

Calculation and Optimization Path of Agricultural Ecological Efficiency in Henan Province

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Abstract:

As an important support for China agricultural development, how to realize the sustainable development of agriculture has become a major problem to be solved urgently in this region. The index system to measure the agricultural ecological efficiency in Henan Province is constructed. This paper adopts the ultra-efficiency DEA method based on SBM to calculate the specific value of the agricultural ecological efficiency in Henan Province. The results show that the agricultural ecological efficiency in Henan province fluctuated from 2009 to 2022. At the same time, according to the calculation results, the optimization path to improve the agricultural ecological efficiency in Henan province is given.

Keywords:

Henan Province, Agro-ecological Efficiency, SBM Super-efficiency Model

1. Introduction

The boundary of Henan province, north latitude 31°23 ~36°22, east longitude 110°21 ~116°39, is located in the central and eastern region of the lower reaches of the Yellow River, bordering Anhui and Shandong in the east, Hebei and Shanxi in the north, Shanxi in the west and Hubei in the south.

Located in the north subtropical and warm temperate region, mild climate, abundant precipitation, suitable for the development of agriculture, forestry, animal husbandry, fishery. According to geographical factors such as terrain and rivers, in 2022, Henan province has a permanent population of 98.83 million, a GDP of 588887 billion yuan, grain planting area of 1772 thousand hectares and grain output of 65.44 million tons. The output value of agriculture, forestry, animal husbandry and fishery reached 1050.1 billion yuan, ranking second in China. Among them, the total output value of agriculture was 656.483 billion yuan, ranking the first in the country. As a major province of agricultural production, Henan province not only has certain theoretical significance to study the spatial and temporal evolution process of agricultural ecological efficiency and its influencing factors, but also has positive practical significance for the high-quality development of agriculture in this region.

2. Theory and Method

2.1. Theory

Concept definition of agricultural ecological efficiency. Ecological efficiency was first established by German scholars Schaltegger and Sur [1] proposed in 1990, the ratio of economic added value to increased ecological environmental impact. After that, more and more scholars in the academic circle have conducted a research on this concept and related content. However, it is difficult to simply consider economic benefits and ignore environmental impact, and the concept of agricultural ecological efficiency arises at the historic moment. In 1995, the concept of ecological efficiency was introduced into China, and domestic scholars have since studied it. Specific to agriculture, agricultural ecological efficiency to pursue the quantity and quality of agricultural products, and to pursue the environmental pollution minimization, which means that agricultural ecological efficiency is the minimum resource input and minimum environmental cost to obtain the biggest economic benefits and the optimal ecological environment, realize the coordinated development of economy and ecology. [2] It is pointed out that the so-called agricultural ecological efficiency is the input-output ratio based on economic indicators and environmental indicators, which belongs to a sustainable development model. Subsequently, Fang Yongli mentioned in the article the concept of agricultural ecological efficiency, think that the agricultural ecological efficiency is a further extension of ecological efficiency, the connotation is “less resource input, less environmental pollution, more economic output”, is the improvement of economic benefits, reduce the consumption of natural resources, and the impact on the environment.

Method of measuring agricultural ecological efficiency. At present, the measure of agricultural ecological efficiency mainly adopts the single ratio method [3,4] indicator system method [5] and model method [6] Etc. These methods have advantages and disadvantages. In the practice of ecological efficiency evaluation, DEA model method is the most widely used. It is based on the concept of relative efficiency and evaluates the relative effectiveness of the decision-making units according to the multi-input and multi-output indicators, which can avoid the subjective factors existing in the weight setting. Among them, the most applied is ultra-efficiency SBM model, which has the advantages of ultra-efficiency DEA model and SBM model. It integrates unexpected output into the model, effectively solves the relaxation phenomenon of input-output and the parallel problem of ranking, and has gradually become the mainstream model for measuring agricultural ecological efficiency. Such as the Bazyli Czyzewsk et al [7], the article mentions that the pressure of the natural environment can be compensated by producing or providing public goods, and that public goods-oriented agriculture is more likely to expand after improving agroecological efficiency. [8] And Through the study of agroecological efficiency in Italy, it is found that fiscal policy will have a certain impact on agroecological efficiency, and the farms in southern Italy pay more attention to sustainability and ecological efficiency. Ahmed [9] constructed the output effect analysis model by using the British financial support expenditure data and farmers income figures, and verified that there is a substitution and complementary relationship between financial support expenditure and farmers income. Some scholars have found that due to the lack of financial expenditure for agriculture, the financial expenditure for agriculture has not played a positive role in promoting the growth of farmers income. [10] The research found that the financial expenditure for supporting agriculture has a certain positive effect on

agricultural production, but on the whole, the financial expenditure for supporting agriculture on agricultural development and farmers income growth is not obvious, mainly affected by the way of financial expenditure for supporting agriculture and unreasonable resource allocation. Strengthening the financial support for agriculture, realizing the rural development and increasing farmers income are the problems that must be paid attention to and solved in China economic development. Domestic scholar Wu Xiaoqing measured the agricultural ecological efficiency of Wuxi from 1998 to 2008, Ding Baogen calculated the agricultural ecological efficiency of 11 provinces of Yangtze River Economic Belt, Wang Yongjing measured the agricultural ecological efficiency of economic belt of Tianshan North slope, An Zenglong measured the ecological efficiency of agricultural enterprises in Beidahuang, and Wang Chenxuan calculated the agricultural ecological efficiency of eastern, central and western China.

2.2. Study Methods

The idea of data envelope analysis (DEA) is to regard the research object as each decision-making unit, comprehensively analyze the input-output ratio of each decision-making unit, and calculate the input-output weight of each decision-making unit as variables, so as to judge whether each decision-making unit is effective through the operation results. The CCR and BCC models developed based on the traditional data envelope model (DEA) do not consider the relaxation of the input and output, and cannot accurately measure the ecological efficiency. Although the SBM model has been improved in the traditional DEA model, it cannot effectively rank the same decision unit, while Super-SBM is a non-radial and non-angular model, and takes the relaxation variables into account, so the efficiency will be more accurate, which can be corrected. Therefore, in the study of Super-SBM model, the Super-SBM model based on unexpected output is adopted and whose fractional expression is:

$$\rho^* = \min \frac{\frac{1}{m} \sum_{i=1}^m x_i^- / x_{i0}}{\frac{1}{s1+s2} \left(\sum_{r=1}^{s1} Y_r^{-g} / Y_{r0}^g + \sum_{t=1}^{s2} Y_t^{-b} / Y_{t0}^b \right)}$$

$$\text{s. t. } X^- \geq \sum_{j=1, \neq 0}^n \beta_j X_j Y^{-g} \leq \sum_{j=1, \neq 0}^n \beta_j Y_j^g Y^{-b} \leq \sum_{j=1, \neq 0}^n \beta_j Y_j^b X^- \geq X_0 Y^{-g}$$

$$\leq Y_0^g Y^{-b} \leq Y_0^b \sum_{j=1, \neq 0}^n \beta_j, Y^{-g} \geq 0, \beta \geq 0$$

The above equation (1) is the target efficiency value; X is the input; Y is the desired output and Y^- is the undesired output; the vector β is the input relaxation; the vector Y^- is the relaxation of the desired output; the vector Y^b is the relaxation of the undesired output; the vector β is the weight vector; the model subscript "0" is the decision unit evaluated. About, strictly monotonous decreasing, and meet 01. For a specific decision unit, when $\rho^* = 1$ and 0 , the decision unit is valid; if $\rho^* < 1$, the decision unit is invalid and the corresponding input and output needs to be improved.

$$\rho^* Y^g Y^b X^- Y^{-g} Y^b \beta \rho^* Y^{-g} Y^{-b} X^- \rho^* Y^{-g} Y^{-b} X^- \rho^*$$

3. Select the Data Sources of the Indicators

The necessary prerequisite of scientific measurement of agricultural ecological efficiency is to construct a perfect input-output index system. Agricultural ecological efficiency includes two connotations of agricultural economy and ecological environment, so the selection of indicators should not only reflect the resource input and expected output, but also reflect the unexpected output caused by excessive resource input. On the basis of grasping the principles of systematization, scientificity and operability, this study refers to Yan Mingtao [11]. On the basis of the selection of academic indicators, the index system of agricultural ecological efficiency is constructed in combination with the actual situation of agricultural development in Henan Province. Among them, agricultural carbon emission reference Li Na and other scholars [12]. The studied carbon emission coefficient and agricultural non-point source pollution are characterized by the comprehensive evaluation index, so as to reduce the undesired output index and improve the accuracy of the overall measurement.

In this paper, agricultural land input, irrigation area, diesel input, diesel input, fertilizer input, pesticide input, agricultural film input, labor input and machinery input and agricultural input as expected output index; agricultural carbon emission and agricultural non-point source pollution emission are established as unexpected output index, as shown in Table 1.

Table 1. *Agricultural ecological efficiency index system.*

Level 1 Indicators	Secondary Indicators	Variable Declaration	Unit
Input of agricultural production factors	Agricultural land investment	The area sown to the crops	A thousand hectares
	Irrigation input	Agricultural irrigation area	A thousand hectares
	Diesel input	Agricultural diesel oil use	Ten thousand tons
	Fertilizer input	Fertilizer input	Ten thousand tons
	Pesticide input	Pesticide use	ton
	Agricultural film investment	Agricultural film usage	ton
	Labor input	Employees in the primary industry	thousands of people
	Mechanical input	Agricultural machinery power	Ten thousand kilowatts
Expect output	agricultural output	gross agricultural production	100 million
Undesired output	carbon emission	Agricultural carbon emissions	Ten thousand tons
	Non point source pollution	Emissions from agricultural non-point source pollution	Ten thousand tons

The research data are mainly derived from the Statistical Yearbook of Henan Province from 2009 to 2022 and the statistical Yearbook of various cities. Among them, the effective irrigation area from 2009 to 2010 was replaced by the average of the statistical yearbook, and the individual missing data was completed by interpolation method. Finally, the panel data of 17 prefecture-level cities in Henan province from 2009 to 2022.

4. Study Results and Analysis

With the help of MaxDEA7.12.10 software, using super SBM-CRS model and super SBM-VRS model respectively measure the 2009-2022 Henan province agricultural ecological efficiency and pure technical efficiency, and according to the scale efficiency of ecological efficiency and pure technical efficiency of Henan agricultural scale efficiency, in order to better explore the Henan agricultural scale expansion and technological progress on the influence of agricultural ecological efficiency. In order to accurately reflect the overall situation of agricultural efficiency in Henan province during the study period, this paper calculates the average level of various efficiency in Henan province according to the measurement results, as shown in Table 2. In addition, in order to directly reflect the temporal change trend of the efficiency, this paper also draws the mean change map of the efficiency, as shown in Figure 2. The change of agricultural ecological efficiency is largely influenced by factors such as farmers production behavior and government policy orientation.

First, from the perspective of agricultural ecological efficiency, Henan generally showed a fluctuating upward trend from 2009 to 2022, from 0.6739 in 2009 to 0.8099 in 2022. It can be divided into four stages: 2009-2016 is the fluctuation rise stage, Up to 0.7336 from 0.6739; In 2017-2019 ushered in a weak decline, Down from 0.7628 to 0.7286; Up sharply in 2019-2021, To 0.8493 from 0.7286, 2021-2022, Down to 0.8099 from 0.8493, The overall "W" type characteristics, In 11 years, the average agricultural ecological efficiency of the province was 0.7623, The peak occurred in 2021, The valley values appeared in 2009. Secondly, from the perspective of pure technical efficiency, the average level during the study period was 0.9399, except that 2018 was significantly lower than the other years, all higher than ecological efficiency and scale efficiency in the other years. The change trend can be divided into two stages: from 2009 to 2018, the fluctuation decreased from 1.0474 to 0.8904; from 2018 to 2022, it increased from 0.8904 to 0.9787. Finally, the mean scale efficiency is 0.8111, and the change is also characterized by two stages, and the change trend is basically consistent with the ecological efficiency. Rose from 0.6433 to 0.8597 in 2009-2021 and decreased significantly in 2021-2022, from 0.8597 to 0.8275.

The change of agricultural ecological efficiency is largely influenced by factors such as farmers production behavior and government policy orientation. The continuous fluctuation of agroecological efficiency from 2009 to 2016 is closely related to the extensive production mode that relies excessively on fossil energy to increase production, Since 2017, Henan has gradually carried out soil testing and fertilizer fertilization, zero growth of chemical fertilizer and promotion of organic fertilizer, The decline of agricultural ecological efficiency has slowed down significantly; In 2018, Henan Province clearly issued the Henan Province 2018-2022 Fertilizer Use Zero Growth Action Plan, which is to point out the direction for fertilizer reduction and efficiency, Under the guarantee of the policy, the agriculture continues to increase the green, During this period, the fluctuation of agricultural ecological efficiency in Henan province increased, The policy has achieved a remarkable effect; besides, In 2016, the General Office of the Provincial Government issued the Opinions on Accelerating the Cultivation of New Professional Farmers, which effectively accelerated the pace of cultivating new professional farmers in Henan, The ranks of high-quality farmers are growing, The awareness of green production is deeply rooted in the peoples hearts, For Henan agricultural ecological efficiency to inject vitality.

From the perspective of efficiency mean, the mean of pure technical efficiency is the highest, the scale efficiency and the second ecological efficiency is the lowest during the research period. Comparing the changing trend of each efficiency, it can be seen that the factors that restrict the improvement of agricultural ecological efficiency in different stages. In 2009-2018, with the decrease of pure technical efficiency and the increase of scale efficiency, the agricultural ecological efficiency is gradually increased; in 2018-2020, due to the large decrease of agricultural ecological efficiency; in 2020-2021, thanks to the large increase of scale efficiency, the agricultural ecological efficiency is generally increased; in 2022, the pure technical efficiency and scale efficiency are decreased simultaneously, leading to the downward trend of agricultural ecological efficiency. Therefore, in the future, we should not only vigorously promote advanced technology, but also actively promote land circulation to guide moderate scale operation, improve pure technical efficiency and scale efficiency, and promote the improvement of agricultural ecological efficiency.

Table 2. Average value of agricultural efficiency in Henan Province from 2009 to 2022.

Year	Ecological Efficiency	Pure Technical Efficiency	Scale Efficiency
2009	0.6739	1.0474	0.6433
2010	0.7552	0.9433	0.8006
2011	0.771	0.9708	0.7941
2012	0.7518	0.9437	0.7967
2013	0.7276	0.9211	0.7899
2014	0.7469	0.9342	0.7995
2015	0.7613	0.8982	0.8476
2016	0.7336	0.9236	0.7943
2017	0.7628	0.9089	0.8392
2018	0.728	0.8904	0.8175
2019	0.7286	0.9083	0.8021
2020	0.7839	1.0101	0.776
2021	0.8493	0.9879	0.8597
2022	0.8099	0.9787	0.8275
average	0.7623	0.9398	0.8111

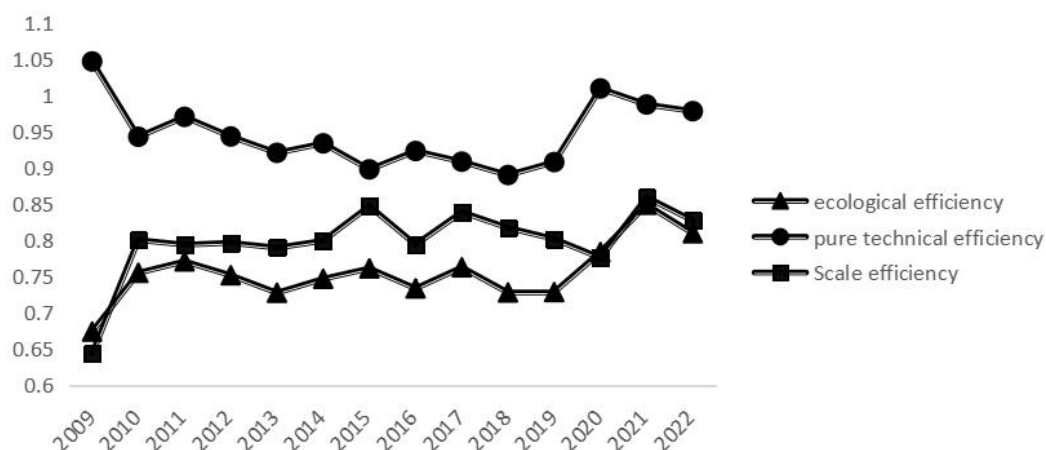


Figure 2. Change chart of agricultural efficiency in Henan Province from 2009 to 2022.

5. Policy Recommendations

Based on the panel data of 17 prefecture-level cities in Henan province from 2009 to 2022, this paper measures the agricultural ecological efficiency of 2009-2022 in

Henan province from 2009 to 2022. On the whole, the agricultural ecological efficiency in Henan showed a fluctuating upward trend from 2009 to 2022.

5.1. Increase special financial funds to support agricultural ecological construction

We should continue to improve the agricultural ecological compensation system to provide financial ecological compensation for the positive externalities of agricultural ecological protection and the uncertainty of benefits. At the same time, we will establish a green and eco-oriented agricultural financial subsidy system, increase financial subsidies for promoting the use of organic fertilizers and green agricultural technologies, support the reduction of the use of traditional chemical fertilizers and pesticides, and strengthen financial support for agriculture to protect the agricultural ecological environment.

5.2. Promote the appropriately scaled operation of agricultural land use

Rational use of all kinds of agricultural land, pay attention to the protection of cultivated land and the improvement of soil quality. The land should be rationally used according to the terrain characteristics and the economic and social needs. We will properly handle land for agriculture, industry and land for urban construction. On the other hand, constantly improve the land transfer system, accelerate the promotion of rural land transfer. By strengthening the standardized operation, encouraging the cities to actively explore the circulation mode to adapt to the local reality and establish and improve the service system of these three aspects to achieve.

5.3. To guide the rational use of chemical fertilizers and pesticides

Use chemical fertilizers and pesticides rationally, improve the use efficiency of pesticides and chemical fertilizers, develop new organic fertilizers, reduce the amount of pesticides, reduce the environmental pollution caused in the process of chemical fertilizer application, and reduce the excessive dependence of agricultural production on chemical fertilizers. To improve the degree of knowledge, specialization and technology of farmers, so that farmers can master scientific fertilization technology, rationally and efficiently fertilize with fertilizer, and use related technologies to improve the content of soil organic matter and increase the unit yield of crops.

5.4. Control of agricultural pollution from the source

Agricultural pollution has become one of the important sources of environmental pollution, agricultural environment protection and agricultural sustainable development conditions, prevent the rural ecological environment deterioration, improve farmers environmental protection consciousness, reasonable development and utilization of agricultural ecological resources and protection, relying on scientific and technological progress, personnel training, technological innovation to improve the overall efficiency of agriculture, the development of ecological agriculture, not to rely on agricultural resources and agricultural pollution as the premise.

6. Conclusions

Chinese-style modernization is a modernization in which man and nature coexist in harmony. Respecting, conforming to and protecting nature is an inherent requirement of building a modern socialist country in an all-round way. Continuous improvement of the ecological environment is one of the important work to continuously improve

people's livelihood, which will have a profound impact on the sustainable and healthy development of society and economy. "The environment is people's livelihood, green mountains are beautiful, and blue skies are happiness." With the comprehensive progress of the construction of a beautiful China, the ecological environment quality has improved steadily, and the discharge of major pollutants has continued to decline. China's sky is bluer, the land is greener, the water is cleaner, and the rivers and mountains have become more colorful. In the face of the people's new expectations for a better life and the new requirements for promoting high-quality development through high-level protection, the pace of building a beautiful China is still accelerating. We will strengthen ecological progress and promote green and low-carbon development. We will fully implement the concept that clear waters and lush mountains are mountains of gold and silver, work together to reduce carbon, pollution, green and growth, and build a beautiful China in China where man and nature coexist in harmony."

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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