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The Relationship between Low-carbon Agriculture and Agricultural Science and Technology Based on Gray Relational Theory

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Abstract The agricultural energy consumption per unit of GDP is selected as an indicator for measuring the development level of low-carbon agriculture. Using gray relational theory, I analyze the relationship between development level of agricultural science and technology and development level of low-carbon agriculture in China. The results show that the correlation between the two is prominent; the number of agricultural science and technology talents, the number of agricultural science and technology patents, and the number of agricultural science and technology input are three major factors influencing the development of low-carbon agriculture. On this basis, I propose to take further effective measures, and put forth corresponding recommendations, in order to improve the level of agricultural science and technology.

Key words Low-carbon agriculture, Agricultural science and technology, Gray relational theory

Currently, there is still no clear definition of low-carbon agriculture. From three aspects, Xu Guangyue[1] expounds the connotation of low-carbon agriculture: (i) In terms of the relationship between agriculture and greenhouse gas emission, low-carbon agriculture aims to achieve the goal of constant decline in the net agriculture-source greenhouse gas emission, by promoting agriculture's carbon sink capacity, and abating agriculture's carbon source capacity. (ii) In terms of function of low-carbon agriculture, low-carbon agriculture is to comprehensively coordinate agriculture's economic, ecological and social functions. (iii) In terms of the connotation factor of low-carbon agriculture, low-carbon agriculture not only includes the factors of circular agriculture, but also includes the components of ecological agriculture, which is typical resource-saving and environment-friendly agriculture. Luo Jiwen[2] believes that the essence of low-carbon agriculture is the low-carbon, high-carbon use of energy, and development of clean energy. Wu Yiping[3] believes that low-carbon agriculture is the modern agriculture based on low consumption, low pollution, and low emission, the essence of which is high efficiency of energy and resource use, clean energy structure and clean production; the core of which is utilization technology innovation of energy and resource, system innovation, and fundamental change of human development concept. Qi Zhenhong, *et al.*[4] believe that low-carbon agriculture is the use of circular economy in agriculture, which aims to develop resource-saving and environment-friendly agricultural production system, with main characteristics of low input, low consumption, low pollution and high efficiency. China's agriculture is still running under the traditional system, having not yet formed a new mechanism conducive to the development of low-carbon agriculture.

As far as I'm concerned, low-carbon agriculture is a mode of economic development, with the agricultural energy conservation and emission reduction as the means and greenhouse gas emission reduction as the goal, using modern techniques and methods to achieve the harmonious development of agriculture and other industries.

To improve the development level of low-carbon agriculture in China, we must draw on the power of agricultural science and technology. For a long time, the level of agricultural science and technology in China is not high, and there is a great gap between the level of agricultural science and technology in China and that in developed countries. For example, the agricultural science and technology input in China is less than one sixth of that in America, less than one fifth of the average level of developed countries, only equivalent to about 50% of agricultural science and technology input in developing countries. Low level of agricultural science and technology largely restricts the improvement in development level of low-carbon agriculture in China. To this end, Central Document No. 1 in 2012 focuses exclusively on the problems of agricultural science and technology, raising improvement in the level of agricultural science and technology to unprecedented height[5-7].

Using gray relational theory, I analyze the relationship between development level of agricultural science and technology and agricultural energy efficiency, in order to draw scientific conclusions, and provide a reference for the development of low-carbon economy.

1 Data source, indicator selection and research method

1.1 Data source Data are from *China Statistical Yearbook*

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(2002 –2010).

1.2 Indicator selection We select the agricultural energy consumption per unit of GDP (denoted as A, unit: t standard coal/10^4 yuan) as the indicator to measure development level of low-carbon agriculture; the number of agricultural science and technology input (denoted as B_1, unit: 10^8 yuan), the number of agricultural science and technology talents (denoted as B_2), and the number of agriculture, forestry, animal husbandry and fishery patents (denoted as B_3), as the indicators to measure development level of agricultural science and technology in China (Table 1).

Table 1 The raw data on the relationship between the agricultural energy consumption per unit of GDP and the level of agricultural science and technology during the period 2002 –2008

Year	A	B_1	B_2	B_3
2002	0.394	9.9	666 998	1 989
2003	0.386	12.4	683 437	2 530
2004	0.359	15.6	704 576	2 758
2005	0.356	19.9	705 720	3 157
2006	0.349	21.4	701 930	4 380
2007	0.288	23.6	701 481	5 053
2008	0.178	25.7	715 774	5 598

The core of the development of low-carbon agriculture is to minimize energy usage in agricultural development, so as to achieve the scientific, stable and sustainable development of agriculture. Therefore, selecting the agricultural energy consumption per unit of GDP as the indicator is scientific for measuring development level of low-carbon agriculture in China. The agricultural science and technology input represents the national fiscal funds used directly for agricultural science and technology; the number of agricultural science and technology talents represents the size of the agricultural science and technology personnel; the number of agriculture, forestry, animal husbandry and fishery patents can better reflect the level of output of agricultural science and technology. Therefore, using these 3 indicators can basically show the level of development of agricultural science and technology in China.

1.3 Research method Gray relational dynamic analysis method is used.

2 Results and analysis

2.1 Modeling steps of gray relational dynamic analysis

2.1.1 Establishing dependent variable reference series and independent variable comparison series of the original series.

The dependent variable reference series is also called the parent series, denoted by $x_0^{(k)}: x_0^{(k)} = [x_0^{(1)}, x_0^{(2)}, x_0^{(3)}, \cdots, x_0^{(k)}]$.

The independent variable comparison series is also called the subseries, denoted by $x_i^{(k)}: x_i^{(k)} = [x_i^{(1)}, x_i^{(2)}, x_i^{(3)}, \cdots, x_i^{(k)}]$ $(i=1, 2, 3, \cdots, n)$.

2.1.2 Nondimensionalizing the original series. In order to eliminate the influence caused by different sizes of order of magnitude so as to facilitate calculation and comparison, we can use the initialization method and the mean method to nondimensionalize the original series.

The calculation formula is $x_i^{(k')} = x_i^k / x_i^{(1)}$ or $x_i^{(k')} = x_i^k / \overline{x_i}$.

2.1.3 Calculating the absolute value of difference between the parent series and each subseries at each time point to find the maximum difference and the minimum difference.

Difference series: $\Delta_i(k) = |x_0^{k'} - x_i^{k'}|$ $(i=1, 2, 3, \cdots, n)$.

Thus difference series: $\Delta_i = [\Delta_i(1), \Delta_i(2), \Delta_i(3), \cdots, \Delta_i(k)]$.

The maximum difference: $\Delta_{max} = \max_i \max_i |x_0^{k'} - x_i^{k'}|$.

The minimum difference: $\Delta_{min} = \min_i \min_i |x_0^{k'} - x_i^{k'}|$.

2.1.4 Calculating the gray relational coefficient

$$L_{0i}^{(k)} = \frac{\Delta_{min} + \lambda \Delta_{max}}{\Delta_i(k) + \lambda \Delta_{max}}$$

where $L_{0i}^{(k)}$ is the correlation coefficient of k numbers in subseries x_i $(i=1, 2, 3, \cdots, n)$ and the parent series x_0; λ is distinguishing coefficient, which is between 0 and 1 (often $\lambda = 0.5$).

2 1.5 Calculating the gray relational degree. In order to calculate the overall relational degree, we need to take into account the importance of the different observation points in the overall observation. Therefore, it is necessary to determine the weight of each point.

Under normal circumstances, we calculate the gray relational degree, using the arithmetic mean method:

$$r_{0i} = 1/n \sum_{k=1}^{n} r_{0i}(k)$$

where r_{0i} is the correlation coefficient between series x_0 and series x_i.

2.1.6 Sequencing of relational degree. According to the size of r_{0i}, I sequence the relational degree. If the relational degree is close to 1, it indicates that the correlation degree will be great. According to experience, when $\lambda = 0.5$ and relational degree is greater than 0.6, the correlation is believed to be significant[8–10].

2.2 Gray relational degree analysis

2.2.1 Calculating the initial value of the series.

Initialization values of the relationship between the agricultural energy consumption per unit of GDP and the level of agricultural science and technology are shown in Table 2.

Table 2 Initialization values of the relationship between the agricultural energy consumption per unit of GDP and the level of agricultural science and technology

	Year						
	2002	2003	2004	2005	2006	2007	2008
A	1	0.979	0.911	0.904	0.886	0.731	0.452
B_1	1	1.253	1.576	2.010	2.162	2.384	2.596
B_2	1	1.025	1.056	1.058	1.052	1.052	1.073
B_3	1	1.272	1.387	1.587	2.202	2.540	2.814

2.2.2 Calculating the difference series. Taking the agricultural energy consumption per unit of GDP as the parent series, we get the difference series, as is shown in Table 3.

Table 3 Difference series and relational coefficient of the relationship between the agricultural energy consumption per unit of GDP and the level of agricultural science and technology

Year	Difference series			Relational coefficient		
	B_1	B_2	B_3	B_1	B_2	B_3
2002	0	0	0	1	1	1
2003	0.274	0.046	0.293	0.812	0.963	0.801
2004	0.665	0.145	0.476	0.640	0.891	0.713
2005	1.106	0.154	0.683	0.516	0.885	0.634
2006	1.276	0.166	1.316	0.481	0.877	0.473
2007	1.653	0.321	1.809	0.417	0.786	0.395
2008	2.144	0.621	2.362	0.355	0.655	0.333

2.2.3 Calculating the range. It can be seen from Table 3 that the maximum difference is 2.362 and the minimum difference is 0.

2.2.4 Calculating the relational coefficient. Taking , we get the correlation coefficient, as is shown in Table 3.

2.2.5 Calculating the relational degree. The relational degree between China's agricultural energy consumption per unit of GDP and various factors of technological development level is: $R_{01}=0.603$, $R_{02}=0.865$, $R_{03}=0.621$.

2.2.6 Sequencing the relational degree. As to the technological development factors influencing the agricultural energy consumption per unit of GDP in China, the sequencing in accordance with the size of relational degree is: $R_{02}>R_{03}>R_{01}$.

3 Conclusions and recommendations

It can be seen from the above analysis that the three factors concerning development level of agricultural science and technology all have a significant impact on the development level of low-carbon agriculture.

The agricultural science and technology factor having the greatest impact on development level of low-carbon agriculture is the number of agricultural science and technology talents in China. We must further take some measures. On the one hand, it is necessary to increase the number of agricultural science and technology personnel, for example, increasing the enrollment number of students majoring in agricultural science in college, in order to provide a reliable source for agricultural science and technology talent. On the other hand, it is necessary to formulate more scientific and effective incentive mechanism, fully mobilize the enthusiasm of the existing agricultural science and technology personnel and fully exploit their potential, to provide the impetus for ceaselessly emerging new scientific and technological achievements.

Another important factor influencing the development level of low-carbon agriculture is the amount of patents in agriculture, forestry, animal husbandry and fishery. In the light of data, the coefficient of correlation between the two is only 0.621, not too high. The reason is that the conversion rate of China's agricultural scientific and technological achievements is low, an average of only 30% to 40%. By contrast, the average conversion rate of agricultural scientific and technological achievements in the developed countries reaches 70% –80%, and the conversion rate of agricultural scientific and technological achievements in Israel even reaches more than 90%.

China should take effective measures, so that the agricultural scientific and technological achievements can be effectively converted. It is necessary to develop effective conversion incentive system of agricultural scientific and technological achievements, and fully mobilize the enthusiasm of the agricultural scientific and technical personnel, for example, making agricultural scientists and technicians participate in the sharing of profit from conversion of agricultural science and technology achievements. On after a large number of agricultural scientific and technological achievements are converted, can agricultural science and technology in China really play the role of promoting the development of low-carbon agriculture.

The agricultural science and technology input also has a significant impact on the development of low-carbon agriculture. At present, the agricultural science and technology input in China is insufficient, only equivalent to about 0.4% of GDP. We should promote the quantity and quality of agricultural science and technology input, and make full use of the limited agricultural science and technology funds; focus on those agricultural technologies that can not only increase agricultural yield, but also save energy. Only by this way can we give play to the role of the agricultural science and technology input to the extreme.

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