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Evaluation of Grain Security in China's Major Grain-Producing Areas Based on the Entropy Weight TOPSIS Method

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Entropy Weight TOPSIS 방법에 기반한 중국의 주요 식량 생산지역의 식량 안전성 평가

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Abstract The major grain-producing areas are the key to ensuring China's grain security. This paper approached the issue from major grain-producing areas, and used the entropy weight TOPSIS method to comprehensively evaluate the grain security of China from 2010 to 2019 from the three dimensions of supply capacity, grain availability, and grain sustainability. The results show that, from the time dimension, the grain security levels of Anhui, Hebei, Heilongjiang, Inner Mongolia, and Sichuan provinces fluctuated upwards; the grain security levels of Henan and Hubei were relatively stable; the other six provinces showed a volatility decline. From the perspective of space, except for Sichuan province, the grain security status of the other provinces was generally at the upper-middle level. In the past ten years, Hunan province boasted the highest level of grain security, whose average output ranks first while Sichuan ranks last in grain production. Finally, the relevant policy recommendations from ensuring grain production capacity and stabilizing grain output, strengthening overall planning and deployment to ensure grain availability, and growing grain scientifically to ensure the sustainability of grain production were proposed to ensure grain security.

요 약 주요 식량 생산지역은 중국의 식량 안보를 보장하기 위한 핵심점이다. 본 연구는 주요 식량 생산지역으로부터의 쟁점 사항들에 접근해보고 공급용량, 식량 가용성과 식량 지속성의 세 가지 측면에 대하여 2010년부터 2019년 사이의 중국의 식량 안보를 전반적으로 평가하기 위하여 Entropy-weight TOPSIS 방법을 사용하였다. 연구 결과를 살펴보면 시간적 차원에서 안후이성, 허베이성, 헤이룽장성, 네이멍구성와 쓰촨성 지방의 식량 안보 수준은 상승하며 변동하였고; 허난성과 후베이성의 식량 안보 수준은 상대적으로 안정적이었으며; 다른 6개 지방은 변동성 있는 하락을 보여주었다. 공간적 측면으로 보면, 쓰촨성 지방을 제외하고, 다른 지방의 식량 안보 상태는 일반적으로 중상위 수준이었다. 최근 10년 동안, 후난성 지방이 전국 평균 생산량 1위를 차지하며 최상의 식량 안보 수준을 보여주었던 반면에 쓰촨성은 식량 생산에 있어 최하위를 차지하였다. 마지막으로, 식량 생산 능력을 확보하고, 식량 생산을 안정화하며, 식량 가용성을 보장하기 위한 전체적 계획과 전략을 강화하고, 식량 생산의 지속가능성을 확보하기 위해 식량을 과학적으로 경작하기 위하여 관련한 정책 제안을 식량 안보를 보장하기 위하여 제시하였다.

Keywords : Grain Security, Entropy Weight TOPSIS Method, Supply Capacity, Grain Availability, Grain Sustainability, Major Grain-Producing Areas

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1. Introduction

The issue of grain security is a major issue related to the national economy and the people's livelihood, and it is the foundation of the country's stability and development[1]. Godfray et al. (2010) pointed out that the continued growth of population and per capita food consumption means that global food demand will grow for at least the next 40 years. On the other hand, industrialization and urbanization will compete fiercely with agriculture in many aspects such as land, water resources, and energy, which will significantly reduce the food production capacity[2]. As we can see, the issue of grain security is still a major issue worldwide. Similarly, grain security is related to economic development, national independence, and social stability in China. The Chinese government has been focusing on grain security as a critical issue and has proposed a new strategy to ensure national grain security against COVID-19. In recent years, although China's grain production has achieved continuous growth under the support of the state's active policies, it still needs imports to make up for the shortage of domestic production[3]. China is in a period of rapid development of industrialization and urbanization. Coupled with the continuous growth of population and the continuous improvement of people's living standards, China's grain security will still face significant pressure in the future[4]. The formulation and improvement of grain security policies require a systematic and objective evaluation of the grain security situation.

The definition of major grain-producing areas is one of the essential strategies to solve the problem of grain security. In 2003, China's Ministry of Finance issued the "Opinions on Reforming and Improving Policies and Measures for Comprehensive Agricultural Development." And the report defined Heilongjiang, Jilin, Liaoning, Inner Mongolia, Hebei, Henan, Shandong, Jiangsu, Anhui, Sichuan, Hubei, Hunan, and Jiangxi as major grain-producing areas based on grain output and other indicators of each province. As the major grain-producing areas have comparative advantages in grain production, grain production is gradually concentrated in the major grain-producing areas. The contribution of grain from the major grain-producing areas from 2000 to 2019 has been maintained at more than 70%. And in 2019, the total grain output of the 13 major grain-producing areas was 524.57 million tons, accounting for 78.92% of the national grain output. The main producing areas have become the core area of national grain production and the vital guarantee area of China's national grain security, which can reflect and determine the grain security of the whole country to a certain extent[5]. Therefore, it is essential to establish an index system for comprehensive evaluation of grain security from the major grain-producing areas to formulate and improve grain security policies and guarantee grain security in China.

2. Literature review

The FAO first proposed the concept of food security in 1974 when it was defined as "ensuring that all people at all times have enough food to survive and be healthy." Since then, FAO's definition of food security has been adjusted as understanding has evolved. The domestic research on food security in China is based on FAO's concept of food security and considers China's national conditions. Most scholars point out that food security in China is grain security and research[6]. In recent years, many scholars have studied the major grain-producing areas and grain security issues.

First of all, related research on the major grain-producing areas. Based on introducing the general situation in major grain-producing areas, Jiang et al. (2015)[4] combined relevant data to analyze the major grain-producing areas' grain yield, planting area, and farmers' income. Zhang et al. (2016)[5] used the DEA-Malmquist index and fixed effects model to analyze the Spatio-temporal evolution and driving forces total productivity of major grain-producing areas in China from 2001 to 2012. In order to develop a deep and systematic analysis of the significant contribution that grain production in major grain-producing areas makes to ensure national grain security, Chen et al. (2017) conducted an objective discussion on its economic development dilemma and the factors of grain production to propose countermeasures on enhancing the benefits compensation and improving compensation mechanism in major grain-producing regions[7]. Xu et al. (2012)[8] used the land comprehensive index evaluation method to analyze temporal and spatial variation of the quantity and quality of cultivated land in major grain-producing areas and study its effect on grain production capacity.

Secondly, the related research on grain security evaluation in China. Zhu (1998) [9] advocated evaluating grain security from four aspects: the change of grain output, grain self-sufficiency rate, the level of grain reserve, and per capita share of grain. Ma et al. (2001)[10] divided grain security into four levels: global, national, family, and individual to construct a grain security early warning system. Ma et al. (2010)[11] used the method of experts questionnaire investigation to develop a quantitative method for evaluating grain security. Based on the internationally accepted concept of grain security, Zhang et al. (2015)[12] constructed indices representing supply, distribution, consumption to appraise the status, trends, and problems of grain security of China. In addition, Zhang et al. (2011)[13], Yao et al. (2015)[6] constructed different index systems and applied different methods to evaluate grain security.

From the previous studies, the literature on the current situation, problems, and evaluation of grain security have been relatively abundant, which are helpful to understand the development situation of major grain-producing areas and the basic evaluation of grain security. However, the previous studies on grain security evaluation have limited sample selection and single indicators. There is little literature that analyzes China's grain security temporal and spatial from the major grain-producing areas. Therefore, based on the international concept of food security and the particularity of grain security in China, this study constructs the evaluation system of grain security from a short-term and long-term grain security perspective, using the entropy weight TOPSIS method to evaluate China's grain security from 2010 to 2019, and analyze the regional differences and spatial distribution, and temporal change of grain security.

3. Analysis method and analyzed data sources

3.1 Study area and data sources

This paper selects the major grain-producing areas including Heilongjiang, Jilin, Inner Mongolia, Henan, Anhui, Liaoning, Shandong, Hebei, Jiangxi, Jiangsu, Hubei, and Sichuan determined by the Ministry of Finance in 2003 as the research samples. The sample selection mainly considers the following two reasons: First, as an essential grain-producing base in China, the major grain-producing areas play a vital role in ensuring China's grain security. In 2019, the total grain output of the 13 major grain-producing areas was 524.57 million tons, accounting for 78.92% of the national grain output.

Table 1. The change of China's grain output in different production areas

(Unit: 1000 tons)

	Major grain-producing areas	
	Grain output	Pct.
2000	32,607.4	70.6%
2005	35,443.2	73.2%
2010	41,184.1	75.4%
2015	47,341.2	76.2%
2016	46,776.4	75.9%
2017	47,073.5	76.2%
2018	51,768.9	78.7%
2019	52,371.0	78.9%

Source: China Agricultural Statistics (1949-2019)

The logic of this paper is mainly to cut from the major grain-producing areas and uses the entropy weight TOPSIS method to reflect the national food security level better. Unless otherwise stated, the data used in this study are most statistical data. The primary data of grain output per capita area, grain sown area, road network density, and per capita grain share are from the China Statistical Yearbook (2011-2020). The data on fertilizers, pesticides, and irrigated areas for grain production are from the China Rural Statistical Yearbook (2011-2020).

3.2 Variables selection and calculation

The connotations of grain security are very diverse, from the initial emphasis on quantitative security, ensuring that everyone has access to grain for survival and health at all times, to the later focus on structural issues of grain access, that is, to ensure that everyone has access to adequate, safe, and nutritious grain at all times, and the connotation of grain security are constantly adjusted and improved as people's understanding deepens. On this basis, in most literature, the grain security has been considered on China's national conditions when conducting relevant research on grain security issues in China. For example, Hu et al. (2013)[14] defined grain security from four dimensions: quantity safety, quality safety, ecological safety, and health safety. Wang (2015)[15] proposed to locate grain security from the perspective of the entire food system and emphasized the safety of feed grain. Therefore, the evaluation indicators of grain security need to be carefully selected.

This study selects the evaluation indicators of grain security from a short-term and long-term

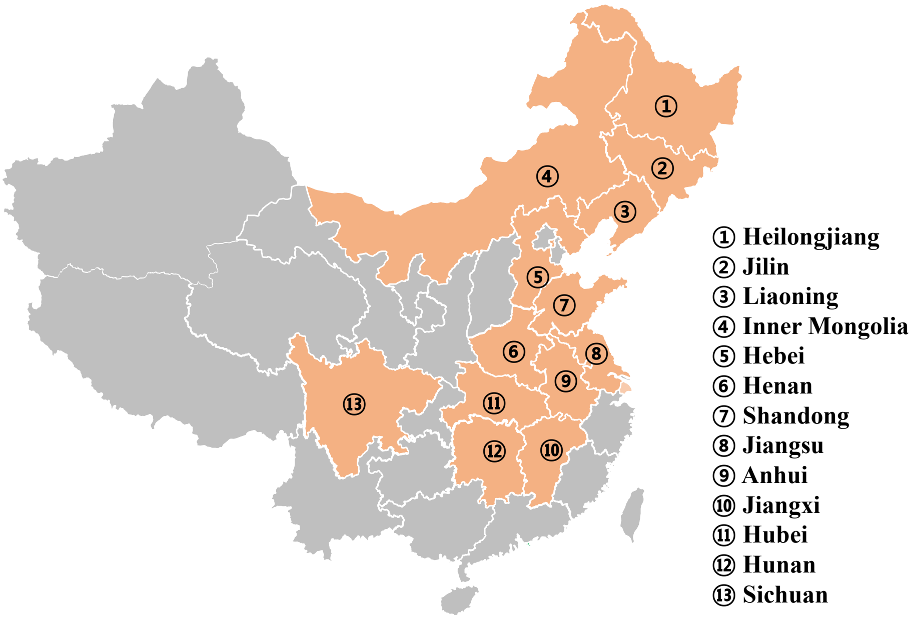

Fig. 1. Divisions of China's major grain-producing areas

perspective. The short-term perspective mainly includes grain supply capacity, while the long-term perspective includes grain availability and sustainability dimensions. Firstly, apart from the consideration of international grain trade, the most fundamental problem of grain security lies in the output and structure of grain production, that is, the problem of grain supply. Secondly, under the premise of sufficient grain supply, it is also necessary to provide people with the ability and opportunity to obtain grain through market allocation, government regulation, and infrastructure construction, which is grain availability. Finally, grain production faces rigid constraints on land and water resources. Excessive use of fertilizers and pesticides improves grain output in the short term, but it causes serious soil compaction and water pollution, which is not conducive to grain security for a long time.

In addition, according to the representativeness, systematicity, independence, and operability principles of the index selection, refer to Zhang et al. (2015), Liu et al. (2014), Cheng et al. (2015), and the "The State of Food Insecurity in the World" published by FAO in 2013, this paper sets the grain output per unit area and the grain sown area at the grain supply level. In the dimension of grain availability, per capita share of grain and road network density is selected. The input of chemical fertilizers, pesticides, and irrigated areas is chosen for this study's sustainability dimension evaluation indicators. The specific setting logic is as follows: (1) Grain supply capacity. Grain security depends on grain supply[12]. Grain output per unit area is an essential indicator of grain supply, especially when the COVID-19 pandemic is rampant and the unstable trading environment. To increase grain output per unit area is to take grain security into our own hands. As a necessary basis for grain production, land has the characteristics of non-trade and natural endowment, which has rigid constraints on grain security[16,17]. (2) Grain availability. The original concept of grain security is defined as "to ensure that anyone can get enough grain for survival and health at any time", indicating that per capita share of grain is a primary content of grain security. And grain security is valid only when grain meets the basic survival needs of humankind. Sufficient and stable grain production is not enough for achieving grain security, but when the grain is not transported well, it will often lead to regional grain security problems[18]. Road networks have become the primary conditions for achieving a balanced grain supply. (3) Grain sustainability. Grain production is a resource-constrained production[19] restricted by land, water, energy, and climate[20,21]. Under resource constraints, it has become the norm to use large amounts of chemical fertilizers and pesticides to increase grain production. Excessive use of chemical fertilizers and pesticides leads to severe agricultural pollution, affecting the quality and quantity of cultivated land. Overuse of fertilizers and pesticides can seriously affect the sustainability of grain production and thus grain security. In addition, the development of irrigated agriculture has improved the land's productive capacity, meeting the water needs of grain production and regulating soil temperature, humidity, and nutrients. It can be seen in Table 2 and Table 3.

3.3 Entropy-weight TOPSIS method

The entropy weight method is an objective weighting method, which can reveal the utility of each index and avoid the interference of subjective factors. Nowadays, this method is widely used in the research of index system evaluation[22]. TOPSIS model is a comprehensive evaluation method based on distance, which Hwang and Yoon first proposed in 1981. The model can objectively and comprehensively reflect the degree of grain security by calculating

Table 2. Index system of evaluation for China's grain security

Index 1	Index 2	Index 3	Unit	Sign	Direction
Grain security	Supply capacity	Grain output per unit area	$kg \cdot ha^{-1}$	x_1	+
		Grain sown area	1000 hectares	x_2	+
	Grain availability	Per capita share of grain	$kg \cdot person^{-1}$	x_3	+
		Road network density	$km \cdot km^{-2}$	x_4	+
	Grain sustainability	Fertilizer inputs	1000 hectares	x_5	-
		Pesticide inputs	1000 hectares	x_6	-
		Irrigation area	1000 hectares	x_7	+

Table 3. Summary descriptive statistics of variables

Index	Mean	Std. Dev.	Min	Max
Grain output per unit area	5800.36	655.08	4010	7493
Grain sown area	6649.32	2780.92	3243	14338
Per capita share of grain	724.13	444.53	395.69	2000.27
Road network density	104.32	50.17	14.30	183.50
Fertilizer inputs	298.86	141.29	116	716
Pesticide inputs	1304.33	848.22	91	4224
Irrigation area	3471.51	1295.69	1408	6120

the closeness degree between evaluation value and ideal solution. Firstly, the entropy weight method gives weight to the evaluation indicators. Then the TOPSIS method is used to comprehensively evaluate the grain security in China's major grain-producing areas. The entropy weight TOPSIS method can fully use the original data information. And it has no special requirements on sample size and is not interfered with by selecting the reference sequence. It has the advantages of intuitive geometric meaning, less information loss, and flexible calculation[23].

Major grain-producing areas are China's major grain production bases, its grain production conditions and the consistency of the production capacity are strong, and the probability of the abnormal value of each index of grain security is small. And these characteristics can effectively avoid the entropy weight TOPSIS method in determining the positive and negative ideal solutions when the problem of excessive deviation, be a more scientific and accurate evaluation of grain security. The specific calculation steps are as follows:

Assuming that there are m regions, n years. Then the matrix $X=(x_{ij})_{m\times n}$ can be obtained according to the original data, x_{ij} means the original value of index j in region i.

$$X=\begin{matrix} x_{11} & \cdots & x_{1j} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{matrix} \tag{1}$$

(1) Standardized data processing:

Standardization of data processing, because units of the index in the evaluation system are different, this study first carries out data processing to compare different indicators and determine the weights for each data normalized. In data processing, each indicator is converted by using the extremum method. The calculation processes are expressed in Eqs. (2) and (3).

The standardized formula for the positive indicators is as follows:

$$x_{ij}^{'}=\frac{x_{ij}-\min x_{ij}}{\max x_{ij}-\min x_{ij}} \tag{2}$$

The standardized formula for the negative indicators is as follows:

$$x'_{ij} = \frac{x_{ij} - \max x_{ij}}{\max x_{ij} - \min x_{ij}} \quad (3)$$

Where x'_{ij} is the value of indicator x_{ij} processed by the extremum method, x_{ij} is the actual value of indicator i in the year j, $\max(x_{ij})$ is the maximum actual value of indicator i in the year j, and $\min(x_{ij})$ is the minimum actual value of indicator i in the year j.

After processing, the standardized data matrix is finally obtained:

$$X' = \begin{matrix} x'_{11} & \cdots & x'_{1j} \\ \vdots & \ddots & \vdots \\ x'_{i1} & \cdots & x'_{ij} \end{matrix} \quad (4)$$

(2) Calculate the proportion of each index:

$$P_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{m} X'_{ij}} \quad (5)$$

(3) Calculation of information entropy of each index:

$$e_j = -\frac{1}{\ln m}\sum_{j=1}^{m}(P_{ij} \times \ln P_{ij}), (0 \leq \ e \leq \ 1) \quad (6)$$

(4) Calculate the redundancy of each index:

$$d_j = 1 - e_j \quad (7)$$

(5) Calculate the weight of each index:

$$w_j = \frac{d_j}{\sum_{j=1}^{m}(d_j)} \quad (8)$$

(6) Construct weighted normalization matrix:

$$Z_{ij} = x'_{ij} \times w_j \quad (9)$$

(7) Determine the optimal and the worst scheme according to he weighted normalization matrix:

$$\begin{aligned} V^+ &= (V_1^+, V_2^+, \cdots, V_m^+) \\ &= \{\max Z_{ij} \mid j = 1, 2, \cdots, m\} \end{aligned} \quad (10)$$

$$\begin{aligned} V^- &= (V_1^-, V_2^-, \cdots, V_m^-) \\ &= \{\min Z_{ij} \mid j = 1, 2, \cdots, m\} \end{aligned} \quad (11)$$

Where in the above formula, V^+ is the optimal solution (positive ideal solution) and V^- is the worst solution (negative ideal solution).

(8) Calculate the Euclidean distance S_i^+ and S_i^- between the target value and the ideal value:

$$S_i^+ = \sqrt{\sum_{j=1}^{m}(V_j^+ - V_{ij})^2} \quad (12)$$

$$S_i^- = \sqrt{\sum_{j=1}^{m}(V_j^- - V_{ij})^2} \quad (13)$$

Where S_i^+ and S_i^- are the distances of the positive and negative ideal solutions, respectively.

(9) To calculate the score of comprehensive evaluation:

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-}, 0 \leq \ C_i \leq \ 1 \quad (14)$$

Where C_i (comprehensive evaluation index) is the closeness of the evaluated target object and the optimal solution, and the C_i value range is $[0,1]$. It reflects the degree of grain security in the region, and the larger the value, the stronger it is.

4. Results and analysis

4.1 Empowerment of the grain security evaluation index

This paper uses the entropy weight TOPSIS method to evaluate China's grain security from 2010 to 2019. Based on the data of 13 provinces from 2010 to 2019, the entropy weight method is used to give objective weight to the evaluation index of grain security constructed above. The analysis is as follows. First, the original data of the evaluation indicators are standardized with the help of Eqs. (2) and (3), and then each evaluation indicator's information entropy and weight are calculated with the help of Eqs. (6), (7), and (8). The calculated results are shown in Tables 4 and 5.

It can be seen in Table 4, according to the ranking of the proportions of the secondary indicators, the weights of grain availability, grain supply capacity, grain sustainability are 0.550295, 0.230216, 0.219489, respectively.

4.2 The evaluation of grain security

The TOPSIS method is used to measure the evaluation results of grain security in major grain-producing areas from 2010 to 2019. According to Eqs (12), (13), and (14), the proximity to positive and negative ideal solutions and the evaluation level in 13 provinces are calculated, and the ranking and mathematical analysis of the results are conducted. Due to space limitations, only the comprehensive evaluation scores from 2010 to 2019 are listed in Table 6. The average comprehensive evaluation scores and ranking of grain security from 2010 to 2019 are shown in Table 7.

As shown from Table 6, during the ten years from 2010 to 2019, the fluctuation trend of China's grain security level can be roughly divided into three types: rising volatility, stable volatility, and declining volatility. The rising volatility provinces are Anhui, Hebei, Heilongjiang, Inner Mongolia, and Sichuan. The regions with stable volatility are Henan and Hubei. At the same time, the other six provinces (Hunan, Jilin, Jiangsu, Liaoning, Shandong) are declining volatility. However, the grain output of the six provinces whose grain security levels have decreased from 2010 to 2019 has generally been steadily rising. Still, the grain security changes have undergone more obvious changes after including other indicator systems. Ma et al. (2010)[11] also point out that the stability and increase of grain production do not necessarily mean grain security, and to ensure grain security that requires a multi-faceted approach.

As shown from Table 7, the grain security value of most provinces is more significant than 0.50, indicating that China's grain security is at an upper-middle level. However, the grain security level of Sichuan is relatively low, and the grain security value in the past ten years from 2010 to 2019 has remained at about 0.427, which is at a low-medium level. This may be due to the large-scale increase in planting oil crops, medicinal crops, and vegetables in Sichuan in recent years, resulting in the squeeze of space for grain production. Specifically, Hunan, Hubei, Heilongjiang, Jilin, Henan, Hebei, Anhui, Jiangsu provinces have grain security values above 0.50. Jiangxi, Shandong, Inner Mongolia, Liaoning, and Sichuan provinces have grain security values below 0.50. In terms of average ranking, Hunan, Hubei, and Heilongjiang are the top three in the 10-year average ranking of grain security. It should be noted that this result is significantly different from the provincial ranking based solely on grain production. The main reason is that the TOPSIS method has considered many aspects of grain security and has many selected indicators. Hence its evaluation of grain security is more accurate and comprehensive.

Table 4. Grain security evaluation index weight

Index 1	Index 2	Index 3
Grain security	Grain supply capacity (0.230216)	Grain output (0.043829)
		Grain sown area (0.186837)
	Grain availability (0.550295)	Per capita share of grain (0.436254)
		Road network density (0.11404)
	Grain sustainability (0.219489)	Fertilizer inputs (0.050688)
		Pesticide inputs (0.033009)
		Irrigation area (0.135792)

Table 5. Weight value of each evaluation indicator

	x_1	x_2	x_3	x_4	x_5	x_6	x_7
Entropy(e_j)	0.985189	0.937014	0.852577	0.961462	0.982871	0.988845	0.954112
Redundancy(d_j)	0.014811	0.062986	0.147423	0.038538	0.017129	0.011155	0.045888
Weight(w_j)	0.043829	0.186387	0.436254	0.11404	0.050688	0.033009	0.135792

Table 6. The comprehensive evaluation scores (C_i-value) of grain security

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Anhui	0.512	0.515	0.517	0.518	0.52	0.521	0.521	0.522	0.523	0.524
Hebei	0.524	0.526	0.528	0.529	0.53	0.531	0.533	0.533	0.533	0.534
Henan	0.534	0.535	0.536	0.536	0.537	0.537	0.537	0.538	0.537	0.537
Heilongjiang	0.536	0.54	0.542	0.545	0.547	0.548	0.55	0.552	0.554	0.556
Hubei	0.558	0.559	0.56	0.56	0.561	0.561	0.56	0.561	0.561	0.561
Hunan	0.562	0.562	0.561	0.561	0.561	0.56	0.56	0.56	0.559	0.557
Jilin	0.556	0.556	0.553	0.549	0.544	0.54	0.536	0.53	0.524	0.521
Jiangsu	0.517	0.515	0.514	0.512	0.509	0.507	0.504	0.501	0.497	0.492
Jiangxi	0.487	0.488	0.488	0.488	0.488	0.487	0.486	0.485	0.484	0.483
Liaoning	0.482	0.483	0.478	0.473	0.464	0.465	0.462	0.455	0.445	0.439
Inner Mongolia	0.426	0.437	0.448	0.458	0.465	0.472	0.479	0.489	0.501	0.507
Shandong	0.513	0.51	0.504	0.497	0.491	0.484	0.476	0.463	0.446	0.425
Sichuan	0.396	0.404	0.41	0.418	0.425	0.434	0.443	0.446	0.449	0.448

Table 7. Ranking of grain security in major grain-producing areas

	Mean(S_i^+)	Mean(S_i^-)	Mean(C_i)	Rank
Hunan	0.029096	0.037074	0.560262	1
Hubei	0.030708	0.039113	0.560204	2
Heilongjiang	0.033353	0.040264	0.547033	3
Jilin	0.028235	0.033308	0.540859	4
Henan	0.035865	0.041495	0.536402	5
Hebei	0.037861	0.042734	0.530270	6
Anhui	0.040343	0.043576	0.519302	7
Jiangsu	0.027615	0.028391	0.506733	8
Jiangxi	0.02609	0.024729	0.486571	9
Shandong	0.014663	0.013716	0.480747	10
Inner Mongolia	0.01974	0.017268	0.468288	11
Liaoning	0.02417	0.021026	0.464628	12
Sichuan	0.009142	0.006669	0.427112	13

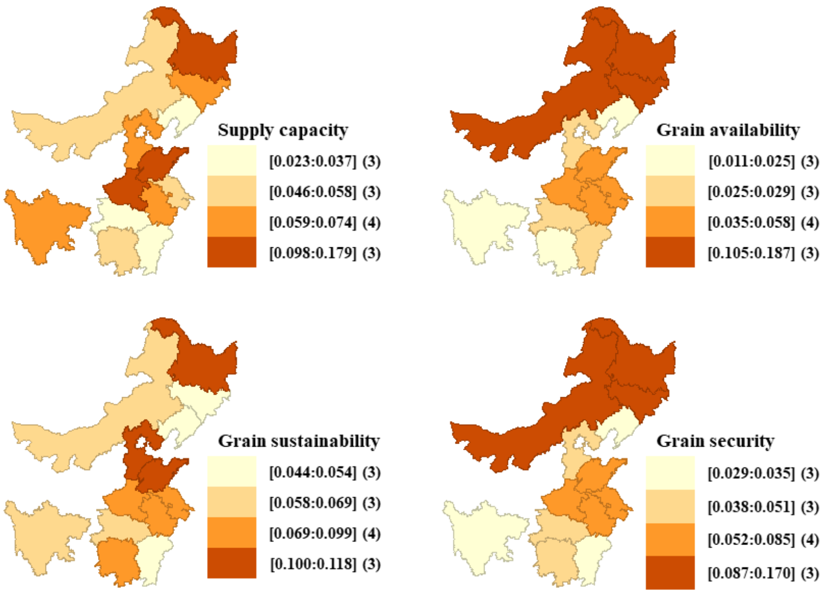

Fig. 2. Spatial distribution of grain security in China's major grain producing areas

4.3 The spatial heterogeneity of grain security

In order to reveal the spatial distribution characteristics of grain security in the major grain-producing areas in China, the spatial distribution of grain security is analyzed in ArcGIS 10.2. In addition, this study explores the spatial heterogeneity of supply capacity, grain availability, grain sustainability, and grain security, respectively, and the results are shown in Fig. 2.

According to the ranking of the proportions of the secondary indicators, the weights of grain availability, grain supply capacity, grain sustainability are 0.550295, 0.230216, 0.219489, respectively. The index of grain availability accounts for the most significant proportion of all secondary indicators, with a weight of 0.550295, indicating that grain availability plays a decisive role in grain security. The differentiation of grain availability is highly correlated with the differentiation of grain security, and both of them mainly concentrate in Heilongjiang, Jilin, Inner Mongolia, Shandong, Jiangsu, Henan, and Anhui. The index of grain availability reflects that it can ensure that anyone can have enough grain for survival and health at any time. Good grain availability is an inevitable process to ensure grain security in China. In addition, in the grain security index system, the weights of grain supply capacity and grain sustainability are 0.230216 and 0.219489, respectively. Grain supply capacity has a more significant contribution value to grain security than grain sustainability. However, compared with grain availability, the weight is lower. This result further indicates that the stability and increase of grain output do not necessarily mean the grain security, which is also consistent with the research conclusions of Ma et al. (2010)[11], Zhang et al. (2015)[12].

5. Conclusions

This study aims to analyze the regional differences, spatial distribution, and temporal change of grain security. Based on the international concept of food security and the particularity of grain security in China, this study constructs the evaluation system of grain security from a short-term and long-term grain security perspective, using the entropy weight TOPSIS method to evaluate China's grain security in major grain-producing areas from 2010 to 2019. This study draws the following conclusions: First, from the perspective of temporal change, the rising volatility provinces are Anhui, Hebei, Heilongjiang, Inner Mongolia, and Sichuan. The regions with stable volatility are Henan and Hubei. At the same time, the other six provinces (Hunan, Jilin, Jiangsu, Liaoning, Shandong) are declining volatility. Secondly, from a spatial perspective, except for Sichuan province, the grain security of other areas is generally at the upper-middle level. In the past ten years, Hunan, Hubei, and Heilongjiang have had the highest levels of grain security, with the 10-year average ranking among the top three, while Sichuan province ranks last. Then, the index of grain availability accounts for the most significant proportion of all secondary indicators, with a weight of 0.550295, indicating that grain availability plays a decisive role in grain security. The weights of grain supply capacity and grain sustainability are 0.230216 and 0.219489, respectively. Grain supply capacity has a greater contribution value to grain security than grain sustainability. However, there is no obvious spatial difference in China's grain security level.

Based on the research conclusions, this paper will further strengthen the national grain security level from the following aspects. The first is to ensure grain production capacity and stabilize grain output. Adhere to a strict farmland protection system on the existing basis, and accelerate the construction of a batch of high-standard farmland. The second is to strengthen overall planning and deployment to ensure grain availability. On the one hand, improve the overall grain allocation and deployment system, focusing on the problem of grain access for the poor and avoiding regional grain security issues. On the other hand, strengthen the construction of rural roads and other infrastructure to improve the efficiency of grain distribution. The third is to grow grain scientifically to ensure the sustainability of grain production. In light of the specific conditions of grain production in major grain-producing areas, the state guilds agricultural universities and research institutes to strengthen research and development of grain science and technology and the cultivation of grain varieties, and develop agricultural techniques for preventing diseases, insect pests and meteorological disasters. This study focuses on evaluating grain security in China's major grain-producing areas and draws some valuable conclusions. However, this study only discusses the major grain-producing areas in China and does not include all provinces in China. Therefore, the research on the differences in the regional grain security system should be strengthened in the future to ensure each region's grain security according to local conditions.

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