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Comprehensive Evaluation and Influencing Factors Analysis of Agricultural Sustainable Development Based On Entropy Method and Path Analysis

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Abstract: First, 14 indicators are selected to make a comprehensive valuation on the regional sustainable development of agriculture in Heilongjiang Province. We use entropy method to comprehensive evaluate 12 cities as an example of sustainable agricultural development. Second, the path analysis was used to analyze the factors affecting the sustainable development of regional agriculture. The results show that resource based cities have the lowest level of agricultural sustainable development. The total retail sales of consumer goods and the total retail sales of consumer goods are important factors that affect the comprehensive evaluation of agricultural sustainable development. Per capita GDP and Gross industrial output value through the total retail sales of consumer goods plays an effective role in promoting the sustainable development of Agriculture.
Keywords: Sustainable development; comprehensive valuation; entropy method component; path analysis; influencing factors

INTRODUCTION

The sustainable development of agriculture is considered to be the foundation of sustainable development of human society [1]. The total land area of Heilongjiang is 473000 million square kilometers, accounting for 4.9% of total land area. Agricultural land area is 39.583 million hectares. Heilongjiang province is rich in soy, rice, corn, wheat, potatoes, other food crops and cash crops.

It is very important to evaluate the level of regional agricultural sustainable development and analyze the influencing factors of sustainable development.

Weight by entropy method and coefficient of variation method, the comprehensive evaluation model of linear weighting is established. Using the model to conduct comprehensive evaluation of agricultural sustainable development in 12 cities of Heilongjiang Province. Then, the path analysis is used to analyze the 5 factors that affect the sustainable development of regional agriculture.

The Theory of the Entropy Method

The Calculation of Composite Index

Supposing that there are m regions and n evaluations for each evaluation object. The original data matrix is $R = \left(r_{ij}\right)_{m\times n}$ $\left(i = 1, 2, \cdots m;\ j = 1, 2, \cdots, n\right)$. In order to eliminate dimensional influence, we use extreme value normalization processing indicator data:

$b_{ij} = \left(r_{ij} - r_{\min}\right)\Big/\left(r_{\max} - r_{\min}\right)$ (1) $\quad b_{ij} = \left(r_{\max} - r_{ij}\right)\Big/\left(r_{\max} - r_{\min}\right)$ (2)

$r_{\min}$ and $r_{\max}$ are the minimum and maximum value of r_{ij}. Formula(1) is used to deal with positive indexes, and formula(2) is used to deal with negative indexes. Then standardized matrix is $B = \left(b_{ij}\right)_{m\times n}$.

Calculate the proportion of indicators $p_{ij} = b_{ij}\Big/\sum_{i=1}^{m} b_{ij}$.

In order to eliminate the possible impact of above-mentioned standardization, Let $b_{ij}' = 1 + b_{ij}$, p_{ij} is corrected to $p_{ij} = b_{ij}' \Big/ \sum_{i=1}^{m} b_{ij}' = (1 + b_{ij}) \Big/ \sum_{i=1}^{m} (1 + b_{ij})$ (3)

Calculate the index of the entropy e_j:

$$e_j = -\left[\sum_{i=1}^{m} p_{ij} \ln(p_{ij})\right] / \ln m \quad , \quad e_j \geq 0 \qquad (4)$$

For a given j, the difference between r_{ij} is inversely proportional to e_j. Calculate the index of the difference coefficient (utility value) $g_j = 1 - e_j$.The Entropy $a_j = g_i \Big/ \sum_{j=i}^{n} g_j$.

According to the additivity of entropy, the total utility value is $D = \sum_{k=1}^{l} D_k$, and the weight of the corresponding subsystem is $A_k = D_k / D$.

Comprehensive Assessment of the Value Calculation

Entropy weighting method is too obvious for abnormal data, which leads to excessive weight of some important indexes. In order to avoid this shortcoming, the entropy method and the coefficient of variation method weighted average are used to weight each index.

$$c_j = (\sigma_j / \bar{x}_j) \Big/ \sum_{j=1}^{n} (\sigma_j / \bar{x}_j) \qquad (5)$$

c_j is the coefficient of variation method weight of each index, σ_j is the standard deviation of each index, $\bar{x}_j$ is the average value of each index.

Final weight of each index is $w_i = (a_j + c_j) \Big/ 2$ and linear weighted comprehensive evaluation model can be established as $Y_i = \sum_{j=1}^{n} w_j \times p_{ij}$

Thereinto, Y_i is comprehensive evaluation, w_j is the final weight of each index, p_{ij} is the value for the standardization of a single evaluation, n is the number of evaluation.

An Empirical Analysis of Sustainable Development of Agriculture

System of indicators of Sustainable Development of Agriculture

According to the sustainable development of the evaluation index system, the guiding ideology of the index system, the theoretical framework, the basic principles and construction methods, we establish the evaluation index system of regional sustainable development of agriculture[2,3](see Table 1).

Table-1: Evaluation Index System of Sustainable Agricultural Development of Heilongjiang

Target layer	Subsystem	Index layer	Index type
The level of sustainable agricultural development	Agricultural population system(B1)	Medical Technical Personnel per million people (person) C11	Positive
		Agriculture Employees(person) C12	Positive
	Agricultural economic system (B2)	Total Power of Agriculture Machinery(10000 kw) C21	Positive
		Farming Total(10000 yuan) C22	Positive
	Agricultural Social system (B3)	Annual Per Capital Disposable Income of Rural Households (yuan) C31	Positive
		Growth Rate of GDP(%) C32	Positive
	Agricultural resources system (B4)	Total Sown Areas of Farm Crops (hm^2) C41	Positive
		The total source capacity of the water resources (100 million cu. m) C42	Positive
	Agricultural environmental system (B5)	Regional waste water emissions (10000t) C51	Negative
		Fertilizer usage(t) C52	Negative
		Area with Flood Prevention Measures (10000 hectares) C53	Positive
		Emission Volume of Smoke Dust(ton) C54	Negative

Calculation of the Comprehensive Evaluation Index Value

The data is from Heilongjiang Statistical Yearbook in 2016. The weight of each index and subsystem are shown in Table 2-Table 4.

Table -2: The weight of each index

	C11	C12	C21	C22	C31	C32	C41	C42	C51	C52	C53	C54
e_j	0.994	0.986	0.990	0.991	0.993	0.985	0.988	0.993	0.995	0.991	0.989	0.995
g_j	0.006	0.014	0.010	0.009	0.007	0.015	0.012	0.007	0.005	0.009	0.011	0.005
a_j	0.057	0.123	0.092	0.078	0.066	0.140	0.110	0.067	0.045	0.079	0.098	0.045
c_j	0.100	0.125	0.117	0.107	0.069	0.061	0.109	0.073	0.038	0.057	0.104	0.039
w_j	0.079	0.124	0.104	0.093	0.067	0.101	0.109	0.070	0.042	0.068	0.101	0.042

Table -3: The Weight of Subsystem

Sub system	B1	B2	B3	B4	B5
weight of Subsystem	0.181	0.170	0.205	0.177	0.267

Based on the linear weighted comprehensive evaluation model, the scores of the 5 systems and composite score are obtained as follows:

Table- 4: Comprehensive Valuation on Regional Sustainable Development of Heilongjiang

Region	B1	B2	B3	B4	B5	Comprehensive evaluation	System clustering results
Harbin	0.144	0.197	0.177	0.166	0.066	0.749	1
Qiqihar	0.116	0.123	0.137	0.135	0.134	0.645	2
Jixi	0.028	0.030	0.143	0.038	0.142	0.381	4
Hegang	0.018	0.004	0.025	0.018	0.158	0.223	4
Shuangyashan	0.027	0.020	0.089	0.035	0.162	0.334	4
Daqing	0.120	0.048	0.163	0.037	0.144	0.5124	3
Yichun	0.018	0.009	0.049	0.053	0.149	0.278	4
Jiamusi	0.051	0.072	0.184	0.078	0.161	0.546	3
Qitaihe	0.018	-0.001	0.101	0	0.149	0.266	4
Mudanjiang	0.049	0.058	0.199	0.079	0.233	0.618	3
Heihe	0.053	0.047	0.243	0.105	0.150	0.598	3
Suihua	0.124	0.115	0.163	0.119	0.165	0.686	2

According to Table 4, we draw a line chart (Figure 1) of sustainable development of agricultural in Heilongjiang.

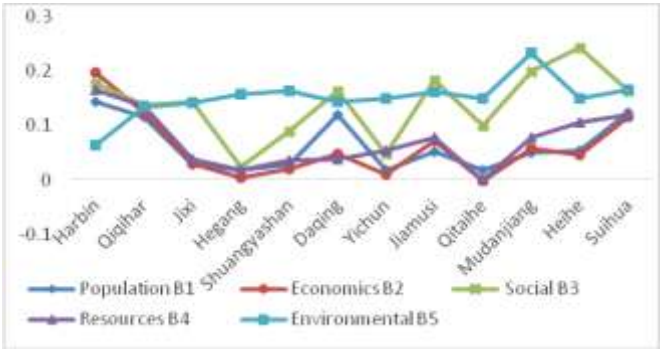

Fig-1: Line Chart of Heilongjiang Agricultural Sustainable Development

According to the scores of 5 systems, we use Hierarchical Clustering Method for classification of 12 cities. The results are shown in figure-1 and Table-4. Based on the cluster dendrogram, 12 cities can be divided into four groups. Draw maps according to classification results as below:

Fig-2: Group of agricultural sustainable development

Harbin is the provincial capital city, and the level of agricultural sustainable development is high. Qigihar and Suihua are large agricultural cities in the province, and the level of agricultural sustainable development is relatively high, and the sustainable development level of each system is balanced. The sustainable development of Daqing, Mudanjiang, Jiamusi and Heihe in the social and environmental systems shows that the four cities have great potential for sustainable agricultural development. Yichun, Qitaihe, Hegang, Shuangyashan and Jixi are mineral resource-based cities, and the level of agricultural sustainable development is relatively low.

Analysis of influencing factors of agricultural sustainable development based on path analysis theory

Path analysis model

Path analysis is a multivariate statistical analysis method to study the direct and indirect effects of variables. On the basis of multiple linear regression analysis, the partial regression coefficient of standardized data was analyzed by path analysis, and the correlation coefficient was decomposed into direct path coefficient and indirect path coefficient, they were used to measure the direct effects of independent variables on dependent variables and the indirect effects of independent variables on dependent variables through other independent variables. Compared with multiple linear regression and correlation analysis, path analysis is more reasonable and accurate for statistical analysis of multivariate influencing factors [4,5].

Path coefficient $P_{iy} = \beta_i \sigma_{x_i} / \sigma_Y$ indicates the direct effect of x_i on Y , β_j is standardized coefficient of regression equation, σ_{x_i} is the standard deviation of x_i , σ_Y is the standard of dependent variable Y . The indirect path coefficient $r_{ij} P_{jy}$ represents the indirect impact of x_i on Y through x_j , $i,\ j = 1, 2, \cdots, n$, $i \neq j$.

Empirical analysis of influencing factors

The comprehensive evaluation results of agricultural sustainable development Y is affected by the total retail sales of consumer goods x_1 , total investment in fixed assets x_2 ,total population in the region x_3 , per capita GDP x_4 and gross industrial output value x_5 .The data came from Heilongjiang Statistical Yearbook in 2016.

The results of linear regression are derived as follows：

Table-5: Results of variance Analysis

	Sum of squares	df	Mean square	F	Sig.
Regression	.329	5	0.066	11.563	0.005
Residual	.034	6	0.006		
Total	.363	11			

Table-6: Coefficient and significance

	Standardized coefficient	t	Sig.
x_1	6.962	5.299	0.002
x_2	-3.522	-3.236	0.018
x_3	-3.001	-2.585	0.042
x_4	-0.924	-.583	0.581
x_5	0.652	0.364	0.728

The regression equation fitted well（$R^2 = 0.952$）. According to Table 4-5, path coefficient of error to dependent variable $\sqrt{1-R^2} = 0.22$. $F = 11,563$, $p = 0.005 < 0.05$ .It is obvious that the regression equation is significant, and the combination of variables is very good for explaining the sustainable development. The direct effect of x_4 and x_5 on dependent variables is not strong, so mainly depend on indirect effect.

Correlation coefficient of dependent variable and independent variable as follows:

Table-7: Results of Pearson Correlations

Pearson correlations	Y	x_1	x_2	x_3	x_4	x_5
Y	1.000	0.602	0.493	0.522	0.185	0.284
x_1	0.602	1.000	0.987	0.987	0.339	0.602
x_2	0.493	0.987	1.000	.983	0.316	0.590
x_3	0.522	0.987	0.983	1.000	0.252	0.534
x_4	0.185	0.339	0.316	0.252	1.000	0.948
x_5	0.284	0.602	0.590	0.534	0.948	1.000

Path analysis results are as follows:

Table-8: coefficient of Path analysis

Sustainable development index	Action factor	Direct path coefficient	Simple correlation coefficients	Indirect path coefficient				
				x_1	x_2	x_3	x_4	x_5
Comprehensive evaluation value Y	x_1	6.96	0.60	-	-3.48	-2.96	-0.31	0.39
	x_2	-3.52	0.49	6.87	-	-2.95	-0.29	0.38
	x_3	-3.00	0.52	6.87	-3.46	-	-0.23	0.35
	x_4	-0.92	0.19	2.36	-1.11	-0.76	-	0.62
	x_5	0.65	0.28	4.19	-2.08	-1.60	-0.88	-

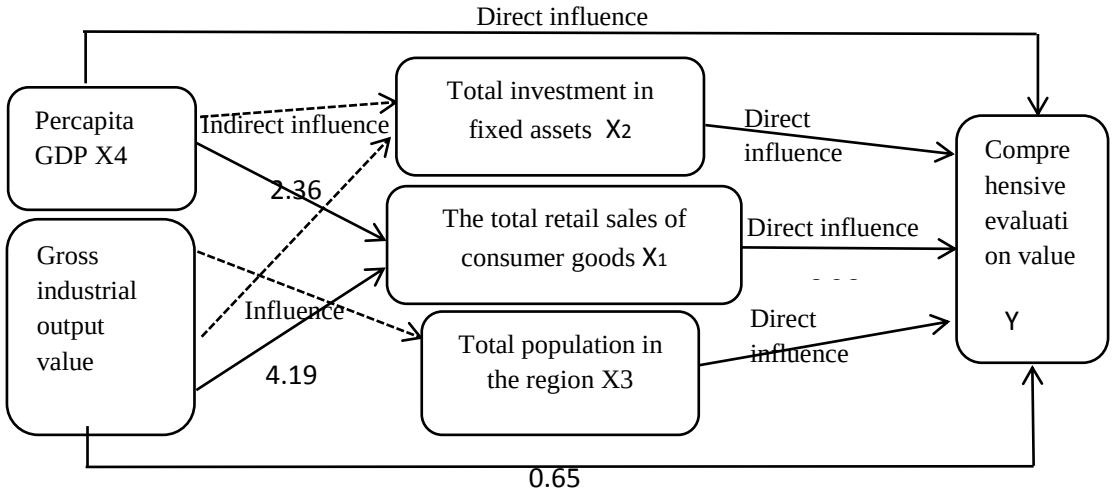

Fig.4 Transmission chart of influencing factors of agricultural sustainable affect the comprehensive It is can be seen form direct path coefficient in Table 8, x_1 , x_2 and x_3 are important factors that evaluation of agricultural sustainable development, x_4 and x_5 have indirect development effects on sustainable development through x_1

Per capita GDP and Gross industrial output value have little direct influence on the sustainable development of agriculture, but through the total retail sales of consumer goods plays an effective role in promoting the sustainable development of Agriculture. There are two main ways to influence agricultural sustainable development indirectly. The first is the total investment in fixed assets as a mediating variable. The second is the total retail sales of social consumer goods as a mediating variable. Therefore, the prosperity of social economy plays an important role in promoting the sustainable development of agriculture. Population change has little effect on agricultural sustainable development in a short period of time.

Harbin is the provincial capital city, and the level of agricultural sustainable development is the highest because of its high economic level. But environment and population are the main factors that restrict its further development. The development of subsystems in Qigihar and Suihua is balanced, and the level of agricultural sustainable development is relatively high. Yichun, Hegang and Qitaihe are mineral resource-based cities, and the development level of each subsystem is low, which limits the level of agricultural sustainable development in this area. Daqing, Jiamusi, Mudanjiang, Heihe, Jixi and Shuangyashan have great potential for the sustainable development of agriculture because of their rich social resources.

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