Research on Food Security and Informatization Management in Hubei Province Based on Gray Forecast Model and Factor Analysis

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Abstract. Food has been the root of people's livelihood since ancient times. Chinese government proposes to guarantee national food security as the bottom line and improve the agricultural protection system. Based on the agricultural and grain-related data of 17 cities and prefectures in Hubei, the gray forecast model is used to get the conclusion that Hubei Province is about to reach the set grain red line and the food security problem needs to be solved urgently. Through constructing the food security evaluation system, using the factor analysis method to classify the food security level of Hubei Province by SPSS. In view of the actual differences in classified fields, the countermeasures to ensure food security were put forward, including intelligent management, agricultural informatization, mechanization of farming, agricultural subsidies and characteristic agriculture. Governments at all levels should give full play to their public management functions, strengthen the flexibility of the food supply chain, and ensure the safety of the food supply chain in Hubei Province.

Keywords: food security · gray forecast model · factor analysis · public management · agricultural informatization

1 Introduction

China's "14th Five-Year Plan" proposes to improve the quality, efficiency and competitiveness of agriculture, to meet the requirements of ensuring the national economy and people's livelihood, to ensure national food security as the bottom line, and to adhere to the most stringent farmland protection system. Under the new policy guidelines, food security is the top priority [1]. As a large agricultural province, Hubei Province is one of the 13 main grain-producing areas in China that has unique natural conditions. In 2019, Hubei only ranked 11th in grain output, 13th in per capita grain ownership and 11th in per unit area, none of which was in the top 10. In 2020, Hubei has pledged to ensure food and energy security, resolutely guarding the red line of permanent basic farmland protection of 58.88 million mu (39,253,000 ha) and the bottom line of grain output of 50 billion jin (2,500 tons). Based on the grain and related data of 17 cities in Hubei Province, the article predicts the food security requirements, and uses factor analysis to classify the food security levels of the cities and prefectures, and finally provides

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Table 1. Grain yield and sown area in Hubei province from 2019 to 2020

	Grain yield (million tons)	Grain sown area (thousand hectares)
2016	2796.35	4816.14
2017	2846.12	4852.99
2018	2839.4656	4847.01
2019	2724.98	4608.6
2020	2727	4645

countermeasures. As food security becomes more and more important today, this study provides theoretical basis and decision-making suggestions for Hubei province to ensure food security, and also provides a reference for other similar provinces in China.

2 Forecast of Grain Yield and Sown Area in Hubei Province

2.1 Gray Forecast Model

GM (1,1) model is used to predict the grain yield and sown area according to the basic data from 2016 to 2020 in Hubei. Data are from the Statistical Yearbook of Hubei Province and the Department of Agriculture of Hubei Province, as shown in Table 1.

The forecasting model of grain yield:

$$x(k+1) = -169848.601179e^{(-0.016955*k)} + 172644.95 \tag{1}$$

The forecasting model of grain sown area:

$$x(k+1) = -269502.328018e^{(-0.01823*k)} + 274318.47 \tag{2}$$

GM modeling software and Excel were used to calculate the relevant data. The posterior error ratio of grain yield was 0.442, and the probability of a small error was 1. According to the prediction accuracy grade table, when 0.35< posterior error ratio <0.45, it is qualified, and the small error probability >0.95, indicating that the prediction grade is good. The posterior variance ratio of grain crop sown area is 0.647, which is less than 0.65 but extremely close to 0.65, and the forecast accuracy is barely, but the P is 1, and the prediction accuracy grade is very good, so the forecast accuracy is acceptable. Therefore, the above gray forecast model has acceptable.

2.2 Forecast Results

Based on the forecast model, the grain production and grain crop sown area for the 5-year period is forecasted as shown in Table 2.

The results show that the grain yield and grain-sown area in Hubei will decrease in the next five years. Although the 2025 data is still within the red line, the downward trend indicates that if the government does not formulate corresponding food security protection policies, it is only a matter of time before the red line is reached. Therefore, the government must provide effective measures to ensure food security.

Table 2. Grain yield and grain sown area forecast in Hibei province from 2020 to 2025

	Grain yield (million tons)	Grain sown area (thousand hectares)
2021	2712.22	4526.23
2022	2666.62	4444.46
2023	2621.79	4364.17
2024	2577.71	4285.33
2025	2534.38	4207.91

3 Analysis of the Food Security Level of Hubei Cities

3.1 Building Food Security Evaluation System

Regarding food security issues, the International Food and Agriculture Organization in 2019 divided food security into four dimensions: food supply level, food availability, food utilization, and stability over some time. Cui, N. and Dong, J. put forward the concept of food security in China's new era, including food production self-sufficiency, ecological environment security, stable output, strong market consumption ability, etc. [2]. Gao, Y., Zhang, Z., and Wang, Z put forward indicators such as grain self-sufficiency rate, grain sown area, road network density, and fertilizer application amount from the supply side and availability [3]. Tang, L., Zhao, W. and Li, S. believe that the evaluation system of Chinese food security evaluation system focuses on the production and supply of food [4]. Based on previous studies, a food security evaluation system consisting of 11 indicators at three levels was established, as shown in Table 3.

In the above indicator system:

The degree of grain production modernization reflects the level and efficiency of a region's grain production modernization, which is an important means to solve food security. Using limited land and human resources to produce more food can solve the problem of declining food production caused by the loss of rural labor.

The basic indicators of grain production intuitively reflect the grain production situation, farmers' living conditions, and the amount of cultivated land in all cities and prefectures in Hubei Province. The first three indicators reflect the basic situation and output efficiency of food production in a region. The latter two indicators reflect the level of economic development in rural areas, economic development will bring more people back to food production and promote the popularization of food production mechanization.

The cultivated land environment includes two major aspects of three sub-indicators, reflecting the occupancy crisis faced by cultivated land, which is represented by two negative indicators of cultivated land area reduction and urban, industrial, and mining land. In terms of the natural protection of cultivated land, the investment of geological disasters is selected, reflecting the amount of investment in the prevention and control of geological disasters in different cities and prefectures.

Table 3. Relevant indicators affecting food security issues

Related indicators affecting food security	***Modernization of food production***	X_1	Annual actual machine farming area
		X_2	Fertilizer application amount
		X_3	Agricultural electricity consumption
	Basic indicators of food production	X_4	Arable land area
		X_5	Grain yield
		X_6	Value added of agricultural output
		X_7	Grain sown area
		X_8	Rural residents' disposable income growth rate
	Arable Land Environment	X_9	Reduction of arable land area
		X_{10}	Urban, industrial and mining land
		X_{11}	Geological disaster input funds

3.2 Factor Analysis of Food Security Level in Hubei Province

A variety of methods have been used to study food security issues, including weighted average calculation [5], AHP [6], objective assignment method [7], Cobb-Douglas production function [8], entropy method combined with fuzzy comprehensive evaluation method [9], multiple linear regression [10], etc. Since the factor analysis method is to recombine according to the information of the original variables and find the common influencing factors, the rotation makes the classification of factor variables clearer and easy to explain related issues. Factor analysis is chosen to study the food security level of 17 cities and prefectures in Hubei Province.

1) Data collection and processing: The data are from the Hubei Statistical Yearbook, the 2019 Hubei Natural Resources Statistical Annual Report, the 2020 Hubei Rural Industry Development Report and related policy reports and websites.

Because the data have different dimensions and the difference of positive and negative indicators, the collected data are processed without dimension and non-negative. The dimensionless processing formula is $x^* = \frac{x-\mu}{\sqrt{\sigma}}$, Among them, μ refers to the average value of the standard data, and σ is the variance of the indicator data. The non-negative processing formula is $z_i = \frac{x_i - min}{max - min}$. Among them, min is the minimum value of the data in the indicator, and max is the maximum value of the data in the indicator.

2) Factor analysis: Using SPSS software for factor analysis, the KMO value and the Bartlett sphere test result are obtained. The KMO value is greater than 0.5, and the Bartlett sphere test is significantly less than the test level 0.05, so the above index values are suitable for factor analysis. According to the initial eigenvalues in the total variance

Table 4. Total variance explained

Ingredients	Initial Eigenvalue			Extraction of the sum of squares of loads			Sum of squared rotating loads		
	Total	*Variance %*	*Cumulative %*	*Total*	*Variance %*	*Cumulative %*	*Total*	*Variance %*	*Cumulative %*
1	7.419	67.442	67.442	7.419	67.442	67.442	5.731	52.098	52.098
2	1.631	14.831	82.273	1.631	14.831	82.273	2.858	25.986	78.083
3	1.088	9.894	92.167	1.088	9.894	92.167	1.549	14.083	92.167
4	0.335	3.042	95.208						
5	0.234	2.124	97.332						
6	0.162	1.476	98.808						
7	0.076	0.687	99.496						
8	0.021	0.193	99.689						
9	0.020	0.180	99.868						
10	0.010	0.088	99.957						
11	0.005	0.043	100.000						

diagram explained by SPSS, the first three principal components accumulate 92.1675%, which explains most of the information of the original data variables, as shown in Table 4.

It can be seen from the rotating component matrix table that component 1 includes the actual mechanical farming area, chemical fertilizer application, rural electricity consumption, cultivated land area, agricultural output value-added value, grain output, sown area of food crops, urban and industrial and mining land. Component 2 is the reduction of cultivated land during the year. Component 3 includes the growth rate of rural residents' per capita disposable income and the investment in the prevention and control of geological disasters. Therefore, factor one (F1) is defined as production and land factors, factor two (F2) is defined as development and land occupation factors, and factor three (F3) is defined as residents' living and environmental factors.

After classifying the components, the scores of each factor and the corresponding comprehensive scores are calculated respectively. The specific methods are as follows:

$$F = \frac{\lambda_1}{\lambda_1 + \lambda_2 + \lambda_3} F_1 + \frac{\lambda_2}{\lambda_1 + \lambda_2 + \lambda_3} F_2 + \frac{\lambda_3}{\lambda_1 + \lambda_2 + \lambda_3} F_3 \tag{3}$$

The scores and ranking data are shown in Table 5.

3) Analysis of the scores of each factor: For F1, the scores of Xiangyang and Jingzhou are significantly higher than other cities, and Wuhan and Ezhou are significantly lower. The main reason is that Xiangyang and Jingzhou have relatively superior natural geographical conditions and developed agriculture since ancient times. The rapid urban construction of Wuhan and the continuous development of secondary and tertiary industries have squeezed the space for grain production. Ezhou is a prefecture-level city with the smallest administrative area in Hubei Province and less grain-sown area.

Table 5. The score of each factor and the descending matrix of the comprehensive score

	F1	F2	F3	Comprehensive Score
Xiangyang	2.15	−0.04	0.02	1.36
Jingzhou	1.82	0.35	−1.04	1.28
Huanggang	0.96	0.59	−0.24	0.86
Jingmen	0.87	−0.06	−0.16	0.63
Yichang	0.44	0.43	1.27	0.52
Xiaogan	0.20	0.68	−0.32	0.46
Wuhan	−1.28	3.01	−0.51	0.28
Enshi	0.56	−0.68	1.43	0.28
Shiyan	−0.60	0.80	2.60	0.04
Suizhou	−0.12	−0.64	−0.44	−0.09
Xianning	−0.38	−0.19	0.01	−0.12
Tianmen	−0.53	−0.73	−0.90	−0.35
Huangshi	−0.88	−0.04	−0.93	−0.36
Xiantao	−0.66	−0.68	−0.81	−0.41
Qianjiang	−0.73	−0.74	−0.64	−0.47
Ezhou	−0.96	−0.48	−0.35	−0.53
Shennongjia	−0.84	−1.57	1.01	−0.77

For F2, the score of Wuhan is significantly higher than that of other cities. The scores of Enshi, Suizhou, Tianmen, and Qianjiang are relatively lower, because the local economic strength is limited, industrial and mining undertakings are less developed, and urban construction is relatively saturated.

For F3, Shiyan scored the highest, followed by Enshi and Yichang. The above regions have vast mountainous areas and need to invest a lot of money in geological hazards to protect the land. At the same time, the growth rate of per capita disposable income of rural residents in Yichang is the highest in the province, although largely it depends on Yichang's developed tourism economy, it can also encourage farmers to stay on their land. Sufficient funds and workers can improve the level of modernized grain production.

4) Analysis of factor composite score: According to the above comprehensive score gap, the 17 cities and prefectures in Hubei are divided into four categories.

The first category includes Xiangyang and Jingzhou. The former is located in the hinterland of Xiangyang Basin, with vast area and wide planting area. Moreover, And Xiangyang's GDP basically ranks the second in Hubei Province. It has a developed economy and relatively sufficient agricultural capital supply. It can realize the promotion of mechanized production and is suitable for the development of food production. In addition, Xiangyang's population is second only to Wuhan, with a wide distribution of rural areas and good agricultural development. Jingzhou has the same natural advantages in food production and has a large plain with abundant water resources and a rich tradition

of paddy field cultivation. In recent years, scientific prevention has been carried out, geological disasters and floods have been alleviated compared with the past.

The second category includes Huanggang, Jingmen, Yichang and Xiaogan. Huanggang has a good agricultural foundation, but the rural per capita disposable income is low, and the "siphon effect" of Wuhan is serious. Lots of working-age workers go out for work, and the reduction of rural labor force greatly affects the agricultural production, and its grain output is in the middle. Jingmen is mostly a mountainous and hilly area and it is difficult to form a large-scale food production. Yichang scored better in the third category, as its per capita GDP ranked first among non-provincial cities in central China and its high per capita disposable income in rural areas attracted people to stay in the countryside. Because of many mountainous areas in Yichang, the input of geological disaster prevention is higher to ensure the safety of grain production and arable land. Xiaogan is close to Wuhan and has a lot of labor migration, however, the natural conditions are superior, and the level of food security is relatively high.

The third category includes Wuhan, Enshi, Shiyan, Suizhou, and Xianning. As the capital of Hubei Province, Wuhan has a dense population and a large demand for food. However, according to the factor score matrix, the second type of development factor has the highest score. Because Wuhan, as the largest city in the central region, has accelerated its expansion of urban construction, the ring line has continued to expand outward, and the occupation of land has increased sharply. Although the country has established a strict red line for arable land, Wuhan's arable land decreased by 1,900.93 ha in 2019, the highest in the province and nearly doubled the second. Suizhou, Shiyan, and other places are restricted by economic levels, a large number of mountains are there and large-scale mechanized farming is hindered.

The fourth category includes Tianmen, Huangshi, Xiantao, Qianjiang, Ezhou, Shennongjia forest area. All the above areas except Shennongjia are located on the edge of Wuhan City and are greatly affected by Wuhan. In addition, although the above areas are located on the Jianghan Plain, with dense waterways and fertile soil, the area of land is small, and the total area of grain and output is small.

4 Suggestions for Countermeasures

4.1 Countermeasures for Wuhan

Wuhan belongs to the third category, but it has its characteristics. It is located in the hinterland of Jianghan Plain, its agricultural development is restricted by the development of secondary and tertiary industries. However, it has a large population and a great demand for food. Wuhan should strengthen the planning and gathering of limited farmland, carry out modern grain production, adjust measures to local conditions, prevent and control pests and diseases, and ultimately increase grain yield per mu. Strengthen its external grain procurement; build modern granaries based on actual conditions, and carry out necessary grain reserves.

4.2 Countermeasures for the Other Four Types of Cities

Xiangyang and Jingzhou have good natural and plant conditions, and their grain production ranks among the top in Hubei Province. The level of food security in these areas

can be further improved. Xiangyang's main food is rice and wheat. Xiangyang has scientifically promote intelligent farming to improve production efficiency. Utilize strong economic strength to promote the modernization of agricultural production and achieve higher output based on "intensive cultivation". Jingzhou is located along the Yangtze River and its arable land is dominated by paddy fields. In the past, floods occurred frequently. In recent years, Jingzhou has increased the construction and inspection of levees along the Yangtze River. The damage caused by floods to food production has been greatly reduced compared with the past. Jingzhou should continue to strengthen the protection of arable land based on its existing flood control experience, and use its natural advantages to supply better quality grains to achieve a double harvest of grain production and economic benefits.

The second category area. Although Huanggang, Jingmen, Yichang, and other places have many mountains, they have a good agricultural foundation. Strengthen small-scale mechanized production, use modern science and technology to increase grain output per mu. Yichang's industry and tourism are developing strongly, rural residents along the scenic area are mostly engaged in the service industry. Farmers are prosperous and do not pay too much attention to food production. The government needs to formulate corresponding incentive policies to allow farmers to carry out food production activities in addition to other revenues to ensure the effective use of arable land. Compared with the above three cities, Xiaogan should take advantage of its population and geographical advantages to play its role as an important food production base, actively promote mechanized production, select high-quality food varieties, and increase yield per mu. At the same time, increase subsidies for agriculture and mitigate the impact of rural population exodus.

The third category area. Shiyan, Suizhou, Xianning, and Enshi have low economic level, small population, lack of rural labor force, high degree of land waste and low degree of mechanization, which can only realize small-scale mechanization farming. Therefore, the above areas should actively promote the reuse of abandoned land, encourage the planting of a variety of cash crops, increase subsidies for food production, improve the living standards of farmers, and promote mechanization and intelligent farming. For mountainous areas, the government must increase funding for geological disasters, ensure the normal production of grain.

The fourth category area. Tianmen, Huangshi, Xiantao, Qianjiang, and Ezhou have better natural conditions, but they are close to Wuhan and undertake some urban functions. The above areas should first keep the cultivated land red line and strictly prohibit the occupation of cultivated land. The area of arable land in the above areas is small, it is difficult to develop large-scale agricultural production, and the efficiency of food production is difficult to improve. Therefore, based on ensuring food production, they should use the advantages of the Yangtze River and other waters to develop a multi-planting.

As one of China's 13 main grain-producing areas, Hubei should be able to scientifically plan, make overall arrangements and carry out modernization to ensure that it does not exceed the grain output and arable land red lines. In addition, the government should actively apply Internet information technology, realize e-government, improve management efficiency and management level. More agricultural funds should be used to improve farmers' smart farming, such as using drones to sow seeds and

spray pesticides. Information technology can be applied to realize informationized food farming, and intelligent farming planning can be carried out according to specific time and weather conditions, so as to realize efficient and environmentally friendly sowing, irrigation, spraying and harvesting, and ensure food security from the perspective of informationization and intelligence.

5 Conclusion

Grey forecasting and factor analysis are used to predict the grain red line in Hubei Province in the next five years, and to make countermeasures for food security in various cities and prefectures. For a populous country like our country, the basic status of agriculture cannot be ignored or weakened at any time. For Hubei Province, maintaining the established red line of arable land and grain production requires not only the efforts of cities and prefectures, but also Hubei Province to improve its information-based office capabilities, achieve effective overall planning, and vigorously promote unmanned, intelligent and efficient grain farming. Food security is a complex and systematic project, and there are still many problems to be studied, such as the resilience of the food supply chain, and the government's subsidies to different entities in the food supply chain.

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