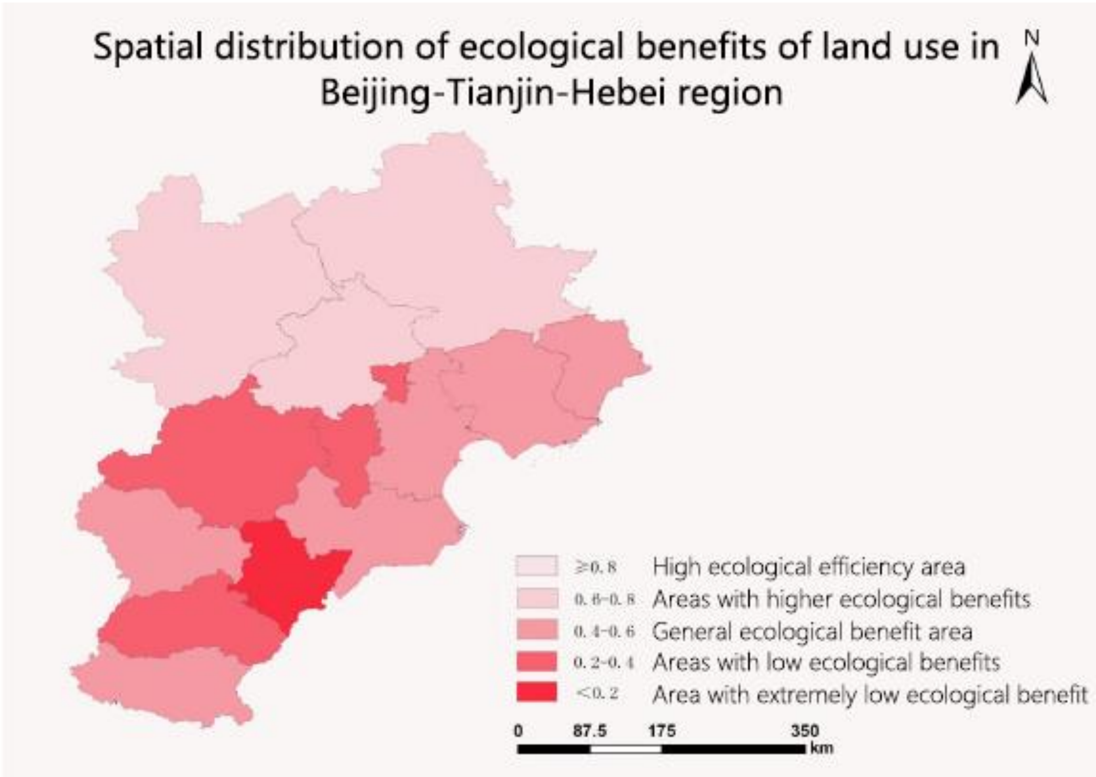

Figure 2.
Distribution of land eco-efficiency.

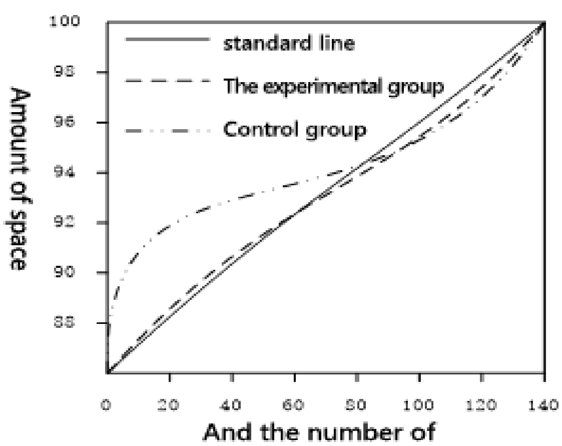

Figure 3.
Standard deviation comparison chart.

According to the data of the standard deviation comparison graph in Figure 3, it can be seen that the overlap of the comparison group is significantly lower than that of the experimental group when the number of parameters and the spatial volume increase, although they keep converging to the standard line. According to the specific data analysis, it can be determined that the deviation rate of the experimental group is narrowed by about 10%, and it can be basically determined that the present proposed evaluation strategy of agricultural land ecological benefits has higher data accuracy.

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In addition to the basic standard deviation comparison, the factor standard deviation comparison was added to this experimental study. Factor accuracy can directly affect the assessment results, so for experiments with more data items, the silver standard deviation results can be introduced as a measurement element of accuracy. Figure 4 shows the results of the standard deviation comparison as a result.

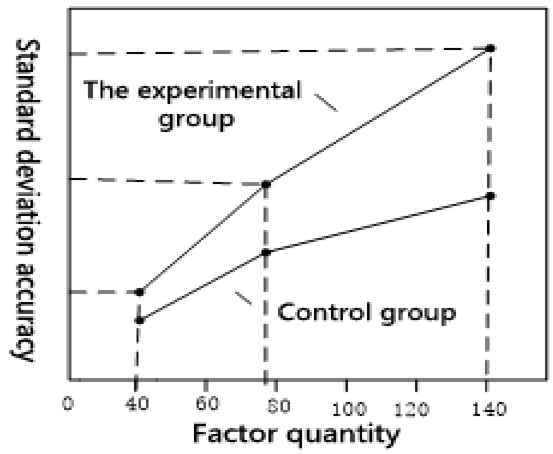

Figure 4.
Factor standard deviation comparison chart.

According to the above analysis results, it can be clearly seen that with the increase of the number of factor terms, the accuracy of factor standard deviation of the experimental group and the comparison group also improved. However, the experimental group is still higher than the comparison group, and its comprehensive accuracy can be improved by about 25%, which once again proves that the proposed evaluation strategy of farmland land ecological benefit analysis has higher accuracy and feasibility.

6. Conclusion

To achieve low carbon and environmental protection, the reasonable planning of farmland eco-efficiency is essential, so based on the development of modern comprehensive land and environmental utilization, the analysis and evaluation strategy of farmland land eco-efficiency is constructed according to the land indexes. Firstly, a comprehensive index system is constructed to deeply analyze the comprehensive utilization degree of farmland land and summarize the theoretical basis and characteristics of ecological benefits of land use; secondly, the weights of each index are determined by relying on entropy value method and variation coefficient method, and finally, the current indexes as well as the corresponding ecological benefits of farmland land are reasonably analyzed and determined through the calculation formula of ecological benefits evaluation.

Because of time and the complexity characteristics of eco-efficiency analysis itself, the eco-efficiency evaluation indexes marked in this study focus more on the differentiated research in spatial scope, and the data intercepted are 2018 data. In the future, in practical research and application, we need to rely on relevant science and technology for in-depth analysis of the time series and spatial differences of the analysis strategy.

In addition because of the open character of the environment, the development of land use eco-efficiency should be in a state of change, so the level of production efficiency will be influenced by policy, time and region. And this proposed evaluation strategy of agricultural land eco-efficiency does not take the above into account, and this is where it needs to be deepened.

Finally, as the ideas of land supply and future low-carbon green development and carbon emission reduction take root, the land use eco-efficiency evaluation strategy, as a land application allocation optimization method, needs to be combined with practical theories to build a larger spatial development environment, and also awaits deeper research depth.

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