Evaluation Index System of Chinese Eco-agriculture Construction

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Abstract: It is an essential task to make a quantitative analysis for the study of Chinese eco-agriculture construction. The research status of evaluation methods of eco-agriculture construction at home and abroad briefly was discussed. The principle, index system and its weight for the comprehensive evaluation of Chinese eco-agriculture construction were explored with an example of comprehensive evaluation on the practice of eco-agriculture construction at Mulan County of Heilongjiang Province.
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Key words: eco-agriculture construction; index system; index weight

1. Introduction

The evaluation of eco-agriculture construction began in the 1960s and had a rapid development in the 1970s. More and more researches have developed in recent years and focus on the evaluation method, evaluation index system and evaluation criterion. The structure of evaluation index system is the core of eco-agriculture evaluation. Gordon，Conway raised the indices of productivity, stability, durability, flexibility or elasticity as the criteria of measuring the agricultural eco-system performance and described the basic behavior of system for the design of agricultural development planning. With the development of environmental sciences, ecological principles and evaluation methods, the framework system was adopted generally such as the framework system of Pressure-State-Respond (PRS) and Goal—Oriented—Concept (GOC). And with the development of mathematical statistics and mathematical models, many new evaluation methods were proposed, such as the statistical method of fuzzy mathematics and the gray system theory.

The evaluation of Chinese eco-agriculture construction (CEA) began in the 1980s. Although the evaluation has wide inquiries, the principle of selecting indices, the quantity of indices and the hierarchic structure have a great difference and the calculation method of index weight is also different. For example, Yousheng Bian(1994)divided the evaluation index system into economic indices, eco-environmental indices and social benefit indices in the effectiveness evaluation of eco-agriculture system construction of Liuminying village Daxing county of Beijing, which included twenty specific indices. Hongliang Sun(1993)brought up twenty-two specific indices from the system structure, function and effectiveness aspects. And Qianji Ye (1987) brought up more than one hundred indices. The National Eco-agriculture County Construction Leading Group Office wrote the book of *"The Eco-agriculture of China"* in 1996. And it divided the index system of eco-agriculture construction into four layers: the first layer was the composite index of eco-agriculture, the second one was the primary production system index, the sub-class production system index and the processing production system index, the third one was the ecological benefit, economic and social benefit of each subsystem, the fourth layer was composed by thirty-six indices. Most scholars generally used the comprehensive evaluation method to evaluate eco-agriculture construction, in addition, Bin Zhang(1997)applied the theory of matter-element model to the evaluation of eco-agriculture construction on the basis of matter-element theory and extension set theory, Dafeng Pan (1999)applied the artificial neural network theory and the back-propagation algorithm to the evaluation of eco-agriculture construction, Zhiping Cao (1997)applied the holographic theory to the evaluation of eco-agriculture construction. The index system of Chinese eco-agriculture construction and its weight are studied on the basis of previous studies.

2. Selected principles of evaluation index system of eco-agriculture construction

(1) The integration and importance principles

The index system should include the key indices of all study objects and it is necessary to reflect the complexity of eco-agriculture construction comprehensively and accurately. But at the same time the more important indices should be reflected separately and the less important indices can be reflected simply and in combination. For the coverage of eco-agriculture construction is broad and involved the coordinate development of economy, society and environment, the index system should highlight key points on the basis of coverage on a certain degree and it can not include all the indices. A few composite indices can be used to replace some relative indices to guarantee the rationalization of system-level structure and the coordination and harmonization of part and whole to provide the necessary data for the comprehensive evaluation of eco-agriculture construction.

(2) The comparability and operation principles

Because the index system which has the same structure can be compared from space-time continuum, the index system of investigating eco-agriculture construction should be comparable. Not only the economic indices but also the ecological indices should have the uniform standards. In addition, the practical function of index system should also be noted. Because the statistical work of eco-agriculture construction is not very good and the data collection has certain difficulty, this index system should be set up with the representative and comprehensive indices according to the hard and easy extent and reliability of gaining statistical data and meet the future needs of eco-agriculture construction.

(3) The reality and prediction principles

The reality principle means the index system should be able to reflect the basic characteristics of eco-agriculture construction from the current reality. So it should have a higher sensitivity, reflect the different characteristics and have stronger effectiveness and a definite purpose. Some predictive index should be set up on the basis of understanding the present status of Chinese eco-agriculture construction, knowing the problems and their causes in the construction and understanding the international trends of eco-agriculture construction. Of course, these indices can not be too far ahead so as to in line with the needs of Chinese eco-agriculture construction.

(4) The dynamic and static unity principle

As a system, eco-agriculture construction is developing and changing constantly and it is the dynamic and static unity. It should have not only the static indices to reflect the ecological, economic and social state but also the dynamic indices to reflect the subsystem's development and changes in a certain period of time. So it can accord to the characteristics that the production cycle is long and the late result is large in the eco-agriculture system to avoid the one-sided behavior of paying attention to the immediate interests and ignoring the long-term interests.

3. The formation of evaluation index system of eco-agriculture construction

The comprehensive benefits of eco-agriculture construction are divided into three aspects including the social benefit, economic benefit and social benefit through the statistical analysis of most eco-agriculture construction evaluation indices frequency and combining the actual conditions of Chinese eco-agriculture construction. And each aspect is subdivided into a number of specific indices. Through the Delphi method and integrating the views of experts, the evaluation index system of eco-agricultural construction which has a three-level and twelve specific indices is formed (Table 1). An explanation of specific indices is as follows:

Table 1. The evaluation index system of eco-agricultural construction

Target layer	Criterion layer	Index layer	Unit
The comprehensive evaluation of eco-agriculture construction A	Ecological benefit B_1	The forest coverage rate C_1	%
		The basic farmland per capita C_2	hectare
		The extent of farmland water conservancy C_3	%
		The quantity of chemical fertilizers C_4	kilogram/hectare
	Economic benefit B_2	The farmers' net income per capita C_5	yuan
		The grain per capita C_6	kilogram
		The commodity rate of agricultural products C_7	%
		The proportion of planting output value to the total agricultural output value C_8	%
	Social benefit B_3	The natural growth rate of population C_9	‰
		The output of meat food per capita C_{10}	kilogram
		The ratio of poverty-stricken population C_{11}	%
		The transfer rate of labor force C_{12}	%

(1) The forest coverage rate

The ecological benefit of forest is particularly important and it not only provides a large number of agricultural outputs but also contributes to improve the agricultural natural resources and environmental conditions for its function of water conservation, climate regulation, soil conservation, windbreak and sand fixation. It can make a broad measure to the Chinese eco-agricultural construction and also reflect the contribution of eco-agriculture to the entire ecosystem from one aspect. Its calculation formula is the ratio of a regional forest area to the land area.

(2) The basic farmland per capita

The basic farmland is the cultivated land which can not be occupied on the basis of overall land use planning, according to the demographic and socio-economic development demand for agricultural products for a certain period in accordance with the "Basic Farmland Protection Regulations". It is part of arable land and mainly that part of high yield and quality of arable land. It can be said that the basic farmland is the minimum demand of arable land in order to meet the demographic and socio-economic development needs in a certain period. This index is calculated as basic farmland area / population in the system.

(3) The extent of farmland water conservancy

The water conservancy is the lifeline of agriculture. Its calculation formula is the ratio of effective irrigation area to the total area of arable land. The effective irrigation area means the farmland or arable land irrigation area which can be irrigated normally in the general year's harvest on the basis of main conveyance system of irrigation project or equipment, having some water and relatively flat land.

(4) The quantity of chemical fertilizers

It reflects the level of chemicalization and the degree of intensive farming of arable land in agricultural production. It is also an important manifestation of modernization means level of agricultural production. At the same time it has a poisoning effect to soil and agricultural products with the growth of use intensity and frequency and will bring serious environmental and food contamination. So it is the negative index to reflect ecological benefit.

(5) The farmers' net income per capita

It reflects the standard of living condition of farmers and the speed of rural economic development and has complementarity with other indices. So it is the main index to evaluate the comprehensive benefits of eco-agriculture construction. Its calculation formula is the ratio of annual net income to the population in the system.

(6) The grain per capita

It refers the output of grain per capita and it is one of the important indices to reflect the economic benefit. Besides food, wheat, corn, Chinese sorghum, millet and other coarse cereals the grain also includes potatoes and beans.

(7) The commodity rate of agricultural products

It refers to the proportion of agricultural products which are sold to the outside by the agricultural products sector to the total agricultural products. This index measures the produce contribution of agricultural sector to the society and also reflects the degree of agricultural marketization. Its calculation formula is the commodity of agricultural products / the total agricultural products in a certain period of time.

(8) The proportion of planting output value to the total agricultural output value

With the development of society and economy, the law of agricultural internal structure is the proportion of planting output value to the total agricultural output value decreases while the proportion of animal husbandry increases and the agricultural structure tends to be reasonable. This index can reflect if the agricultural structure is reasonable to some extent.

(9) The natural growth rate of population

The population is an important social factor and has a great impact on the ecological environment. It can be said that the good and bad of regional ecological environment are decided by the behavior of people entirely, therefore, it is chosen as one of the indices to reflect the social benefit. Its calculation formula is the ratio of yearly birth ratio-death ratio.

(10) The output of meat food per capita

It reflects the nutritional level per capita to some extent. So it is one of the indices to reflect the social benefit. The meat food mainly refers to pork, beef, mutton and other meat products.

(11) The ratio of poverty-stricken population

The eco-agriculture construction should combine with the work of poverty alleviation and change the type of blood transfusion into the type of hematopoiesis. And it should also change the production conditions, enhance the capacity of fighting natural calamities to turn resources advantage into produce advantage and lead the poverty-stricken population cast off poverty and set out on a road to prosperity.

(12) The transfer rate of labor force

The existence of a large number of surplus labors will restrict the growth of farmers' income, agricultural development, as well as the healthy operation of economy as a whole. It is the key to solve the problem of agriculture, rural areas and farmers and the building of a new socialist countryside to transfer the rural surplus labor force successfully. Its calculation formula is the ratio of rural labor force that has been transferred to the rural surplus labor force.

4. The evaluation methods of eco-agriculture construction

The comprehensive score method of evaluation index is adopted. Its advantage is that it can use a figure to express the situation of eco-agriculture construction through synthesizing the strength and weakness of each index to summarize and analyze the advantage and disadvantage of program and measure in general.

4.1 The determination of index weight

Because the different elements perform different functions to the system and they change as the temporal and spatial changes, and the people's requirements and hope to the system are different, the weight of each index is different. And it embodies the importance of evaluation index in the system. The determination of index weight may adopt Analytical Hierarchy Process (AHP). It is brought up by the famous American professor T.L. Saaty and has an important impact on the field of evaluation index. The basic steps are as follows:

First, establishing the hierarchy structure of successive stage: as indicated in table 1, A layer is the target layer, that is, comprehensive evaluation of eco-agriculture construction; B layer is a criterion layer, including the ecological benefit, economic benefit and social benefit; C layer is the index layer, that is the specific indices of ecological benefit, economic benefit and social benefit.

Second, the judgment matrix is established: the upper layer indices are regarded as the criterion and the relative importance of this layer's two indices are compared to write the judgment matrix (Table 2). The relative importance of two comparative indices is expressed with the 1-9 scale method, as shown in Table 3.

Table 2. The judgment matrix

A	**B_1**	**B_2**	…	**B_n**
B_1	B_{11}	B_{12}	…	B_{1n}
B_2	B_{21}	B_{22}	…	B_{2n}
…	…	…	…	…
B_n	B_{n1}	B_{n2}	…	B_{nn}

Table 3. The measure of AHP

Measure	**Meanings**
1	The two indices are important equally
3	Compared to two indices, an index is slightly more important than the other
5	Compared to two indices, an index is obviously more important than the other
7	Compared to two indices, an index is strongly more important than the other
9	Compared to two indices, an index is absolutely more important than the other
2,4,6,8	The mean of two close judgment

Third，the single-level sorting (the calculation of single-level weight vector) and the consistency check: The single-level sorting is the weight sorting (weight vector) of this layer's indices to the upper layer's indices. Its calculation method can be summarized to the problem of calculating the eigenvalues and eigenvectors of judgment matrix. As the largest eigenvalue λ_{max} of structural n-order comparative matrix is not necessarily equal to n, the relative error of λ_{max} and n is regarded as the consistency index (CI) of comparative matrix, that is, $CI = (\lambda_{max}-n) / (n-1)$ to limit this error, among them λ_{max} is the largest eigenvalue of the judgment matrix and n is the order of judgment matrix. The consistency ratio (CR) is CR = CI / RI, among them the RI is the random consistency index for different order (Table 4).

Table 4. The random homogeneity index (RI)

Order n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

When CR <0.1, the judgment matrix. The ratio value of relative importance between indices is got through seeking advice from experts for three rounds and the comparative judgment matrix is established. The weight value of comprehensive benefit of eco-agriculture construction in accordance with the above steps is obtained (Table 5).

CR = 0.0289 <0.1 through the consistency check. So it shows that the total sorting of C layer to the target layer A has the satisfactory consistency and it can be used for the comprehensive evaluation of Chinese eco-agriculture construction.

Table 5. The weight of each index

Index	Weight w_i	Index	Weight w_i	Index	Weight w_i
C_1	0.0693	C_5	0.2923	C_9	0.0275
C_2	0.1612	C_6	0.1257	C_{10}	0.0439
C_3	0.0415	C_7	0.0457	C_{11}	0.0740
C_4	0.0252	C_8	0.0753	C_{12}	0.0184

4.2 Benefit calculation and analysis

Each index not only reflects the different content but also adopts different dimension in the selected 12 indices. For example, it can not be aggregated because the unit of grain differs from the unit of income, therefore, it is necessary to convert each index into the same measure to express the degree of eco-agriculture construction, and that is, the standardization dispose of each index should be done. There are many ways for the standardized dispose of indices. The method of converting the score of indices into a unified dimensionless value is adopted. The way of range definition of index score is that the highest and lowest values of indices in the nationwide scope are obtained first, then the maximum value and minimum value of each index is determined in accordance with the actual situation of Chinese eco-agriculture construction and the interval of every score between them is determined accordingly. Nine grade scores are adopted, that is, the change range of each index is from 1 to 9(Table 6).

Table 6. The benefit measure value

Measure	1	2	3	4	5	6	7	8	9
The forest coverage rate	≤5	10	15	20	25	30	40	50	≥55
The basic farmland per capita	≤0.011	0.024	0.037	0.050	0.063	0.076	0.089	0.102	≥0.115
The extent of farmland water conservancy	≤10	20	30	40	45	50	55	60	≥65
The quantity of chemical fertilizers	≥13.67	13.33	13.00	12.67	12.33	12.00	11.33	10.67	≤10
The farmers' net income per capita	≤1000	1500	2000	2500	3000	3500	4000	4500	≥5000
The grain per capita	≤300	350	400	450	500	550	600	650	≥700
The commodity rate of agricultural products	≤10	15	20	25	30	35	40	45	≥55
The proportion of planting output value to the total agricultural output value	≥80	75	70	65	60	55	50	45	≤40
The natural growth rate of population	≥5	4.5	4	3.5	3	2.5	2	1.5	≤1
The output of meat food per capita	≤50	75	100	125	150	175	200	225	≥250
The ratio of poverty-stricken population	≥7	6.5	6	5.5	5	4.5	4	3	≤2
The transfer rate of labor force	≤10	20	30	35	40	45	50	55	≥60

Note: The net income for farmers per capita was in 2004 prices

The formula of comprehensive evaluation of various benefits (ecological benefit, economic benefit, social benefit or comprehensive benefits) is:

$P_iW_i=P_1W_1+P_2W_2+\ldots\ldots+P_nW_n$ (P_1, $P_2\ldots\ldots$ P_n is

the score of various indices and W_1, W_2……W_n is the weight of various evaluation indices).

5. The evaluation application example: the comprehensive evaluation of eco-agriculture construction of Mulan County of Heilongjaing Province

This evaluation system of Chinese eco-agriculture construction is used to make a positive analysis of Mulan County of Heilongjiang province. The basic situation of eco-agriculture construction of Mulan County in recent years is shown in Table 7. It can be drawn from Tables 6 and 7 the scores of various indices (see Table 8).

Table 7. The basic condition of eco-agriculture construction of Mulan County

Index	2004	2005	2006
The forest coverage rate	43.5	43.7	43.9
The basic farmland per capita	0.071	0.078	0.076
The extent of farmland water conservancy	34	50	51
The quantity of chemical fertilizers	12.14	12.41	14.09
The farmers' net income per capita	3015	3248	3550
The grain per capita	400	416.5	418.4
The commodity rate of agricultural products	61	42	56
The proportion of planting output value to the total agricultural output value	72.4	69	75.1
The natural growth rate of population	3.7	5.7	6.7
The output of meat food per capita	121.3	162.8	196.1
The ratio of poverty-stricken population	14	14	13
The transfer rate of labor force	30	43.5	44.8

Source: Mulan County statistics bureau

Table 8. The score of each index

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
2004	7	5	3	6	5	3	9	3	4	4	1	3
2005	7	6	6	5	5	3	7	3	1	5	1	5
2006	7	6	6	1	6	3	9	2	1	6	1	6

Note: The data are calculated according to Tables 6 and 7

The benefit evaluation value of eco-agriculture construction of Mulan County can be obtained through calculating the benefits of various indices and aggregate in accordance with the tables 5 and 8. From the evaluation value of table 9 it shows that the comprehensive benefits of eco-agriculture construction of Mulan County grew steadily in 2004-2006, it grew 4.34 percent in 2005 and grew 5.83 percent in 2006. Among them, the growth of economic benefit was more obvious and the growth of ecological and social benefits was relatively slower. The local farmers have improved the standard of living, net income per capita grew by 17.7 percent, the rate of agricultural products was higher than before, the proportion of planting output in the agricultural output has some improvement and the grain per capita was also growing steadily in the three years. The ecological benefit of Mulan County in these three years was not very stable and had a decline in 2006. Although the forest coverage rate, the basic farmland per capita and the extent of farmland water conservancy have increased, the excessive use of fertilizer made the ecological benefit grow slowly. The

social benefit in these three years has increased steadily. The ratio of poverty-stricken population decreased by 1 percent in 2006, the transfer rate of labor force increased by 14.8 percent, the output of meat food per capita increased by 74.8 percent. But the natural growth rate of population has been in the growth trend and made the growth of social benefit slow. Therefore, Mulan County should reduce the quantity of chemical fertilizers substantially, guarantee the area of basic farmland per capita, increase the commodity rate of agricultural products and control the population growth strictly so that the regional eco-agricultural construction will climb one story higher.

Table 9. The benefit evaluation of eco-agriculture construction of Mulan County

	Ecological benefit	Economic benefit	Social benefit	Comprehensive benefits
2004	1.5416	2.4758	0.4148	4.4322
2005	1.8273	2.3844	0.413	4.6247
2006	1.7265	2.6928	0.4753	4.8946

Note: the data are calculated in accordance with tables 5 and 8

4. Conclusions

As a means of achieving sustainable agricultural development the eco-agriculture construction is essentially the process of economic and ecological environmental coordinate development. The evaluation of eco-agriculture construction benefit and system diagnostics should be done regularly based on the objectives and requirements of ecological and economic system development. Through the identification of selected principles of evaluation index system of eco-agriculture construction and constructing the evaluation index system, the comprehensive evaluation method is used to evaluate the benefits of eco-agriculture construction qualitatively and quantitative. And through regarding the eco-agriculture construction of Mulan County as an example it conducted a benefit evaluation and pointed out its achievements and shortcomings in the development of eco-agriculture. It offered a diagnostic method to the system in order to facilitate the scientific and rational adjustment based on the results of evaluation and system diagnosis.

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References

[1] Yousheng Bian. The evaluation index and evaluation method of ecological economy of large and middle scale farm. Rural Ecological Environment 1994 (in Chinese);10(2):10-14.

[2] Hongliang Sun. The theory and method of eco-agriculture. Science Press of Shandong Province, China.1993：10-80.

[3] Qianji Ye. Eco-agriculture: the future of agriculture. Chongqing Press, China.1987 (in Chinese):22-40..

[4] Bin Zhang. The matter-element model and its application in agriculture. Agricultural System Science and Comprehensive Study 1997 (in Chinese);13(4):295-298.

[5] Dafeng Pan. The study of multi-index comprehensive evaluation of neural network. Agricultural System Science and Comprehensive Study 1999 (in Chinese);15(2):105-107.

[6] Zhiping Cao. The comprehensive evaluation method of cycle function of agricultural eco-system. Rural Ecological Environment 1997(in Chinese);13(3):6-10

[7] Changsheng Li, Zhongke Feng. Sustainable development ability of state-owned forest region in Heilongjiang Province, Northeast China. Journal of Beijing Forestry University 2005 (in Chinese);27(2):105-107.

[8] Marten G. R.Productivity, stability, sustainability, equitability and autonomy as properties for agroecosystems assessment. Agricultural System 1988;26(4):291-316.

[9] Linhai Mei, Hongyan Nie. The research of eco-agriculture benefit evaluation system. Ecological Economy2005 (in Chinese); (11)：83-86.

[10] Satty T.L.. The Analytic Hierarchy Process. Mcgraw Hill Inc. , USA.1980:1-100