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Multifactor Mathematical Modeling Analysis on Re-optimizing Global Food Systems

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Abstract: *Food relates directly to human livelihood. It is also one of the most important things that we care about. In this paper, our model is consisted of several small models, such as the AHP model, the TOPSIS model and the EWM model. It is aimed to analyze the relationship between food production, food supply chain and the food system, with advantages in flexibility, ductility and adaptability. Applying our model to practical data, simulating the currency of nowaday world, learning and improving through documents and literature, the model now has the ability to analyze different factors and estimate the food system. Through combining research in different fields, a re-optimization for the global food system is carried out to solve the issue.*

Keywords: *Mathematical Modeling, AHP model, TOPSIS model, EWM model, Food Systems*

1. Introduction

We have to admit that the world is undergoing colossal changes at no period and without any precedent. For today's human society, the inequality of social development leads to the facilitation of poverty, hunger, disease and other phenomena. It's a signal of warning that the world's economy, agriculture, and health aren't developed enough to what we expected them to be. Several economic crises have demonstrated the fragility of our economic system, and sudden epidemics such as Ebola and COVID-19 have demonstrated the fragility of our health system. When the economic system suffers and the health system is severely damaged, livelihood issues become urgent problems to be addressed. Our global food system is fragile, and there is hunger even in the most developed countries. The problem is already particularly acute. [1]

For only the case of the COVID-19 pandemic alone, a virus which swiped the entire world has pulled back the global economy and caused many countries collapsing or even giving up their medical defenses. People's livelihood is facing huge crisis, needless to say food safety and food reserves when the safety of human life cannot be guaranteed. There was chaos and panic all over the world, food and medical supplies were raided, and prices were driven to sky-high levels. Many are struggling not because they were infected by the virus, but because the lack essential supplies such as food and water. Otherwise, why are there so many people lining up for miles waiting at the food banks for necessary daily supplies?[2]

2. The Analytic Hierarchy Process Model

(1) Establish a hierarchical structure model

(2) Construct a judgment matrix

Pairwise comparison between the left factor and the upper factor, fill in the table, carry out paired comparative analysis, and establish a positive reciprocal matrix[3].

(3) Hierarchical single sorting and consistency check

The weight of each index is determined by arithmetic mean method and square root method, and then the average value is taken

Among: a_{ij} is judging the elements in the matrix, (compare the results in pairs)

n is judging the order of the matrix Then normalize each index.

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Normalization method:

$$\mathrm{W_i} = \frac{W_i}{\sum_{i=1}^{n} w_i} \tag{1}$$

(4) Calculate the maximum eigenvalue of the judgment matrix λmax

Calculating

$$\lambda_{max} = \sum_{i=1}^{n} \frac{B_i * W}{n * W_i} \tag{2}$$

In which Bi is the ith vector of the judgment matrix

(5) Calculate the consistency index (c_i) of the judgment matrix and test its consistency

$$C_{\mathrm{i}} = \frac{\lambda_{max} - n}{\mathrm{n} - 1} \tag{3}$$

n is the dimension Define the consistency ratio $c_r = (i/r_i)$

Generally speaking, when the coincidence ratio (c_r) is less than 0.1, it is considered that the inconsistency degree of A is satisfactory within the allowable range. Through the coincidence test, its normalized feature vector can be used as the weight vector, otherwise, it is necessary to reconstruct the comparison matrix A to adjust a_{ij}.

(6) Because the number n = 5, the average random consistency index, r_i = 1.12. Therefore, the consistency index c_r is

$$X_1 = \begin{bmatrix} 1 & 3 & 2 & \frac{1}{3} & 5 \\ \frac{1}{3} & 1 & \frac{1}{3} & \frac{1}{7} & 4 \\ 1 & & 1 & 2 & 6 \\ \frac{2}{2} & 3 & 1 & 1 & 9 \\ 3 & 7 & \frac{2}{2} & & \\ \frac{1}{5} & \frac{1}{4} & \frac{1}{6} & \frac{1}{9} & 1 \end{bmatrix} \tag{4}$$

$$\lambda_{max} = 5.2526 \tag{5}$$

$$\mathrm{CI} = 0.0631 \tag{6}$$

$$\mathrm{R_I} = 1.12 \tag{7}$$

$$C_r = 0.0564 < 0.1 \tag{8}$$

3. The Technique for Order Preference by Similarity to Ideal Solution Model

(1) The Application Reason

According to the analytic hierarchy process, it is found that the units of sample quantity are not consistent, and not all of them are uniform standards. For example, the fourth hunger index is a reverse standard, so it is necessary to apply reciprocal method in forward direction[4].

Therefore, we choose the superior and inferior solution distance method.

(2) Standardize the matrix (forward)

Standardized formula

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$$z_{\mathrm{ij}} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{9}$$

That is, each element is divided by the sum of the squares of the elements in its column and then marked with a root.

(3) Calculate the score and normalize it

Construct a scoring formula for calculation, (x-min)/(max-min).

Transform into after deformation(x, distance from minimum value)/(X, distance from maximum value, plus distance between x and minimum value)

Define the maximum value

$$z^{+} = [z_1^{+}, z_2^{+}, \dots, z_m^{+}] = \left[max\{z_{11}, z_{21}, \dots, z_{n1}\}, max\{z_{12}, z_{22}, \dots, z_{n2}\}, \dots, max\{z_{1m}, z_{2,m}, \dots, z_{nm}\}\right] \tag{10}$$

Define the minimum value

$$z^{-} = [z_1^{-}, z_2^{-}, \dots, z_m^{-}] = \left[min\{z_{11}, z_{21}, \dots, z_{n1}\}, min\{z_{12}, z_{22}, \dots, z_{n2}\}, \dots, min\{z_{1m}, z_{2,m}, \dots, z_{nm}\}\right] \tag{11}$$

Then we define the distance between the ith evaluation object and the maximum value

$$d_i^{+} = \sqrt{\sum_{j=1}^{m} \left(z_j^{+} - z_{ij}\right)^2} \tag{12}$$

Define the distance between the ith evaluation object and the minimum value

$$d_i^{-} = \sqrt{\sum_{j=1}^{m} \left(z_j^{-} - z_{ij}\right)^2} \tag{13}$$

From this, we can calculate the normalized scores of (di) evaluation objects

$$\mathrm{S_i} = \frac{d_i^{-}}{d_i^{+} + d_i^{-}} \tag{14}$$

It is obvious that 0 is less than or equal to Si and less than or equal to 1, and the larger Si is, the larger Di is, that is, the closer it is to the maximum value.

(4) According to the analytic hierarchy process (see the code for details)

4. The Entropy Weight Method Model

(1) Optimization reasons

According to the data, only topsis method is slightly one-sided, which makes the information reflected by the data insufficient[5].

This introduces Shannon's entropy weight method

Define

$$I_i = \log_2\left(\frac{1}{p_i}\right) = -\log_2 p_i \tag{15}$$

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$$E_j = -\ln(n)^{-1} \sum_{i=1}^{n} p_{ij} \ln p_{ij} \tag{16}$$

(2) The analytic hierarchy process and the indexes in TOPSIS method are used to list a new matrix, and then the matrix is quantized and uniformly processed.

At the same time, the matrix is uniformly quantified as a positive index here.

(3) The processing matrix standardizes the data in the matrix define

$$Y_{ij} = \frac{X_{ij} - min(X_i)}{max(X_i) - min(X_i)} \tag{17}$$

(4) Calculate the entropy value of index number Hj

$$H(j) = \sum_{j=1}^{n} p_j \times \log_2\left(\frac{1}{p_j}\right) \tag{18}$$

(5) Entropy weight is obtained by calculation ω'_j

(6) When optimizing, the subjective weights in hierarchical analysis are combined

Define

$$p_{\mathrm{ij}} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_y} \tag{19}$$

(7) Finally, the three schemes are weighted and summed, and arranged before and after

Define

$$\mathrm{F} = \sum_{i=1}^{n} \lambda_i \times W_j \tag{20}$$

5. The Final Model

(1) Using AHP to calculate subjective weight, λ_1, λ_2, $\lambda_{3.}$

Through the above method, the table of weights and maximum standard values is obtained by usin the mathematical tool MATLAB, and then included in the new matrix, thus a new group of matrices is obtained λ_{ij}。

(2) The matrix is obtained by the distance method of superior and inferior solutions a_{ij} Firstly, the data is listed as a one-line matrix, and the matrix z_{ij} is obtained after standardization Then, the matrix is normalized by the normalization formula,

$$\mathrm{S_i} = \frac{d_i^-}{d_i^+ + d_i^-} \tag{21}$$

Then, let S_i correspond to ai respectively

Finally, the corresponding five rows and three columns matrix can be obtained by repeating it three times $a_{ij.}$

(3) Integrate the elements in the final scoring matrix

Let

$$\mathrm{f_{ij}} = \lambda_{\mathrm{ij}} \times a_{ij} \tag{22}$$

(4) Entropy weight method to calculate information weight

Through entropy weight method, the information entropy H_j and entropy weight W_j are calculated

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from ten to twenty samples in previous years.

6. Applications and Solution of Problems

(1) What happens if food is optimized for fairness and sustainability?

From the model, in order to the sustainable development plan, we have TGO indicators, GYpH, pCCLA indicators such changes will be relatively smooth, this model will be on the basis of the original, the score changes will be relatively small, even negligible difference, the sustainable development in the model can reflect the information is very limited. But if it turns out to be very low, it's a very poor score. But after sustainability, the numbers swing smoothly and nicely, and our index scores change dramatically, even to the point of ranking. It is found that after sustainable development, we can determine the effectiveness of development through model observation.

If we focus on the development of all relevant indicators per capita for the sake of equitable development, then in the ideal situation, if the impact on other indicators is small, then according to the results of the model, there will be a big change. Due to the difference of information entropy in different regions, our results are also different. Therefore, through our model, we can first grade the undeveloped plans, and then grade the development degree accordingly, until we find the small gap in the scheme layer. From this, we can predict the degree and impact of equitable development.

(2) How many years will it take for such a system to be implemented?

It is difficult for our model to tell an accurate time number, but we can predict the current situation or the current policy through the prediction of the grey model. Then through the model to find a reasonable scheme, after linear programming, change the data in the score, until better than the gray expected after the data. For example, the score of Scheme 2 is optimized to a certain extent through grey prediction, and the policies are determined to fill into the model after linear programming. The annual difference between the two methods is calculated to determine the ideal number of years for the implementation of the policy and how fast and convenient the policy will be compared with other policies.

(3) What are the benefits and costs of changing the priorities of the food system? What's going to happen?

Reasonable changes in the order can bring about a more stable situation. It is shown in the model that the scoring results of several schemes are close to each other, while the overall level rises. How- ever, it will also bring some costs. For example, blindly pursuing the stability of data in the model will lead to some extreme phenomena, such as overcultivation of land and over-exploitation of resources.

(4) What are the differences in these benefits and costs between developed and developing countries?

Compared with developed countries, the data in the model of developing countries will have obvious deviation, which will lead to the next decision of developing countries, and the benefits will not be very large, because the main problem is to solve poverty and hunger. The resulting cost may not be large, and even the cost will be saved to a certain extent. Compared with developing countries, developed countries tend to be the opposite. They may invest more costs to make the income greater, which usually takes a large proportion in the link of distribution and sales.

(5) Practical application of the model

Our model was introduced to two countries, namely, Germany, a developed country, and Mexico, a developing country

The table is as follows:

Table 1: Mexico Result

	Information Weight	AGP	ATCLA	ATGO
TGO	0.24413	0.2106721	0.0427118	0.29818425
GYpH	0.14983	0.0049472	0.0077448	0.00569794
pCCLA	0.30822	0.0000002	0.0000001	0.00000050
HI	0.21946	0.0000005	0.0000002	0.00000003
GDP	0.07835	0.0000011	0.0000188	0.00000565
SCORE		0.05217286	0.011589176	0.073650044

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Table 2: Germany Result

	Information Weight	AGP	ATCLA	ATGO
TGO	0.2384	0.211017053	0.04278318	0.29868259
GYpH	0.12671	0.002161135	0.00338326	0.00248909
pCCLA	0.41208	0.000000218	0.00000013	0.00000058
HI	0	0.000029679	0.00000978	0.00000201
GDP	0.22282	0.000000320	0.00000554	0.00000167
SCORE		0.050580464	0.010629491	0.071521936

References

[1] The 2021 Food Systems Summit, United Nations, 2020. Retrieved from: 'https://www.un.org/ sustainabledevelopment/ food-systems-summit-2021/'.

[2] Mbow, C., Rosenzweig, C. E., Barioni, L. G., Benton, T. G., Herrero, M., Krishnapillai, M., ... & Diouf, A. A. (2020). Food security.

[3] Smith, M. D., Rabbitt, M. P., & Coleman-Jensen, A. (2017). Who are the world's food insecure? New evidence from the Food and Agriculture Organization's food insecurity experience scale. World Development, 93, 402-412.

[4] Barker, M., & Russell, J. (2020). Feeding the food insecure in Britain: learning from the 2020 COVID-19 crisis. Food Security, 12(4), 865-870.

[5] Hobbs, J. E. (2020). Food supply chains during the COVID-19 pandemic. Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 68(2), 171-176.