The Evaluation on Ecological Agricultural Development in Sichuan Province on the Basis of Grey Relational Analysis

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Abstract By using the grey relational model, 14 indexes of ecological agricultural development in Sichuan Province from 1997 to 2008 are analyzed. According to the relational degree results, the ecological agricultural development in 12 years can be divided into three stages: the first stage is from 1997 to 2000, with the shape of inverted U; the second stage is from 2001 to 2004, belonging to transition stage with slow growth rate; the third stage is from 2005 to 2008, belonging to the stage of rapid growth. It draws conclusion that per capita grain yield is an important element for evaluating ecological agricultural construction. Besides, reducing the energy consumption of per unit production, improving labor productivity and increasing agricultural science and technology application and input on agricultural infrastructure construction are the engine for developing Sichuan ecological agriculture.

Key words Ecological agriculture, Grey relational degree, Sichuan Province, China

Agriculture worldwide is experiencing a structural adjustment and reform in order to face the severe tends of resource shortage, environmental pollution and ecological transmutation. Ecological agriculture is put forward under such circumstance. It is a new comprehensive agricultural system, with rational ecology and good function circulation, which combines modern science and technology achievements with fine traditional agricultural technologies and integrates agricultural production, rural economic development ecological environment management and resource protection and high-efficient application into a whole by using ecology, ecological economics and system science. Ecological agriculture is characterized by integrating economic interests, social benefits and ecological benefits and it is the collection of sustainable agriculture, modern agriculture and industrialized agriculture[1].

As a big province in western China, the population in Sichuan Province accounts for 27.9% of total population among ten provinces in western China and the GDP of Sichuan Province takes 28.9%[2] of total GDP in western China. Sichuan is a granary province, as well as an important base for Chinese grain crops, cash crops and live pigs. It is the biggest vegetable "basket" in western China[3]. Within Sichuan Province, the forest, water resources and river runoff list top in western China and even in the whole nation, so it is also an important ecological shelter in the middle and upper stream of the Yangtze River. Developing ecological agriculture in Sichuan Province has bright prospects and can facilitate the rapid development of local economic development promptly. Constructing ecological agriculture is conducive to enhancing the sustainable development capability of Sichuan Province, improving environmental quality of ecology within the province, promoting ecological economic development and adjusting industrial structure.

Sichuan Province owns 20 years' experiences in launching ecological agricultural pilots, at present; it has had two national level ecological villages, 150 provincial ecological villages and 450 city and county level ecological villages. Hence, deep analysis on Sichuan ecological agriculture is of great significance in ecological agriculture construction in west China.

1 Research method and data source

1.1 Research method

1.1.1 Grey relational degree model. The grey relational analysis came from the grey system theory put forward by Professor Deng ju-long. Its basic thought is to weight relational degree according to the developing trend of each element and the similarity and disparity degree of the elements[4]. If two series have similar curve, close distance, then the relational degree of the two is big; or else, the relational degree is small. Grey relational degree model has lower demand on the number and distribution of the samples than regression analysis and it is often used to quantitative comparison analysis of development and changing system, so it is suitable for studying the developing and changing trend of Sichuan ecological agriculture. The specific analysis method is as follows:

Let the reference series $Y_{0j} = \{X_{01}, X_{02}, \cdots, X_{0n}\}$ comparison series $Y_{ij} = \{X_{i1}, X_{i2}, \cdots, X_{im}\}$, $(i = 1, \cdots, n, j = 1, \cdots, m)$, according to the grey theory, the grey relational coefficient ξ_{ij} is:

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$$\xi_{ij} = \frac{\Delta_{\min} + \rho\Delta_{\max}}{\Delta_{ij} + \rho\Delta_{\max}}$$

In the formula, $\Delta_{ij} = |X_{0i} - X_{ij}|$: $\Delta_{\min} = \min_{1\leqslant i\leqslant n}\min_{1\leqslant j\leqslant m}|X_{0j} - X_{ij}|$; $\Delta_{\max} = \max_{1\leqslant i\leqslant n}\max_{1\leqslant j\leqslant m}|X_{0j} - X_{ij}|$; ρ is identification coefficient, according to the current practice, its value is 0.5. Then grey relational degree γ_i is:

$$\gamma_i = \frac{1}{m}\sum_{j=1}^{m}\xi_{ij}$$

1.1.2 Construction of evaluation index system. Benefits of the system is the direct aim sought by people, so the evaluation on the development of Sichuan ecological agricultural development is based on the evaluation on the comprehensive benefits of index system. The paper constructed the comprehensive evaluation system for Sichuan ecological agriculture by using the frequency statistics according to the features and characteristics of Sichuan ecological agricultural construction, by flowing the principals of integrity, feasibility and dynamicity, as well as the ecological, economic and social benefits[5-7]. The specific evaluation system includes content from three aspects and 14 participating factors. The first one is agricultural economic development index, including net income per capita of rural household, agricultural labor productivity, agricultural land productivity and social fixed capital investment in agriculture, forest, animal husbandry, sideline business and fishery. This kind of indexes are used to reflect the agricultural economic developmental level in the process of developing agricultural development. The second one is agricultural ecological indexes. Among them, the environment quality indexes include prevention and control rate of forest diseases and pests, forest coverage rate and popularity of rural household toilets; resource use indexes include effective irrigation rate, intensity of fertilizer usage and agricultural energy consumption index. The two kinds of indexes reflect the ecological environment change in the development of agriculture and resource use situation of agricultural production respectively. The third one is social development indexes, including natural growth rate of population, Engel coefficient of rural households, and application of science and technology results in agriculture, forestry, animal husbandry, sideline business and fishery, per capita grain production. The index is mainly used to reflect the social development degree.

1.1.3 Determination of index weight. In classical grey analysis, the calculation of grey degree supposes that the indexes with equal weights. But in view of the different features and characteristics of each index, and the different contribution degree of evaluation, so the paper changes the weights to give the indexes new weights. In the frequently used weighting methods, the objective weighting method(for example variation coefficient, entropy method and so on) does not rely on people's subjective judgment and has strong objective feature comparing with subjective weighting method(for example AHP method and Delphi method). Therefore, the paper adopts the widely used variation coefficient method in objective weighting method to determine the weight of indexes to let the sample statistics to determine the distribution of weight, so as to avoid the influence of subjective factors.

The specific weight of each index w_j is:

$$w_i = \frac{CVx_i}{\sum_{i=1}^{n} CVx_i}$$

In the equation, the variation coefficient $CVx_i = \frac{sdx_i}{\overline{x_i}}$.

Table 1 Comprehensive index system and index weight of Sichuan ecological agriculture

Evaluation index		Specific index	Meaning of the index
Agricultural economic development index		x_1 refers to per capita income of rural households(0.082 7)	Reflecting the living situation of famers
		x_2 refers to agricultural labor productivity (0.145 9)	Gross production of agriculture, forestry, animal husbandry and fishery/agricultural labors, is the comprehensive economic index that reflects the agricultural labor productivity of an area
		x_3 agricultural land productivity(0.075 7)	Agricultural gross production/total sown acreage of agricultural crops, directly reflects the economic interests of agricultural production
		x_4 social fixed capital investment on agriculture, forestry, animal husbandry, sideline business and fishery (0.203 3)	Currency expression of constructing agriculture, forestry, animal husbandry, sideline business and fishery and the workloads of purchasing fixed assets
Ecological index	Environment quality index	x_5 prevention and control rate of forest disease, pests(0.029 7)	Comprehensive prevention and control area of diseases and pest/area of diseases and pests
		x_6 forest coverage(0.046 1)	Area of forest/total land area, referring the important role played by the index in protecting the improving the macro-ecological environment of the area
		x_7 popularity of rural household toilets (0.067 6)	One of the indexes that represent rural living environment
	Resource use index	x_8 effective irrigation rate(0.032 3)	Effective irrigation land area/total area of farmland
		x_9 intensity of fertilizer use(0.057 0)	Quantity of fertilizer use/sown acreage of agricultural crops

Continued (Table 1)

Evaluation index	Specific index	Meaning of the index
	x_{10} agricultural energy consumption index (0.062 0)	The index reflects the situation of energy consumption level and energy saving situation
Social development index	x_{11} natural growth rate of population (0.100 6)	The index reflects the developmental momentum of regional population. Population is an important social element, which has great significance on ecological environment
	x_{12} Engel coefficient of rural households (0.025 7)	Per capita food consumption expenditure/per capita consumption expenditure, reflecting the social developmental degree
	x_{13} application items of science and technology of agriculture, forestry, animal husbandry, sideline business and fishery (0.051 5)	The index reflects the science and technology input degree on agriculture, forestry, animal husbandry, sideline business and fishery
	x_{14} per capita grain production (0.019 9)	Total grain production/total population, reflecting the social security and food safety degree

1.2 Data source 14 relevant statistics of agricultural indexes ranging 12 years are selected. The statistics mainly come from *Sichuan Statistical Yearbook*[8], *Sichuan Yearbook*[9], *Sichuan Economic Yearbook*[10] and *Chinese Statistical Yearbook*[2].

Due to the great disparity among different evaluation indexes, in order to eliminate the influences of dimensions, extreme value of the statistics is standardized. Among the statistics, ecological agriculture is the agricultural model that needs low consumption and sustainable development, so the indexes X_9 (intensity of fertilizer use), X_{10} (agricultural energy consumption index), X_{11} (natural growth rate of population) and X_{12} (Engel coefficient of rural households) are taken as negative indexes and the rest are positive indexes.

The paper studies the developing and changing situation of Sichuan ecological agriculture, in order to conduct quantitative analysis on the development and change of Sichuan ecological agriculture. In the following grey relational analysis, the time axis is taken as the division evidence and the economic index in year i is used as a comparison series $Y_i\{i \mid 1 \leqslant i \leqslant 12\}$, at the same time, taking the best statistics in the indexes of Sichuan ecological agriculture in the previous years to form the target series Y_0.

2 Results and analysis

2.1 Calculation results of relational degree (1) Relational coefficient can be calculated by using one target series and 12 comparison coefficients. The results can be seen on Table 2.

Table 2 The relational coefficient of target series and comparison series

	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9	Y_{10}	Y_{11}	Y_{12}
X_1	1.000 0	0.654 8	0.687 3	0.697 7	0.831 8	0.857 6	0.552 9	0.902 3	1.000 0	0.525 6	0.495 5	0.377 9	0.333 3
X_2	1.000 0	0.336 2	0.381 0	0.333 3	0.352 0	0.357 4	0.368 2	0.430 8	0.513 9	0.605 9	0.778 8	1.000 0	0.880 0
X_3	1.000 0	0.333 3	0.363 9	0.410 3	0.441 2	0.482 1	0.537 8	0.564 9	0.627 9	0.706 8	0.630 8	0.818 2	1.000 0
X_4	1.000 0	0.333 3	0.339 2	0.368 4	0.434 2	0.480 3	0.690 0	1.000 0	0.998 2	0.883 5	0.900 5	0.880 7	0.875 2
X_5	1.000 0	0.333 3	0.343 5	0.348 8	0.354 9	0.363 8	0.377 3	0.392 2	0.441 9	0.480 7	0.521 7	0.679 9	1.000 0
X_6	1.000 0	0.333 3	0.345 3	0.347 2	0.353 6	0.359 4	0.372 3	0.385 7	0.436 5	0.465 0	0.504 7	0.691 8	1.000 0
X_7	1.000 0	0.341 4	0.343 5	0.334 6	0.335 0	0.333 3	0.348 3	0.354 7	0.421 0	0.435 7	0.425 4	0.590 7	1.000 0
X_8	1.000 0	0.333 3	0.336 1	0.339 2	0.344 8	0.350 9	0.363 4	0.361 3	0.371 6	0.406 3	0.469 4	0.582 0	1.000 0
X_9	1.000 0	0.333 3	0.384 6	0.466 7	0.522 4	0.593 2	0.573 8	0.339 8	0.573 8	0.393 3	0.660 4	0.432 1	1.000 0
X_{10}	1.000 0	0.813 4	0.932 0	1.000 0	0.725 6	0.333 3	0.422 6	0.368 6	0.424 9	0.463 4	0.366 5	0.414 8	0.454 7
X_{11}	1.000 0	0.333 3	0.381 0	0.415 6	0.533 3	0.603 8	0.666 7	0.800 0	0.864 9	0.842 1	0.842 1	0.8421	1.000 0
X_{12}	1.000 0	0.333 3	0.365 7	0.377 3	0.523 8	0.520 0	0.552 1	0.552 1	0.488 1	1.000 0	0.725 9	0.630 0	0.647 1
X_{13}	1.000 0	0.962 2	1.000 0	0.777 3	0.642 6	0.595 3	0.577 9	0.495 8	0.458 8	0.433 1	0.502 8	0.351 8	0.333 3
X_{14}	1.000 0	0.646 8	0.380 5	0.395 2	0.373 6	0.334 5	0.333 3	0.351 3	0.381 6	0.428 1	0.376 6	0.776 0	1.000 0

(2) combining weghiting in Table 1 and relational coefficients in Table 2 to calculate the relational degree of each series (Table 3).

Table 3 Relational degree of each comparison series

Reference series	Relational degree	Reference series	Relational degree
Y_1	0.479 9	Y_7	0.473 3
Y_2	0.517 4	Y_8	0.530 0
Y_3	0.532 3	Y_9	0.536 6
Y_4	0.499 6	Y_{10}	0.548 3
Y_5	0.435 9	Y_{11}	0.608 0
Y_6	0.465 5	Y_{12}	0.816 4

2.2 Analysis on the developmental momentum of Sichuan ecological agricultural development According to the 12 relational degrees of comparison series, the curve of relational degree of ecological agricultural development in Sichuan Province can be made up (Fig. 1). It can be seen from Fig. 1 that the overall level of ecological agricultural development in Sichuan Province is between 0.435 9 and 0.816, with upward trend.

According to the changes of relational degree , the ecological agricultural development in Sichuan Province from 1997 to 2008 can be divided into three stages:

The first stage is from the year of 1997 to 2000, in the

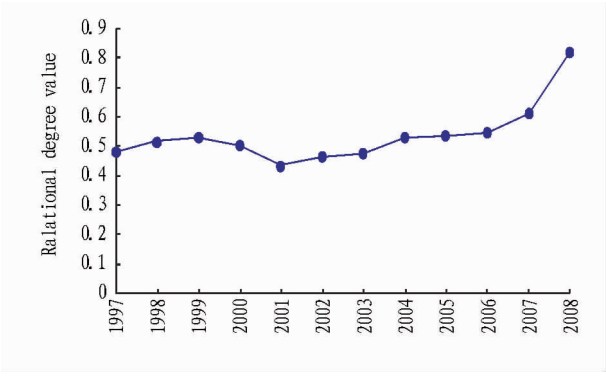


Fig. 1 Relational degree of ecological agricultural development in Sichuan Province

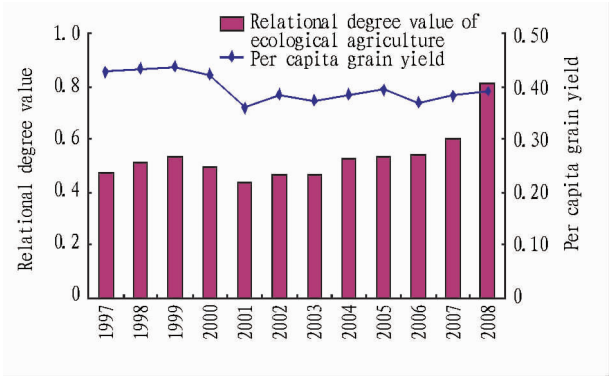
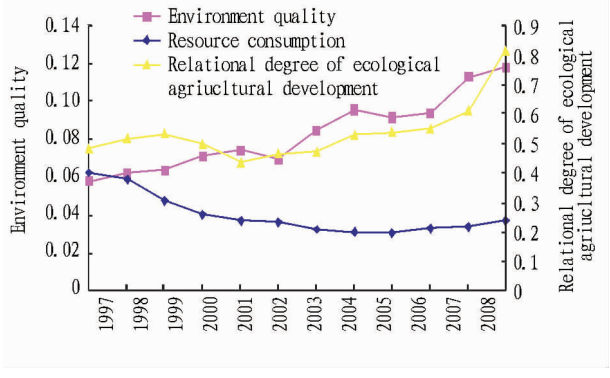


Fig. 2 relations between relational degree of Sichuan ecological agricultural development and per capita grain production

stage, the development showed the shape of inverted " U". From 1997 to 1999, it was in upward tending, but after 1999, the development of ecological agriculture showed downward trend. From the original statistics, in this stage, most indexes of ecological agricultural construction in Sichuan Province changed following the same developmental tend and had no special fluctuations, except for Engel coefficient of rural households and grain production per capita. The two indexes changed with different tend after 1999. In the first three years of the stage, the Engel coefficient of rural households kept the gradual devclining tends, but in 2000, the coefficient increased 1 percentage, which was related to the stable economic development of the whole Province and the small rebound of price. But it can not be concluded that economic development can not promote ecological agricultural development. The per capita grain production index decreased from 0.438 9 t/people in 1999 to 0.362 2 t/people in 2001, with the decrease rate of 11%, but in the same period, the natural population growth rate kept the descending tend, so the decrease of per capita grain production had something to do with the aggregate grain production (Fig.2). In 1998, Sichuan Province was hit by great flood, so in 2001, the grain production dropped 9.99 million t sharply. It all indicated that the shrink of grain acreage from 1999 to 2001 and the drop of grain production are the key for the decelerating of ecological agricultural development. Food security is closely related to ecological agricultural construction and per capita grain production is the important factor for evaluating construction achievements of ecological agriculture.

As a saying goes" people lives on food". Food is not only the important strategic materials concerns national welfare and people's livelihood and national economic security, but also relates to the basic living materials of the masses and the key to maintaining social stability. At present, there are two ways for improving grain production. The first one is to improve the per unit yield of crops and the other way is to promote the " big grain" plan, for example, transforming the agricultural crop residues to meat, milk and so other kinds of food[11]. The ecological agriculture, with the feature of recycling , establishes a complete agricultural recycling biological chain, which is jointly participated by animals and plants, takes biological way to replace chemical way to prevent and control pest problems and takes the animal dropping as the organic fertilizer to ensure grain production and realize food safety.

The second stage is from 2001 to 2004, belonging to transitional stage. The construction of ecological agriculture shows the slow growth status and the relational degree increased simultaneously from 0.435 9 to 0.530 0. combining with the original data, the growth of each index in this stage was slow and under the 10%, only the per unit energy consumption indexes of agriculture, forestry, animal husbandry, sideline production and fishery began to decline from 2002 which was contradictive to that in four years ago. In planning the evaluation index system, the per unit energy consumption of agriculture, forestry, animal husbandry, sideline production and fishery were taken as negative indexes. In this stage, the decrease of per unit energy consumption and the increase of relational degree of ecological agricultural construction better provide the reasonability of the consumption. Different from the environmental indexes, the indexes indicate resource per unit production value of agriculture, forestry and animal husbandry had reversed relation with ecological agricultural construction(Fig.3).



Note: resource consumption index only includes intensity of fertilizer use and agricultural energy consumption. The environmental quality evaluation index is the sum of three items of indexes.

Fig. 3 Relations of Sichuan ecological agricultural developmental relational degree with environmental index and resource consumption index

On this stage, the average annual growth rate of ecological agricultural development relational degree was 12%, but from Fig.1, it is known that the growth rate dropped obviously in 2003. from the perspective of the specific indexes, the val-

ues of the fixed assets investment and science and technology application in 2003 were lower than the previous year, the two weights ranks the first and the eighth in the whole evaluation system. Therefore, it can be predicted that under the situation that the basic index is stable or with stable change rate, the fixed assets investment and agricultural science and technology application has great influence on the development of Sichuan ecological agriculture. To be specific, perfecting the diversified agricultural input mechanism and optimizing agricultural expenditure structure are the crucial points for further increasing the input on agriculture.

Besides, the agricultural science and technology can enhance the replace rate of resources and use return rate of resource to accelerate the pace of ecological agricultural development. Although the contribution rate of agricultural science and technology in Sichuan Province has improved, the growth is slow[2]. Therefore, it is necessary for creating favorable agricultural science and technology investment environment; establish diversified collecting channels of agricultural science and technology; promote the organization and application of "production, studying and research" and facilitate the enterprises to become the main body of agricultural science and technology.

The third stage was from 2005 to 2008, it is the stage of rapid growth. In the stage, each index will grow with large rate; the following five indexes have come to the maximum value. The popularity rate of toilets (43.90%), per capita net income of rural households (4 121.21 yuan), labor productivity rate (1 785.5 yuan/people), land productivity (1 634.5 yuan/hm^2), investment of fixed investment (28.171 billion yuan), among them the labor productivity had the highest growth. In 2008, the labor productivity is the 1.759 times of than in 2005. It can be deduced that the index has the similar growth tend with the relational degree of ecological agricultural development. At the same time, the weight of labor productivity rate ranked the second in the whole ecological agricultural system in Sichuan Province. It can be inferred that agricultural labor productivity rate played a promotion role in the development of ecological agriculture. Ecological agriculture is three dimensional agricultural developmental mode which collects sustainable agriculture, agricultural industrialization and agricultural modernization. In China, in order to realize the above aim, the industrialized development of agriculture should be paid much attention to and the labor productivity rate should be improved. It is also one of the important measures for securing food safety.

3 Conclusions

In the first place, the evaluation index system of ecological agricultural development in Sichuan Province is established. The developmental momentum of ecological agriculture in Sichuan Province is analyzed by using grey relational analysis. According to the comprehensive relational degree of ecological agricultural development in Sichuan Province, the historical development level of ecological agriculture in Sichuan Province is low but in recent years, it has great improvement. The developmental process of ecological agricultural development in Sichuan Province is divided into three stages. The first stage is from 1997 to 2000, with the shape of reverted "U"; the second stage is from 2001 to 2004, and it is the development and transitional stage; the third stage is from 2005 to 2008 and it is the rapid growth stage.

In the second place, the food safety is closely connected with ecological agricultural construction. Per capita grain production is an important element for evaluating ecological agricultural construction. But resource consumption, especially the per unit yield consumption of agriculture, forestry, animal husbandry and sideline production and fishery are contradictive to ecological agricultural construction. The application of science and technology fruits plays a promoting role in ecological agricultural development. At the same time, the investment of basic construction plays an important role in ecological agriculture. The two are both the engines for ecological agricultural development of Sichuan Province. The stimulation functions of labor productivity rate to ecological agricultural development demands the ecological agricultural to realize industrialized development.

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(From page 118)

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