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Global Food System Optimization based on Analytic Hierarchy Process

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Abstract

Select low-income consumption index, production index, trade index, and greenhouse gas emissions as the standard level, sustainability, profitability, efficiency, and equ ity as the executive level, and determine the target level based on surveys and expert suggestions. The standard level and the executive level have relative indicators Proportion, construct the analytic hierarchy process model, optimize the food system by changing the relative ratio between the indicators of the executive level. After the optimization, the system pays more attention to sustainable development and equity, and it is solved by matlab. In contrast with the system before optimization, the optimized food system is not only for profit, but also for sustainable development and equity issues, so that the food development is optimized in the direction of optimization.

Keywords

Grain System Optimization, Analytic Hierarchy Process, Matlab.

1. Introduction

In recent years, the food issue has always attracted people's attention. The number of hungry people in the world is increasing, and the issue of food security is imminent. Food security has always been a top priority for people's livelihood and an important foundation for economic development, social stability and national security.[1] The issue of food security is not only an important economic issue, but also a political issue that cannot be ignored.[2] What does food security mean? It is to meet the needs of all mankind for food, to meet the nutritional and health needs of mankind, and to meet the diversified needs of mankind for food.[3] The new crown epidemic is very likely to trigger a new round of international food supply crisis and food price crisis. Natural disasters such as deliberate floods have brought certain serious threats to agricultural production. The complicated international political and economic environment has put a severe test on the food supply of some countries.[4].

2. Data Sources and Model Assumptions

The weights given to variables in the model are based on the relative ratio between the two based on surveys and expert suggestions. In order to solve the problem, the following assumptions are put forward:

There is no invalid data, and the relative proportions between variables are absolutely valid; Natural disasters, severe weather and other factors will affect the stability of the ecosystem, which will affect the food system. Negative impact. Since such damage is difficult to measure, this article does not consider the damage caused by major disasters to the food system.

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3. Food System Optimization Model based on Analytic Hierarchy Process

3.1 Research Ideas

According to the existing research, combined with the analytic hierarchy model, determine the target layer, the criterion layer and the execution layer, the criterion layer and the execution layer respectively establish the corresponding indicators, and optimize the food system by changing the relative ratio between the bottom indicators, using matlab software Solve.

3.2 Research Methods

3.2.1 Indicator Construction

First quantify the indicators. The target level is the food optimization system, and the criterion level is the low-income consumption index, production index, trade index, and greenhouse gas emissions. The final scores of these four indicators are used to measure the quality of the food system. The executive level is The sustainability, profitability, efficiency and equity of the food system. Establish a hierarchical analysis structure diagram. See Table 1.

Table 1. Symbols

Serial Number	Symbol	Definition
1	O	Food System Optimization
2	C_1	Low Income Consumption Index
3	C_2	Production Index
4	C_3	Trade index
5	C_4	Greenhouse Gas Emissions
6	P_1	Sustainability
7	P_2	Profitability
8	P_3	Efficiency
9	P_4	Equity

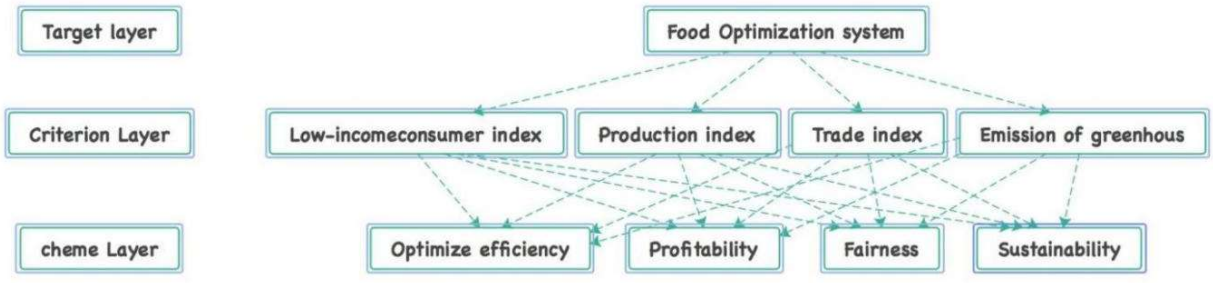

Figure 1. Analytic hierarchy structure diagram

3.2.2 Model before Optimization

According to the investigation and expert advice, the relative scale between P1,P2,P3,P4 was obtained, and the ratio of Pi's importance to O was expressed by aij. The result of the ratio of the importance of each pair of P1,P2,P3,P4 is expressed by a paired comparison matrix.

$$A=(a_{ij})_{n*n},\ a_{ij}>0, a_{ji}=1/a_{ij}$$

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Criteria Layer vs Target Layer.

The model before optimization pays more attention to profitability and production efficiency of the food system, and pays less attention to sustainable development and fairness. Therefore, the relative weights of each indicator P1 and P4 account for a higher proportion.

Step1: Calculation of Eigenvalues and Weight Vectors.

Matrix:

$$A=\begin{array}{c} \begin{matrix} P_1 & P_2 & P_3 & P_4 \end{matrix} \\ \begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{4} & \frac{1}{3} \\ 2 & 1 & 1 & 4 \\ 4 & 1 & 1 & 5 \\ 3 & \frac{1}{4} & \frac{1}{5} & 1 \end{bmatrix} \end{array}$$

The maximum eigenvalue and weight vector are obtained by normalizing the matrix:

$$L_{max} = 4.1596$$
$$W=(0.1006,0.3095,0.4029,0.1870)^T$$

Step2: Consistency Test.

The consistency check refers to the determination of the allowable range of inconsistency for A. Among them, the only non-zero characteristic root of the n-th order uniform matrix is n; the largest characteristic root of the n-th order reciprocal matrix A, if and only at that time, A is a uniform matrix. Since λ is continuously dependent, the more λ is greater than n, the more serious the inconsistency of A, and the consistency index is calculated by CI. The smaller the CI, the greater the consistency.

Calculation of consistency indicators (CI):

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

The corresponding mean random consistency index (RI) lookup:

Table 2. Consistency Checklist

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58	1.59

Consistency ratio (CR) calculation:

$$CR = \frac{CI}{RI}$$

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According to the software calculation, CR=0.0591<0.1, it meets the consistency requirements, so the weight vector above is effective.

Criteria Layer vs Scheme Layer.

Step1: Calculation of Eigenvalues and Weight Vectors.

$$P_1=\begin{bmatrix} 1 & 2 & 3 & \frac{1}{2} \\ \frac{1}{2} & 1 & 2 & \frac{1}{3} \\ \frac{1}{3} & \frac{1}{2} & 1 & \frac{1}{3} \\ 2 & 3 & 3 & 1 \end{bmatrix} \quad P_2=\begin{bmatrix} 1 & 2 & 2 & 2 \\ \frac{1}{2} & 1 & 1 & \frac{1}{2} \\ \frac{1}{3} & 1 & 1 & 2 \\ \frac{1}{2} & 2 & \frac{1}{2} & 1 \end{bmatrix}$$

$$P_3=\begin{bmatrix} 1 & \frac{1}{3} & \frac{1}{2} & \frac{1}{3} \\ 3 & 1 & 2 & 3 \\ 2 & \frac{1}{2} & 1 & 2 \\ 3 & \frac{1}{3} & \frac{1}{2} & 1 \end{bmatrix} \quad P_4=\begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{3} & 1 \\ 2 & 1 & 2 & 3 \\ 3 & \frac{1}{2} & 1 & 2 \\ 1 & \frac{1}{3} & \frac{1}{2} & 1 \end{bmatrix}$$

The maximum eigenvalues and weight vectors of P_1, P_2, P_3, P_4 are normalized as follows:

$$L_{max1}=4.0710, W_1=(0.2829,0.1636,0.1059,0.4476)^T$$
$$L_{max2}=4.1170, W_2=(0.3909,0.1701,0.2303,0.2088)^T$$
$$L_{max3}=4.1649, W_3=(0.1076,0.4448,0.2581,0.1896)^T$$
$$L_{max4}=4.1031, W_4=(0.1444,0.4192,0.2970,0.1394)^T$$

Step2: Consistency Test.

According to the software calculation, CR_1= 0.0263,CR_2 =0.0433,CR_3 =0.0611,CR_4 =0.0382, it meets the consistency requirements, so the weight vector above is effective.

Weight Matrix:

Table 3. Weight matrix before optimization

	Index weight	Low Income Consumption Index	production index	Trade index	Greenhouse Gas Emissions	Index Score
Sustainability	0.1006	0.2829	0.1636	0.1059	0.4476	0.1006
Profitability	0.3095	0.3909	0.1701	0.2303	0.2088	0.3095
Efficiency	0.4029	0.1076	0.4448	0.2581	0.1896	0.4029
Equity	0.1870	0.1444	0.4192	0.2970	0.1394	0.1870

3.2.3 Model after Optimization

Criteria Layer vs Target Layer.

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The model before optimization pays more attention to sustainable development and fair production efficiency, and pays less attention to profitability and grain production efficiency, so the relative weights of each indicator P2 and P3 account for a higher proportion.

Step 1: Calculation of Eigenvalues and Weight Vectors.

Matrix:

$$A=\begin{array}{c} \begin{matrix} P_1 & P_2 & P_3 & P_4 \end{matrix} \\ \begin{bmatrix} 1 & 3 & 3 & 1 \\ \frac{1}{3} & 1 & 1 & \frac{1}{4} \\ \frac{1}{3} & 1 & 1 & \frac{1}{2} \\ 1 & 4 & 2 & 1 \end{bmatrix} \end{array}$$

The maximum eigenvalue and weight vector are obtained by normalizing the matrix:

$$L_{max}=4.0458$$
$$W=(0.3743,0.1172,0.1399,0.3686)^T$$

Step 2: Consistency Test.

According to the software calculation, CR=0.0170<0.1, it meets the consistency requirements, so the weight vector above is effective.

Criteria Layer vs Scheme Layer.

Step 1: Calculation of Eigenvalues and Weight Vectors.

$$P_1=\begin{bmatrix} 1 & 2 & 2 & \frac{1}{2} \\ \frac{1}{2} & 1 & 1 & \frac{1}{3} \\ \frac{1}{2} & 1 & 1 & \frac{1}{3} \\ 2 & 3 & 3 & 1 \end{bmatrix} \quad P_2=\begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{2} & 1 \\ 2 & 1 & 1 & 2 \\ 2 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

$$P_3=\begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{2} & 1 \\ 2 & 1 & 1 & 2 \\ 2 & 1 & 1 & 1 \\ 1 & \frac{1}{2} & 1 & 1 \end{bmatrix} \quad P_4=\begin{bmatrix} 1 & 5 & 3 & 1 \\ \frac{1}{5} & 1 & 1 & \frac{1}{3} \\ \frac{1}{3} & 1 & 1 & \frac{1}{4} \\ 1 & 3 & 4 & 1 \end{bmatrix}$$

The maximum eigenvalues and weight vectors of P_1, P_2, P_3, P_4 are normalized as follows:

$$L_{max1}=4.0104, W_1=(0.2628,0.1409,0.1409,0.4554)^T$$

$$L_{max2}=4.2621, W_2=(0.1641,0.3282,0.2731,0.2346)^T$$

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$$L_{max3}=4.0606, W_3 = (0.1692, 0.3383, 0.2879, 0.2046)^T$$

$$L_{max4}=4.0432, W_4 = (0.4050, 0.1044, 0.1099, 0.3806)^T$$

Step 2: Consistency Test.

According to the software calculation, $CR_1=0.003$, $CR_2=0.0971$, $CR_3=0.0225$, $CR_4=0.0160$, it meets the consistency requirements, so the weight vector above is effective.

Weight Matrix.

Table 4. Weight matrix after optimization

	Index weight	Low Income Consumption Index	production index	Trade index	Greenhouse Gas Emissions	Index Score
Sustainability	0.3743	0.2628	0.1409	0.1409	0.4554	0.3743
Profitability	0.1172	0.1641	0.3282	0.2731	0.2346	0.1172
Efficiency	0.1399	0.1692	0.3383	0.2879	0.2046	0.1399
Equity	0.3686	0.4050	0.1044	0.1099	0.3806	0.3686

4. Conclusion

According to the software solution, more attention was paid to the profitability and efficiency of the food system before the priority was changed, while equity and sustainability were ignored. The optimized model increases the emphasis on equity and sustainability, and the food system is optimized and not just for profit.

By changing the priorities, the whole food system is not just about profit, but more distributive equity and sustainability of the whole food system.

5. Suggestions

5.1 Establish a National Food Security System

Food security has rich strategic connotations. In the post-epidemic era of globalization, it is necessary to "jump out of food to look at food", place food security in the open environment of global agriculture, and expand the concept of food security in breadth, breadth and depth. , To form a comprehensive and three-dimensional food security system.[5] The state should give macro-control, moderately intervene in the country's grain market, and form a good system to enable the grain market to function normally and safely.

5.2 Promote Good Ecological Development

It is necessary to uphold the concept of sustainable development, strengthen ecological restoration and pollution control, realize soil protection and land recuperation, and consolidate the material basis for long-term food security.[6]The problem of food security does not only depend on this production line of food, soil, water resources, etc. have a very important impact on food. Protecting the resources of the first production line is conducive to the development of food security in a favorable direction.

In the future, we will continue to strengthen global food and agricultural governance and strengthen the coordination mechanism for food security at the national and regional levels.[7]We should establish a sound food security system to ensure food security issues.

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