

Hierarchic Analysis on Influencing Factors of Grain Security in Henan Province Based on Grey Incidence Model

Fan-lin MengCollege of Information and Management
Science, Henan Agricultural University
Zhengzhou 450002, China
Email: fanlin_meng@163.com**Bing-jun Li***College of Information and Management
Science, Henan Agricultural University
Zhengzhou 450002, China
Email: zzbjun@163.com**Na Wang**College of Information and Management
Science, Henan Agricultural University
Zhengzhou 450002, China
Email: sqiuwangna@163.com

Abstract – Influencing factors of grain security have the nature of multi-hierarchy, and acting intensity the influencing factors on different levels is different. Based on the established hierarchic influencing factor set of grain security and the comprehensive coefficient of quantitatively expressing grain security in this paper, we conduct hierarchic analysis on influencing factors of grain security in Henan Province by grey incidence analysis model. The results of grey incidence analysis of influencing factors in the first hierarchy and grain supply, grain demand and grain circulation in the second hierarchy of the influencing factor set are obtained respectively. The results show that grain supply has the most significant impact on grain security in the first hierarchy of influencing factors set, and that inputs of agricultural means of production, people's rations and the price indices of agricultural means of production in the second hierarchy of influencing factors set have significant impact on grain security. So government should take effective measures to improve the comprehensive capacity of grain production for guaranteeing grain security.

Keywords – Grain Security, Influencing Factors, Grey Incidence Model, Hierarchic Analysis.

I. INTRODUCTION

Grain security is a big problem related to national economy and people's livelihood. Various countries in the world pay high attention to it. As the first big province for agriculture, grain production and population in china, Henan Province plays an important and special role in ensuring china's grain security. Therefore, the grain security problem from Henan Province is not allowed to neglect at any time.

As we know, there are many kinds of factors influencing on grain security. Many scholars researched on the relationship among the complex influencing factors of grain security at different angles or in different methods, and have made a series of research achievements. Song Xiaoqing^[1] sought the key influencing factors of grain security by using comparative analysis and space measuring analysis; Liu Xing^[2] analyzed the influencing factors from the link of production and circulation in Northeast China; Reference [3]-[5] respectively analyzed the influencing factors of grain security in Yunnan Province, Zhejiang Province and Heilongjiang Province by

using grey incidence analysis; Fu Qingye^[6] analyzed the effects of the development of bio-ethanol on grain security in China by using the evaluation results of China's grain security and grey incidence analysis. Those research achievements provide technical support for scientific guidance of improving grain security, but paid not or less attention to the complexity and uncertainty of grain security, and lack of the hierarchical action characteristic analysis of different influencing factors.

The influencing factors of grain security have the nature of multi-levels, and the action intensity of the influencing factors on different levels is different. Under the existing research results, this paper attempts to establish the hierarchic influencing factor set of grain security based on grain supply, grain demand and grain circulation, put forward the comprehensive index of expressing grain security, conduct the hierarchic analysis on influencing factors of grain security in Henan Province by grey incidence analysis model, and provide a theoretical basis for formulating reasonable and effective grain security policies.

II. HIERARCHIC INFLUENCING FACTOR SET AND QUANTITATIVE EXPRESSION OF GRAIN SECURITY

A. Influencing factor set of grain security

Grain security is complex system engineering, involved with social, economic, technological, etc. various aspects. Grain supply, grain demand, grain circulation and other links all can affect grain security. Starting with the above aspects, this paper chooses representative influencing factors as researching objects of grain security and establishes the hierarchic influencing factor set by reference to the existing researches and overall consideration of the principles of systemic nature, relative independence, and the availability of influencing factor's sample data, shown in Table I.

B. Quantitative expression of grain security

The risk of grain security come from the aspects and links of grain system, and the risk degree in different links is different. So it is difficult to employ only one index for comprehensively and completely judging and expressing the situation of grain security from the whole nation region. To solve this problem, here introduces the comprehensive coefficient of grain security^[7], and chooses 5 indexes, including self-supply rate of grain Z , per capita grain

The work was supported in part by the Soft-science Foundation of Henan Province (142400410727); Innovation Scientists and Technicians Troop Construction Projects of Henan Province (094100510013)

possession L , grain yield per hectare D , farmland areas per person G , and fluctuation coefficient of grain production B , which can be feasible to express and describe the entire situation of grain security objectively, and have strong operability. After normalizing, the 5 indexes are denoted as Z_1, L_1, D_1, G_1, B_1 respectively. Then based on carrying on these indexes normalized

weighting processing, we can obtain comprehensive coefficient of grain security F by (1).

$$F = W_1 \times Z_1 + W_2 \times L_1 + W_3 \times D_1 + W_4 \times G_1 + W_5 \times B_1 \quad (1)$$

Where, W_1, W_2, W_3, W_4, W_5 are the weights of indexes, they can be obtained by Delphi method.

Table I: Influencing factor set of grain security

First Hierarchy (Code)	Second Hierarchy (Code)	Measure Unit
supply (X)	The employed persons of farming forestry animal husbandry and fishery (X_1)	10^4 persons
	Year end area of plow land in use (X_2)	10^7m^2
	Total power of agricultural machinery (X_3)	10^4kw
	Effective irrigated area (X_4)	10^7m^2
	Consumption of chemical fertilizer by 100% effective component (X_5)	10^7kg
	Consumption of chemical pesticides (X_6)	10^7kg
	Plastic film use for agricultural (X_7)	10^7kg
	Electricity consumption in rural (X_8)	10^8kwh
	grain planting area (X_9)	10^7m^2
demand (Y)	Ration consumption of per capita (Y_1)	Kg / person
	Output of feed (Y_2)	10^7kg
	Output of alcoholic beverages (Y_3)	10^7kg
	Output of instant noodles (Y_4)	10^7kg
	Output of quick-frozen rice and wheat flour foods (Y_5)	10^7kg
	Total population (Y_6)	10^4 persons
circulation (Z)	Growth rate of output of grain (Z_1)	%
	Engel's coefficient in rural area (Z_2)	%
	Retail price indices of food (Z_3)	%
	Price indices of agricultural means of production (Z_4)	%
	Consumer price indices of grain (Z_5)	%
	Self-supply rate of grain (Z_6)	%

III. GREY INCIDENCE ANALYSIS MODEL

The grey incidence analysis, proposed by Professor Deng Julong in 1982, is one of the most important decision-making methods in Grey Systems Theory. The conventional grey incidence analysis is called Deng's incidence analysis. It is a method that can describe and compare the situation of system development quantitatively. According to the basis of math and the principle of grey incidence four axioms, it can determine incidence coefficient and incidence degree between reference sequence and comparison sequence. Since Deng Julong^[8] proposed the grey incidence analysis model,

considering the different characteristics of research objects, Xiao Xiping^[9] proposed points degree of incidence and interval degree of incidence II, Liu Sifeng^[10-12] proposed absolute degree of grey incidence, relative degree of grey incidence, and synthetic degree of grey incidence, Wang Qingyin^[13] proposed B type degree of incidence and C type degree of incidence, Tang Xiangwu^[14] proposed T type degree of incidence, Dang Yaoguo^[15] proposed slope degree of incidence and interval degree of grey incidence I, and Xiong Jinping^[16] proposed vector degree of incidence and complex degree of incidence.

Based on the actual situation of grain security, we conduct hierarchic analysis of influencing factors of grain security in Henan Province by using Deng's grey incidence analysis model in this paper. The basic principle and steps are as follows:

Supposes that the system characteristic behavior sequence is

$$X_0 = (x_0(1), x_0(2), \dots, x_0(n));$$

System's correlation factor sequence is

$$X_i = (x_i(1), x_i(2), \dots, x_i(n))(i = 1, 2, \dots, m).$$

For $\xi \in (0,1)$, let

$$\xi_{0i}(k) = \frac{\min_k |x_0(k) - x_i(k)| + \xi \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \xi \max_k |x_0(k) - x_i(k)|} \quad (2)$$

$$\gamma(X_0, X_i) = \frac{1}{n} \sum_{k=1}^n \xi_{0i}(k) \quad (3)$$

Where, ξ is the distinguishing coefficient, commonly takes 0.5. $\xi_{0i}(k)$ is the incidence coefficient. $\gamma(X_0, X_i)$ is called Deng interrelatedness, relative interrelatedness or general interrelatedness. This paper chooses the most popular Deng interrelatedness to do grey incidence analysis. Its general steps are as follows:

The first step: Calculate the initial image of every sequence. Let

$$X'_i = X_i / x_i(1) = (x'_i(1), x'_i(2), \dots, x'_i(n))(i = 0, 1, 2, \dots, m) \quad (4)$$

The second step: Calculate the absolute difference sequence, denoted as

$$\Delta_i(k) = |x'_0(k) - x'_i(k)|, \quad (5)$$

$$\Delta_i = (\Delta_i(1), \Delta_i(2), \dots, \Delta_i(n)) \quad i = 1, 2, \dots, m$$

The third step: Calculate the minimum difference and the maximum difference, denoted as

$$M = \max_i \max_k \Delta_i(k), \quad m = \min_i \min_k \Delta_i(k) \quad (6)$$

The fourth step: Calculate the incidence coefficient

$$\gamma_{0i}(k) = \frac{m + \xi M}{\Delta_i(k) + \xi M}, \quad \xi \in (0,1) \quad (7)$$

$$k = 1, 2, \dots, n; \quad i = 1, 2, \dots, m$$

The fifth step: Calculate the grey incidence degree

$$\gamma_{0i} = \frac{1}{n} \sum_{k=1}^n \gamma_{0i}(k); \quad i = 1, 2, \dots, m \quad (8)$$

IV. HIERARCHIC ANALYSIS ON INFLUENCING FACTORS OF GRAIN SECURITY IN HENAN PROVINCE

A. The calculation of grain security comprehensive coefficient in Henan Province

Using *Statistical Yearbook of Henan 2014*^[17], we can obtain the data of calculating grain security comprehensive coefficients in Henan Province. Based on the data, weights of Z_1 , L_1 , D_1 , G_1 , B_1 in (1) are given as 0.3, 0.25, 0.2, 0.15, 0.1 respectively, then we can obtain the grain security comprehensive coefficients from 2000 to 2013, shown in Table II.

Table II: The comprehensive coefficients of grain security of Henan Province from 2000 to 2013

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<i>F</i>	1081	1111	1116	948	1127	1188	1284	1310	1317	1318	1311	1320	1327	1331

B. The hierarchic analysis on influencing factors of grain security in Henan Province

1) The first hierarchy analysis of influencing factors

To quantitatively describe grain supply, grain demand and grain circulation in the first hierarchy of influencing factor set, where, grain supply is expressed by grain yield X ; grain demand is expressed by the total Y of ration consumption, output of feed and output of food industry; grain circulation is expressed by the average value Z of all factors including in the index.

Regarding F in Table II as the behavioral sequence, and data of X , Y and Z obtained from *Statistical Yearbook of*

Henan 2014^[17] as the related factor sequences. Then using (2) and (3), we can obtain the results of grey incidence analysis of influencing factors in the first hierarchy of the influencing factor set, shown in Table III.

From Table III, in the first hierarchy of the influencing factor set, the incidence order of influencing factors of grain security in Henan Province is: grain yield (X) > grain circulation (Z) > grain demand (Y). The biggest influencing factor is grain supply, the second is grain circulation, and the third is grain demand. Therefore, to improve grain security situation, government should not only emphasize grain demand and grain circulation, but also pay great attention to grain supply.

Table III: Grey incidence analysis of grain security grain supply, grain demand and grain market circulation in Henan Province from 2000 to 2013

	Grain Yield (X)	Grain Demand (Y)	Grain Circulation (Z)
Degree of incidence	0.7871	0.6430	0.6512
Incidence order	1	3	2

2) *The second hierarchy analysis of influencing factors*

Using *Statistical Yearbook of Henan 2014*^[17], we can obtain respectively the data of influencing factors of grain supply, grain demand, and grain circulation.

First, regarding X as the behavioral sequence, and X_1 ,

X_2 , X_3 , X_4 , X_5 , X_6 , X_7 , X_8 , X_9 , as the related factor sequences. Then using (2) and (3), we can obtain the results of grey incidence analysis of influencing factors of grain supply in the second hierarchy of the influencing factor set, shown in Table IV.

Table IV: grey incidence analysis of influencing factors of grain supply in Henan Province from 2000 to 2013

Year	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
2000	3559	6875.3	5780.6	4725.31	420.71	9.55	9.19	125.80	9029.60
2001	3472	6907.3	6078.7	4766.00	441.73	9.85	9.41	134.61	8822.79
2002	3393	7262.8	6548.2	4802.36	468.83	10.20	9.86	141.36	8975.10
2003	3321	7187.2	6953.2	4792.22	467.89	9.87	9.88	144.59	8923.30
2004	3235	7177.5	7521.1	4829.10	493.16	10.12	10.16	157.69	8970.07
2005	3128	7201.2	7934.2	4864.12	518.14	10.51	10.84	172.15	9153.40
2006	3039	7202.4	8309.1	4918.80	540.43	11.16	11.84	188.82	9455.80
2007	2910	7201.9	8718.7	4955.84	569.68	11.80	12.66	223.43	9468.03
2008	2837	7202.2	9429.3	4989.20	601.68	11.91	13.07	237.36	9600.00
2009	2754	7265.7	9817.9	5033.03	628.67	12.14	14.14	257.76	9683.61
2010	2698	7287.7	10195.9	5080.96	655.15	12.49	14.70	269.41	9740.17
2011	2655	7309.7	10515.8	5150.44	673.71	12.87	15.16	281.82	9859.87
2012	2611	7331.8	10872.7	5205.63	684.43	12.83	15.52	290.03	9985.15
2013	2541	7354.0	11150.0	4975.97	696.37	13.01	16.78	305.42	10081.81
Degree of incidence	0.6504	0.7753	0.6688	0.7708	0.7947	0.9302	0.7937	0.5908	0.7775
Incidence order	8	6	7	4	2	1	3	9	5

From Table IV, the incidence order of influencing factors of grain supply in Henan Province is: consumption of chemical pesticides (X_6) > consumption of chemical fertilizer by 100% effective component (X_5) > plastic film use for agricultural (X_7) > effective irrigated area (X_4) > grain planting area (X_9) > year-end area of plow land in use (X_2) > total power of agricultural machinery (X_3) > the employed persons of farming

forestry animal husbandry and fishery (X_1) > electricity consumption in rural (X_8).

Second, regarding Y as the behavioral sequence, and Y_1 , Y_2 , Y_3 , Y_4 , Y_5 , Y_6 as the related factor sequences, then using (2) and (3), we can obtain the results of grey incidence analysis of influencing factors of grain demand in the second hierarchy of the influencing factor set, shown in Table V.

Table V: Grey incidence analysis of influencing factors of grain demand in Henan Province from 2000 to 2013

Year	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
2000	216.96	185.03	141.45	-183.68	-27.68	9488
2001	189.39	207.46	146.69	-133.97	-3.45	9555
2002	196.96	250.9	137.43	-84.26	20.78	9613
2003	194.52	309.15	137.99	-34.55	45.01	9667
2004	191.65	385.99	174.73	15.16	69.24	9717
2005	170.36	475.2	227.53	64.87	93.47	9768
2006	167.35	637.95	283.07	114.58	117.7	9820
2007	162.29	829.6	387.68	135.89	136.12	9869
2008	180.09	1101.47	448.77	136.82	156.11	9918
2009	151.78	866.02	468.41	158.51	181.43	9967
2010	146.94	1109.53	525.05	212.53	220.88	10437
2011	118.51	1457.13	562.44	245.03	253.98	10489
2012	116.32	1476.82	627.13	275.06	250.69	10543
2013	119.54	1409.40	562.44	347.21	365.13	10601
Degree of incidence	0.9276	0.719	0.8495	0.7859	0.56	0.9636
Incidence order	2	5	3	4	6	1

From Table V, the incidence order of influencing factors of grain demand in Henan Province is: Total population (Y_6) \succ Ration consumption of per capita (Y_1) \succ Output of alcoholic beverages (Y_3) \succ Output of instant noodles (Y_4) \succ Output of feed (Y_2) \succ Output of quick-frozen rice and wheat flour foods (Y_5).

Third, regarding Z as the behavioral sequence, and $Z_1, Z_2, Z_3, Z_4, Z_5, Z_6$ as the related factor sequences, then using (2) and (3), we can obtain the results of grey incidence analysis of influencing factors of grain circulation in the second hierarchy of the influencing factor set, shown in Table VI.

From Table VI., the incidence order of influencing factors of grain circulation in Henan Province is: Price indices of means of agricultural production (Z_4) \succ Retail

price indices of food (Z_3) \succ Self-supply rate of grain (Z_6) \succ Consumer price indices of grain (Z_5) \succ Engel's coefficient in rural area (Z_2) \succ Growth rate of output of grain (Z_1).

From the obtain results in Table III, Table IV, Table V and Table VI, we can see that: grain supply among three factors in the first hierarchy of the influencing factor set of grain security has the most significant impact on grain security; in the second hierarchic analysis, the inputs of agricultural means of production among nine factors has the biggest impact on grain supply; people's rations among six factors has a maximum impact on grain demand; the price indices of agricultural means of production among six factors has the greatest impact on grain market circulation. These results are in accord with qualitative analysis, and they are reasonable and acceptable.

Table VI: Grey incidence analysis of influencing factors of grain circulation in Henan Province from 2000 to 2013

Year	Z_1	Z_2	Z_3	Z_4	Z_5	Z_6
2000	-3.57	49.7	96.9	99.6	84.8	171.97
2001	0.45	48.6	100.8	99.1	100.7	190.41
2002	2.19	48	100.3	100.8	97.8	184.51
2003	-15.21	48.2	105.2	101.9	103.5	153.36
2004	19.35	48.6	114.8	111.4	128.1	175.82
2005	7.56	45.4	103.2	107.9	101.4	181.46
2006	11.57	40.9	102.1	101.2	101.7	182.80
2007	2.60	38	115.4	106.1	108.6	169.70
2008	2.29	38.3	116.1	120.9	107.7	147.84
2009	0.44	36	101.2	98.1	107.1	169.08
2010	0.89	37.2	108.7	103.1	110.3	150.96
2011	1.94	36.1	112.4	111.1	109.8	147.34
2012	1.73	33.8	103.1	105.4	104.1	146.23
2013	1.33	34.4	105.6	101.3	106.6	144.60
Degree of incidence	0.6594	0.9418	0.9821	0.9844	0.9487	0.9737
Incidence order	6	5	2	1	4	3

V. CONCLUSION

The influencing factors of grain security are complex, have hierarchic and uncertain properties. This paper establishes the hierarchic influencing factor set of grain security based on grain supply, grain demand and grain circulation, puts forward the comprehensive index of quantitatively expressing grain security, conducts the hierarchic analysis on influencing factors of grain security in Henan Province by grey incidence analysis model. The research results show that:

First, grey incidence analysis model can be regarded as an effective and powerful tool to analyze the influencing factors of grain security. It can solve the problems with various sample sizes and distributions, and the computation amount is small. Its application has more advantages than that of many methods in statistics, such as regression analysis, variance analysis, and principal component analysis and so on.

Second, grain supply among three factors has the biggest impact on grain security in the first hierarchy of

influencing factor set. That is to say: safe grain supply is important and necessary for ensuring grain security. The inputs of agricultural means of production and cultivated area have significant impact on grain supply in the second hierarchy of influencing factor set. So for grain supply security, the government should appropriately increase investment in agricultural means of production and increasingly improve grain production condition. Meanwhile it is important for government to take effective measures to strengthen the management of rural land system, improve comprehensive capacity of grain production, protect and sharpen standardized farmland, and keep cultivated area stable. It is essential to strengthen low-yielding land transformation as the central work of high standard basic farmland construction and the combined agricultural development, develop dry agriculture positively. Apart from that, guaranteeing grain security also requires to perfect the grain processing system and improve the level of comprehensive utilization of grain resource.

Third, people's ration has a maximum impact on grain demand; the price index of agricultural means of production has the greatest impact on grain market circulation. Therefore, for effectively improving grain demand and grain market circulation, it is important and necessary for government to take effective measures to strengthen the management of people's ration and agricultural means of production. At the same time, it is essential for government to think highly of establishing alert system of grain security as soon as possible, making systematic evaluation index system of grain security, publicizing the situation of grain security timely, and setting up grain emergency plan to solve the dangerous situation in time.

REFERENCES

- [1] Song Xiaoqing. The influencing factors of China grain security from 1999 to 2007. *Journal of Geographical Sciences*, 2012,67(6):793-803.
- [2] Liu Xing, Zheng Guiting. The influencing factors of grain security and analysis of safeguard measures in Northeast China. *Journal of Changchun Normal University (Humanities and Social Sciences)*, 2013,32(3):11-15.
- [3] Tong Yan, Pan Yujun, Zhu Haiyan. Quantitative analysis on the influence factor of food security in Yunnan Province. *Territory and Natural Resource Study*, 2011(4):43-44.
- [4] He Manxi. The influencing factor of grain production based on grey correlation analysis. *Agricultural Economy*, 2011(2):3-5.
- [5] Zhang Shouzhong, Li Yuying. The change of grain production in Heilongjiang since 1990. *Shanxi Journal of Agricultural sciences*, 2009,55(1):152-156.
- [6] Fu Yeqing, Bi Yuping. The grey correlation analysis between the development of bio-ethanol and China grain security. *Inquiry into Economic Issues*, 2011(5):15-19.
- [7] Wang Guomin, Lu Tingting, Zhou Qingyuan. A comprehensive evaluation of food security of China from 1978 to 2010. *The Journal of Shanghai Administration Institute*, 2013(2):64-73.
- [8] Deng Julong. The tutorial of grey system theory. *Wuhan: Huazhong University of Science and Technology Press*, 1990.
- [9] Xiao Xiping, Song Zhongmin, Lifeng. The basis and supply of grey technology. *Beijing: Science Press*. 2005.
- [10] Liu Sifeng, Dang Yaoguo, Fang Zhigeng. The theory and supply of grey system. *Beijing: Science Press*. 2010.
- [11] Xie Naiming, Liu Sifeng. Research on evaluations of several grey relational models adapt to grey relational axioms. *Journal of Systems Engineering and Electronics*, 2009,20(2):304-309.
- [12] Gu Hui, Song Bifeng. Study on effectiveness evaluation of weapon system s based on grey relational analysis and TOPSIS. *Journal of Systems Engineering and Electronics*, 2009,20(1): 106-111.
- [13] Wang Qingyin. The grey relation analysis of B-model. *Journal of Huazhong University of Science and Technology*, 1989,17(6):77-81.
- [14] Tang Wuxiang. The concept and the computation method of T's correlation Degree. *Journal of Applied Statistics and Management*, 1995,14(1):34-37.
- [15] Cui Jie, Dang Yaoguo, Liu Sifeng. Novel properties of some grey relational analysis models. *Systems Engineering*, 2009,27(4): 65-70.
- [16] Xie Naiming, Liu Sinfeng. The parallel and uniform properties of several relational models. *Systems Engineering*, 2007, 25(8): 98-103.
- [17] Henan Statistical Bureau. Statistical Yearbook of Henan 2014. *Beijing: China Statistics Press*. 2014.

AUTHORS' PROFILE



Fan-lin Meng

was born in Jiyuan, China on February 22, 1992. She is a postgraduate student in College of Information and Management Science, Henan Agricultural University. Her major is agricultural information management and decision support system. And her research filed is grey system theory. She has published four articles on the topics related to agricultural system engineering and grey system theory.

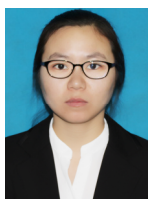
Email: fanlin_meng@163.com



Prof. Dr. Bing-jun Li

was born in Biyang, China on December, 1968. He is a Professor in College of Information and Management Science, Henan Agricultural University. He got the PhD degree from China Agricultural University in 1998, and engaged in the postdoctoral research work in Nanjing University of Aeronautics and Astronautics in 2005. He was hired as PhD supervisor in Henan Agricultural University in 2006, and visiting Professor in Osaka University in 2007. He has published about forty articles on the topics related to agricultural system engineering and grey system theory. He has also served as reviewer for numerous international journals.

Email: zzbjun@163.com



Na Wang

was born in Shangqiu, China on February 15, 1988. Her research filed is grey system theory, and she has published several articles in the filed of grey system theory. She got the Master degree in management science and engineering in 2014 from Henan Agricultural University.

Email: sqjuwangna@163.com