ICIC Express Letters
Part B: Applications
Volume **9**, Number **7**, July **2018**

ICIC International ©2018 ISSN 2185-2766
pp. 641–648

MODEL AND APPLICATION OF CITY MODERN AGRICULTURE EVALUATION BASED ON G1 AND VARIATION COEFFICIENT METHODS

Baofeng Shi[1,*], Jiaqi Zhang[1], Juan Liu[1], Xiaoling Wang[2] and Jing Wang[1,*]

[1]College of Economics and Management
Northwest A&F University
No. 3, Taicheng Road, Yangling 712100, P. R. China
{ JiaqiZhang1995; liu_juan_107 }@163.com
[*]Corresponding authors: { shibaofeng; jing.wang }@nwsuaf.edu.cn

[2]Donlinks School of Economics and Management
University of Science and Technology Beijing
No. 30, Xueyuan Road, Haidian District, Beijing 100083, P. R. China
wangxiaoling@ustb.edu.cn

Received December 2017; accepted March 2018

Abstract. *This paper creates an evaluation model based on G1 and variation coefficient methods for city modern agriculture. First of all, we give weight to those evaluation attributes by the subjective G1 weighting and the objective variation coefficient weighting methods respectively. Then we combine the weights by maximizing deviations approach. Secondly, the time weight is introduced to integrate cross section data by using a nonlinear program approach. Finally, we compute the comprehensive scores of city modern agriculture for 10 Chinese sub-provincial cities. Empirical results show that the proposed model can effectively extract the advantages and disadvantages in city modern agriculture. Researchers and governments can seek measures to improve their modern agriculture development level.*

Keywords: City modern agriculture, G1, Variation coefficient, Combination weight

1. **Introduction.** Chinese cities are experiencing the rapid economic development as well as the urbanization process. Thus, many problems occur immediately. How to improve agricultural development in China becomes a burning issue. By assessing the development status of different cities' modern agriculture, we can mine their bottleneck factors. Then governments can make or adjust corresponding modern agriculture development policies to improve the modern agriculture development levels.

There are many studies available for city modern agriculture evaluation. Pretty et al. pointed out that agriculture has a far-reaching impact influence on many elements of economies and ecosystems [1]. In 2010, William proposed the concept of the modern agriculture. And then, he emphasized that the development of modern agriculture plays a vital role in meeting future food needs [2]. Wang assessed Bijie's level of modern agriculture development from four aspects of agricultural support level, agricultural output level, agricultural social development level and agricultural sustainable development level [3]. In order to measure the development level of modern agriculture, some scholars tried to utilize factor analysis method to rank the attributes which affect the development of modern agriculture [4]. Zhao et al. proposed an eco-agriculture evaluation model by using the PP (Projection Pursuit) approach [5]. Zhao and Yao developed a modern agriculture evaluation index system. The index system includes five aspects, such as the agricultural infrastructure construction and the material equipment level, the

DOI: 10.24507/icicelb.09.07.641

level of agricultural production, the agricultural economic efficiency and the agricultural organizational and informational level [6]. The analytic hierarchy process (AHP) method has been used to establish the assessment model of modern agriculture [7-9]. Soltanmohammadi et al. proposed an evaluation model of land use by utilizing the entropy-weight TOPSIS method [10]. By applying hierarchical cluster analysis approach, Chen et al. assessed the agricultural development level of Northeast China [11]. Wang analyzed the agriculture competitiveness status of Shandong province based on principal component and hierarchical cluster analysis methods [12].

Although the existing studies have made great progress in city modern agriculture evaluation issues, there are still some drawbacks. Most of the current evaluation methods focus on either subjectivity or objectivity. Subjective weighting methods can reflect the experience of experts but lack the use of original data. Objective weighting methods can indicate the value of original data but lack the references from experts.

In order to overcome the above shortcomings, the paper advances in three aspects. Firstly, this paper creates a city modern agriculture evaluation model by combining subjective G1 weighting method and objective variation coefficient weighting approach skillfully. Secondly, in order to calculate the time weight, we introduce time degree to integrate cross section data in the evaluation process. Then, by using the modern agriculture development data on 10 sub-provincial cities in China, empirical results indicate the corresponding advantageous and disadvantageous factors for each sub-provincial city. The paper can help the authorities to make or adjust corresponding modern agriculture development policies.

The rest of the paper is organized as follows. Section 2 introduces the design and methodology. Section 3 presents the data and empirical analysis of our city agriculture evaluation model for 10 sub-provincial cities in China. Section 4 gives the conclusions.

2. Design and Methodology of the Study.

2.1. **Standardization of original data.** In order to remove the influence of dimensions, we should standardize the original data into dimensionless numbers within the interval $[0, 1]$ firstly [13]. The attribute data can be classified into two classes: positive attributes and negative attributes. The positive attributes mean that the greater their modern agriculture evaluation values are, the better the city modern agriculture development is. While the negative attributes show that the smaller their modern agriculture evaluation values are, the better the city modern agriculture development is. Let C_{ij} refer to the original data of the j-th object in the i-th attribute, H_{ij} denote the standardized score of the j-th object in the i-th attribute, and n be the amount of objects. We can standardize the positive attributes and negative attributes using Equation (1) and Equation (2) respectively [14].

$$H_{ij} = \frac{C_{ij} - \min\limits_{1\le j\le n}(C_{ij})}{\max\limits_{1\le j\le n}(C_{ij}) - \min\limits_{1\le j\le n}(C_{ij})} \tag{1}$$

$$H_{ij} = \frac{\max\limits_{1\le j\le n}(C_{ij}) - C_{ij}}{\max\limits_{1\le j\le n}(C_{ij}) - \min\limits_{1\le j\le n}(C_{ij})} \tag{2}$$

2.2. **Weighting methods of G1 and variation coefficient.**

(1) Calculation of the attributes' G1 weighting

G1 method is a subjective weighting method which can express the authority of experts. As we can see in Table 1, the evaluation attributes include criterion layers and attribute layers. To get the weight of each attribute, we should process the standardized scores as the following steps [15].

Step 1: To determine the importance of the evaluation attributes. Let m denote the amount of attributes. We select the most important attribute as X_1. Then we select the most important attribute among the rest ones as X_2. The rest data can be processed in the same way until the last attribute is marked as X_m.

Step 2: To identify the important degree between adjacent attributes X_{k-1} and X_k. We mark this degree as r_k $(1 \leq k \leq m)$.

Step 3: Let W_m^G represent the weight of attribute m. The weight of attribute m can be computed by Equation (3).

Step 4: Let W_{k-1}^G represent the weight of attribute $(k-1)$ and W_k^G represent the weight of attribute k $(k = m, m-1, \ldots, 3, 2)$. The weight of attribute $(k-1)$ can be computed by Equation (4). The weight vector of attribute layers is $W_i^G = \left(W_1^G, W_2^G, \ldots, W_m^G\right)$.

$$W_m^G = \left(1 + \sum_{k=2}^{m} \prod_{i=k}^{m} r_i\right)^{-1} \tag{3}$$

$$W_{k-1}^G = W_k^G r_k, \quad k = m, m-1, \ldots, 3, 2 \tag{4}$$

(2) Calculation of the attributes' variation coefficient weighting

Variation coefficient method is an objective weighting method which can avoid the interferences of subjective factors. Let μ_i denote the weight based on variation coefficient method of attribute i, and $\overline{H_i}$ denote the mean of standardized score of attribute i. The variation coefficient weighting μ_i can be calculated by Equation (5).

$$\mu_i = \frac{\sqrt{\sum\limits_{j=1}^{n} \left(H_{ij} - \overline{H_i}\right)^2 / n}}{\overline{H_i}} \Bigg/ \sum_{i=1}^{m} \frac{\sqrt{\sum\limits_{j=1}^{n} \left(H_{ij} - \overline{H_i}\right)^2 / n}}{\overline{H_i}} \tag{5}$$

(3) Determination of attributes' comprehensive weights

In order to work out the comprehensive weight vector of subjective and objective weighting methods, the paper creates a model as Equation (6). This model makes the total deviations of all evaluation objects into maximization as Equation (7) according to maximizing deviations method [16]. Let $W_i = (W_1, W_2)$ denote the weight vector of subjective and objective weighting methods.

$$D = \sum_{j=1}^{n} \sum_{i=1}^{m} \sum_{t=1}^{m} |H_{ij} - H_{tj}| W_i \tag{6}$$

$$\max D = \sum_{j=1}^{n} \sum_{i=1}^{m} \sum_{t=1}^{m} |H_{ij} - H_{tj}| W_i$$
$$\text{s.t.} \begin{cases} \sum\limits_{i=1}^{m} W_i^2 = 1 \\ W_i \geq 0, \quad i = 1, 2, \ldots, m \end{cases} \tag{7}$$

where $W_i = \theta_1 W_i^G + \theta_2 \mu_i$, W_i is the weight vector of comprehensive weights.

2.3. **Establishment of the modern agriculture evaluation model.** Let H_j^k denote the score of the j-th object in the k-th year, H_{ij}^k is the standardized score of the j-th object in the i-th attribute in the k-th year, W_i^k is the comprehensive weight of the i-th attribute in the k-th year, and we can compute the evaluation score in each year by Equation (8).

$$H_j^k = \sum_{i=1}^{m} W_i^k H_{ij}^k \tag{8}$$

In order to identify the time weight $\omega = (\omega_1, \omega_2, \ldots, \omega_t)$ of cross section data, we utilize the nonlinear formulation model as shown in Equation (9) [17]:

$$\max \left(-\sum_{k=1}^{t} \omega_k \ln \omega_k \right)$$
$$\text{s.t.} \begin{cases} \lambda = \sum_{k=1}^{t} \dfrac{t-k}{t-1} \omega_k \\ \sum_{k=1}^{t} \omega_k = 1 \\ \omega_k \geq 0,\ k = 1, 2, \ldots, t \end{cases} \tag{9}$$

where k denotes time series, t is the amount of cross section data, ω_k denotes the time weight of the k-th year, and λ denotes time degree. If λ tends to 1, we value previous data; if λ tends to 0, we value current data.

Let H_j denote the comprehensive score of the j-th object, t is the amount of cross section data, H_j^k is the score of the j-th object in the k-th year, and ω_k is the time weight of the k-th year. We can calculate the comprehensive score of modern agriculture by Equation (10).

$$H_j = \sum_{k=1}^{t} H_j^k \omega_k \tag{10}$$

3. Empirical Analysis.

3.1. Sample and data source.

The data for city modern agriculture evaluation comes from statistical yearbooks and statistical bulletins of 10 Chinese sub-provincial cities from 2012 to 2014. Some sub-provincial cities such as Wuhan and Jinan only have incomplete data, so the five sub-provincial cities are not evaluated. These rest ten sub-provincial cities include inland cities and coastal cities, well-developed cities and developing cities. The geographical spans contain almost entire China. Shenyang and Dalian are in the northeast of China; Qingdao, Nanjing, Hangzhou, Ningbo and Xiamen are in the east of China; Guangzhou is in the south of China; Chengdu is in the southwest of China; Xi'an is in the northwest of China. Thus, it can be seen that the sample is typical and complete. So the results of this city modern agriculture evaluation are objective, believable and referential. The original data is shown as Column 6 to 35 in Table 1.

Table 1. The original data of 10 Chinese sub-provincial cities for city modern agriculture evaluation

(1) Nos.	(2) Criterion layers	(3) Attributes	(4) Attribute type	Xi'an				Ningbo		
				(6) 2012	(7) 2013	(8) 2014	…	(33) 2012	(34) 2013	(35) 2014
1	X_1 Agriculture input level	X_{11} Effective irrigation ratio	Positive	72.407	65.593	68.844	…	61.868	59.556	64.935
…		…	…	…	…	…	…	…	…	…
3		X_{13} Manpower in unit area	Negative	0.105	0.097	0.090	…	0.104	0.111	0.117
4		X_{14} Agriculture fixed assets investments for unit agriculture worker	Positive	8644.274	6622.906	7155.780	…	4884.976	3973.011	8832.981
…	…	…	…	…	…	…	…	…	…	…
16	X_6 Agriculture support level	X_{61} Financial support for agriculture	Positive	7.549	6.842	5.950	…	8.715	8.552	8.189
17		X_{62} Agricultural acreage per capita	Positive	0.432	0.426	0.418	…	0.803	0.796	0.736

3.2. **Analysis of the empirical results.** Taking the original data of positive attributes and negative attributes C_{ij} from Column 6 to 35 of Table 1 into Equation (1) and Equation (2) respectively, the standardized scores H_{ij} can be obtained, as shown in Column 3 to 32 of Table 2.

In order to calculate the weight scores, by G1 method, we identify a new order relation of criterion layers and attribute layers and identify the important degree r_k between adjacent attributes X_{k-1} and X_k $(1 \leq k \leq m)$. The new order relation in criterion layers and attribute layers is shown in Column 2 to 3 of Table 3. The weights based on G1 method are shown in Column 7 of Table 3. Putting the standardized data H_{ij} from Column 3 to 32 in Table 2 into Equation (5), the weights based on variation coefficient weighting method in each year are shown in Table 3. Taking the standardized data H_{ij} from Column 3 to 32 in Table 2 into Equations (6) and (7), the weight vectors of comprehensive weight in each year can be shown as Column 8 to 10 in Table 3.

Table 2. The standardized scores of 10 Chinese sub-provincial cities for city modern agriculture evaluation

(1) Nos.	(2) Attributes	Xi'an			...	Ningbo		
		(3) 2012	(4) 2013	(5) 2014	...	(30) 2012	(31) 2013	(32) 2014
1	X_{11} Effective irrigation ratio	0.519	0.333	0.275	...	0.000	0.086	0.147
...	...	...	...	...	...	...	...	...
3	X_{13} Manpower in unit area	0.749	0.783	0.807	...	0.752	0.742	0.728
...	...	...	...	...	...	...	...	...
16	X_{61} Financial support for agriculture	0.796	0.712	0.592	...	1.000	1.000	1.000
17	X_{62} Agricultural acreage per capita	0.248	0.249	0.247	...	0.538	0.539	0.497

Table 3. Attributes' weights for modern agriculture evaluation

(1) Nos.	(2) Criterion layers	(3) Attributes	(4) μ_i^{2012}	(5) μ_i^{2013}	(6) μ_i^{2014}	(7) W_i^G	(8) 2012 Weight vectors (θ_1, θ_2)	(9) 2013 Weight vectors (θ_1, θ_2)	(10) 2014 Weight vectors (θ_1, θ_2)	(11) Time weights	(12) Combination weights
1	X_1 Agriculture output level	X_{11} Agriculture labor productivity	0.129	0.111	0.098	0.08822	(0.4865, 0.5135)	(0.4414, 0.5586)	(0.4875, 0.5125)	2012 (0.0263)	0.09466
2		X_{12} Land productivity	0.084	0.075	0.088	0.07351				2013 (0.1474)	0.08010
3		X_{13} Grain productivity	0.045	0.040	0.048	0.06683				2014 (0.8263)	0.05640
...	...	...	...	...	...	...					...
15	X_6 Agriculture economic structure	X_{61} Household business operation income ratio	0.056	0.059	0.071	0.04948	–	–	–		0.05950
...		...	...	...	...	...				–	...
17		X_{63} Forestry, animal husbandry and fishery ratio	0.062	0.060	0.069	0.03171					0.05031

TABLE 4. Comprehensive scores of 10 Chinese sub-provincial cities for city modern agriculture evaluation

(1) Nos.	(2) Criterion layers	Xi'an				...	Ningbo			
		(3) 2012	(4) 2013	(5) 2014	(6) Comprehensive scores	...	(39) 2012	(40) 2013	(41) 2014	(42) Comprehensive scores
1	X_1	0.079	0.068	0.075	0.074	...	0.022	0.021	0.025	0.024
...	...	...	...	...	...	...	...	...	...	...
6	X_6	0.045	0.048	0.031	0.034	...	0.048	0.052	0.044	0.045
7	Total	0.373	0.337	0.309	0.315	...	0.365	0.358	0.407	0.399

TABLE 5. Ranks of 10 Chinese sub-provincial cities for city modern agriculture evaluation

(1) Nos.	(2) Criterion layers	(3) Xi'an	(4) Chengdu	(5) Nanjing	(6) Hangzhou	(7) Dalian	(8) Xiamen	(9) Shenyang	(10) Qingdao	(11) Guangzhou	(12) Ningbo
1	X_1	3	8	4	10	7	2	6	5	1	9
...	...	...	...	...	...	...	...	...	...	...	...
6	X_6	9	10	7	6	2	4	1	3	8	5
7	Comprehensive scores	8	10	1	9	6	2	5	3	7	4

TABLE 6. The ward cluster results for city modern agriculture evaluation

Classify	The First Class	The Second Class	The Third Class
City	Nanjing	Xiamen; Qingdao; Ningbo Shenyang; Dalian; Guangzhou	Xi'an; Hangzhou; Chengdu

We assume the time degree λ is 0.2 [17]. Take the standardized data H_{ij} from Column 3 to 32 in Table 2 into Equation (9) to compute the time weight in each year. The results are as shown in Column 11 of Table 3. And then, we can obtain the comprehensive weights, as shown in Column 12 of Table 3. According to Equation (8), we obtain the scores of 10 Chinese sub-provincial cities for city modern agriculture evaluation in each year. The results are shown in Table 4. According to Equation (10), we calculate the comprehensive scores of 10 Chinese sub-provincial cities, as shown in Table 4.

According to the results in Table 4, we obtain the ranks of the modern agriculture comprehensive scores of 10 Chinese sub-provincial cities, as shown in Table 5. In order to classify the level of city modern agriculture directly, we draw a Ward cluster results, as shown in Table 6.

As it can be seen from Table 5 and Table 6, the level of city modern agriculture in Nanjing is the highest while in Chengdu is the lowest. We can explore the reasons of the different levels in city modern agriculture. (1) According to the results in Column 12 of Table 3, the combination weight of 'X_{11} Agriculture labor productivity' is the biggest. So it is very important for governments to develop the agriculture labor productivity to improve the level of city modern agriculture. At the same time, the combination weight of 'X_{44} Manpower in unit area' is the smallest. It means that manpower in unit area is not the determining factor of city modern agriculture evaluation. (2) The development of city modern agriculture is unbalanced. As it can be seen in Row 7 of Table 5, the development of city modern agriculture in the east and south of China such as Nanjing, Qingdao, Ningbo, Xiamen and Guangzhou is better. The northeast region of China such as Shenyang and Dalian mediates in the evaluation. The west area of China such as Xi'an and Chengdu develops slowly. It implies that the level of development of city modern agriculture in China tends to decrease progressively from southeast to northeast and to west. (3) Different sub-provincial cities have different advantage and disadvantage factors in city modern agriculture development. As mentioned above, Nanjing ranks the first in 'X_3 Agriculture sustainable development' and 'X_4 Agriculture input level'. We can infer that sustainable development and agriculture input are essential to build a better modern agricultural city. Chengdu is the last one in 'X_2 Agriculture social economic development level' and 'X_6 Agriculture economic structure'. It suggests that the behindhand economic development limits the development of city modern agriculture.

4. **Conclusions.** To help the authorities to adjust or make the corresponding modern agriculture development policies, the paper assesses the city modern agriculture development level. First, this paper establishes a city modern agriculture evaluation model by combining subjective G1 weighting method and objective variation coefficient weighting approach. And then, the created model is verified by the data from 10 sub-provincial cities in China. Empirical analysis results are provided as follows. (1) The attribute 'X_{11} Agriculture labor productivity' has the greatest influence on the city modern agriculture development. (2) The development of sub-provincial cities modern agriculture is unbalanced. It tends to decrease progressively from southeast to northeast and to west. (3) Different sub-provincial cities have different advantage and disadvantage factors in city modern agriculture development.

The contribution of this paper is summarized as follows. First of all, this paper calculates the attributes' weights, by combining objective weighting and subjective weighting methods. Secondly, this study has practical significance for developing sub-provincial cities' modern agriculture in China and it can also provide a reference for development of modern agriculture in other countries' cities.

This evaluation model can have some extensions. There are 15 sub-provincial cities in China, but we only utilized 10 sub-provincial cities' data, which may be not enough. When investigating evaluation model should be period longer. The data from 2011 to 2016 can be taken into consideration.

Acknowledgements. The authors are grateful for funding support from the National Natural Science Foundation of China (Nos. 71503199, 71704010, 71471027, 71373207 and 71171031), the China Postdoctoral Science Foundation Funded Project (Nos. 2015M5726 08, 2016M591082 and 2016M591082), the Basic Business Project of Humanities Social Sciences for Central University (No. 2015RWYB09), the Natural Science Basic Research Project in Shaanxi Province (No. 2016JQ7005). Special thanks go to the Youth Talent Cultivation Program of Northwest A&F University (No. Z109021717).

REFERENCES

[1] J. Pretty, C. Brett et al., Policy challenges and priorities for internalizing the externalities of modern agriculture, *Journal of Environmental Planning and Management*, vol.44, no.2, pp.263-283, 2001.

[2] C. M. William, *Modern Agriculture and Its Benefits – Trends, Implications and Outlook*, Global Harvest Initiative, 2010.

[3] J. Wang, Evaluation on modern agriculture development in Bijie, *Chinese Journal of Agricultural Resources and Regionals Planning*, vol.35, no.5, pp.88-94, 2014.

[4] L. T. Hai, H. Schnitzer et al., An integrated eco-model of agriculture and small-scale industry in craft villages toward cleaner production and sustainable development in rural areas – A case study from mekong delta of Vietnam, *Journal of Cleaner Production*, vol.137, pp.274-282, 2016.

[5] X. Y. Zhao, Q. Fu, Z. X. Xing et al., Improvement of projection pursuit model and the application in integrated evaluation of eco-agricultural construction, *Transactions of the Chinese Society of Agricultural Engineering*, vol.22, no.5, pp.222-225, 2006.

[6] L. P. Zhao and Z. G. Yao, Research on modern agriculture evaluation index system of yellow river delta efficient ecological economic zone, *Advances in Social Science Education and Humanities Research*, vol.41, pp.632-637, 2015.

[7] R. B. Thapa and Y. Murayama, Land evaluation for peri-urban agriculture using analytical hierarchical process and geographic information system techniques: A case study of Hanoi, *Land Use Policy*, vol.25, no.2, pp.225-239, 2008.

[8] K. Rezaei-Moghaddam and E. Karami, A multiple criteria evaluation of sustainable agricultural development models using AHP, *Environment, Development and Sustainability*, vol.10, no.4, pp.407-426, 2008.

[9] R. Toledo, A. Engler and V. Ahumada, Evaluation of risk factors in agriculture: An application of the analytical hierarchical process (AHP) methodology, *Chilean Journal of Agricultural Research*, vol.71, no.1, pp.114-121, 2011.

[10] H. Soltanmohammadi, M. Osanloo et al., An analytical approach with a reliable logic and a ranking policy for post-mining land-use determination, *Land Use Policy*, vol.27, no.2, pp.364-372, 2010.

[11] X. Chen, Y. Wang, L. Wan and R. Xie, Study on the eco-agriculture regionalization based on hierarchical cluster analysis in Northeast China, *Economic Geography*, vol.32, no.1, pp.137-140, 2012.

[12] X. R. Wang, Principal component-hierarchical cluster analysis based empirical research of regional agriculture competitiveness in Shandong, *Chinese Agricultural Science Bulletin*, vol.32, no.29, pp.131-135, 2013.

[13] B. Shi, H. Yang, J. Wang and J. Zhao, City green economy evaluation: Empirical evidence from 15 sub-provincial cities in China, *Sustainability*, vol.8, no.6, pp.1-39, 2016.

[14] B. Shi, N. Chen and J. Wang, A credit rating model of microfinance based on fuzzy cluster analysis and fuzzy pattern recognition: Empirical evidence from Chinese 2157 small private businesses, *Journal of Intelligent & Fuzzy Systems*, vol.31, no.6, pp.3095-3102, 2016.

[15] D. L. Park, M. W. Trucksess et al., Solvent-efficient thin-layer chromatographic method for the determination of aflatoxins B1, B2, G1, and G2 in corn and peanut products: Collaborative study, *Journal of AOAC International*, vol.77, no.3, pp.637-646, 1994.

[16] F. Yin, L. Lu, J. Chai and Y. Yang, Combination weighting method based on maximizing deviations and normalized constraint condition, *International Journal of Security and Its Applications*, vol.10, no.2, pp.39-50, 2016.

[17] Y. Guo, Y. Yao and P. Yi, Method and application of dynamic comprehensive evaluation, *Systems Engineering – Theory & Practice*, vol.27, no.10, pp.154-158, 2007.