Research on Model Optimization of Food system Dynamics based on SD-SOP

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Abstract. With the development of productive forces and the existence of an effective food system, the problem of world hunger is gradually being solved. However, on the one hand, 821 million people in the world are still malnourished, and on the other hand, the waste of food is shocking. The comparison of these two situations shows that the current food system is seriously unfair. With the development at the expense of the natural environment, there is also uncertainty about whether people can enjoy food in a sustainable, healthy and safe way. Therefore, our group was asked to do some optimization research on the food system. In order to better simulate the operation of the food system. First of all, we design a food system model based on the system dynamics model, which includes four subsystems: economy and trade, environmental health, social production and politics. and the basic operation system of the system is formed on the basis of many variables in these four fields. Then, based on the variables in the grain system, we summarize four aspects of measuring the characteristics of the grain system, namely, profitability, efficiency, fairness and sustainability, and summarize 11 quantifiable evaluation system indicators. Then, the analytic hierarchy process is used to determine the weight and evaluation function of each index in the comprehensive evaluation system. Finally, using the goal programming model, taking the fairness and sustainability indicators as constraints, the minimum value of the system comprehensive evaluation function is used to optimize the food system dynamics model. After optimization, we get the final SD-SOP model and determine that China's optimized grain system will be realized in 2030.

Keywords: SD-SOP model, Analytic Hierarchy Process, Goal planning Global dynamic model

1. Introduction
The current food system consists of major food producing countries, exporting countries, and large multinational food merchants. Such a food system aims at profitability and emphasizes profitability and efficiency. Even if a sufficient amount of food can be produced to satisfy the lives of all people, it is not possible to achieve a fair distribution to meet the needs of the hungry because of the interests of
distribution. At the same time, food production and food prices will also fluctuate from time to time due to the characteristics of profitability. If we do not change the current status of the food system that emphasizes profitability and efficiency, under greater pressure in the future, the global process of getting rid of hunger and improving the environment will be greatly affected [1].

Therefore, the optimization of the food system is imminent. The food system should shift from focusing on profitability and efficiency to prioritizing sustainability and fairness. Only in this way, the development of the food system will not cause damage to the environment, and the number of hungry people in the world will be reduced with more equitable food distribution.

2. Model Analysis and Subsystem Construction

2.1. Food model analysis
The influencing factors of the food system include multiple factors in many aspects, and these factors influence each other and are related to each other. The change of any one factor will have a chain effect, so it is impossible to conduct a static analysis on a certain factor alone. Based on the above characteristics and some previous work [2], we use a system dynamics model that can reflect the causal relationship within the system and conduct dynamic analysis of the system to model the food system.

Based on research by Hawkes and others [3], we found that the links of modern food are agricultural production, collection, storage, processing, transportation, food sales, eating, food waste and disposal. This is a circular process, which is affected by multiple factors from the four major aspects of economy, society, environment, and politics [4]. Therefore, for the modeling of the food system, we first construct the corresponding four sub-systems that affect the food system, and then combine them to form a comprehensive system dynamics model of the food system.

2.2. Subsystem construction
The amount of food allocated to each person is not the same, but also has a different amount of food consumption, serious and even lead to different degrees of malnutrition. This is the embodiment of the unfair distribution of food in society. Social food production and consumption can better reflect the process described above, so the social production subsystem of food is constructed with easy-to-quantify consumption and production as the main medium.

The total domestic food output reflects the total amount of food that a country can really produce, which is related to the national arable land area and per unit yield. The area of national cultivated land is the embodiment of the development potential of a country's agricultural production, which determines the total domestic food output to a great extent. The yield per unit area is determined by many factors. The early unit yield mainly depends on manpower, and the higher the unit labor input, the higher the unit yield. With the progress of science and technology, science and technology play a more and more important role in the production of agricultural products. Although manpower still plays a positive role in promoting per unit yield, its importance and influence are gradually decreasing. Scientific breeding, scientific planting and other advanced agricultural technologies help to greatly increase the output of agricultural products. With the progress of modern mechanical automation technology, modern machinery is widely used in food production. The mechanical power is gradually replaced by labor, the total mechanical power per unit is improved, and efficient automatic production is realized. The rational use of chemical fertilizers and pesticides and the moderate increase in the use of chemical fertilizers and pesticides per unit have promoted the growth of the output of agricultural products and improved the ability of agricultural products to resist insect pests.

The food system takes GDP as the main index and guidance, which has a profound impact on all aspects of factors. The total amount of pollutant emissions feedback the degree of damage to the ecological environment caused by the food system. Therefore, based on these two factors, we build an environmental ecological subsystem model to analyze the damage of the food system to the ecological environment and the negative impact of the destruction of the ecosystem environment on the food
system. The increase of the total amount of pollutant discharge will do harm to many aspects. The increase of environmental pollutants will pollute cultivated land, degrade cultivated land and reduce food production. The food system cannot achieve sustainable development. Pollution factors will spread and accumulate through the food chain. At the same time, with the increase of environmental pollutants, it is difficult to guarantee the health and safety of food, and human health will be affected. Serious ones may even be fatal, thus affecting the population. However, with the high level of economic development, more funds can be spent on improving the environment, increasing investment in pollution control and reducing the total amount of pollutants discharged.

By stipulating the area of cultivated land, the political subsystem can ensure the size of the area of cultivated land. By encouraging technological progress, the per unit yield can be effectively increased. The implementation of these two policies can ensure that the total domestic food output can reach a certain volume, the net food import will not exceed a certain proportion, maintain the country's food security, and make the country occupy a certain advantage in the food economy and trade [5].

Through the control of the proportion of food waste, the political subsystem not only improves the fairness of the food system to a certain extent, but also contributes to the fact that the wasted food is not harmful to the environment, and ensures the sustainability of the food system.

3. Model building
The level of economic development (per capita GDP), GDP, difference in per capita food consumption, malnutrition rate, total pollutant emissions and proportion of food waste directly use the above-mentioned parameters as indicators. Comprehensive indicators such as food income, food self-sufficiency rate, food reserve rate, food foreign trade dependence, input-output efficiency will be elaborated below.

Food income refers to the income that domestically produced food can bring. We can get:

\[ FI = DFP \cdot TDFP \]  

Among it, food income is FI, domestic food prices are DFP, and total domestic food production is TDFP.

The food self-sufficiency rate refers to the ratio of the total domestic food production to the total food consumption, which reflects the country's ability to meet the needs of food [6]. The formula is expressed as:

\[ FSR = \frac{TDFP}{TFC} \]  

Food foreign trade dependence refers to the proportion of national food consumption that depends on international food trade to import food, which reflects the national food safety index to a certain extent. According to Xu Tian's research [7],

We can get:

\[ FFTD = \frac{NFI}{TFC} \]  

4. Data processing and hierarchical analysis

4.1. Data processing
In the above indicators, each indicator has a different dimension, and there is a big difference between the absolute values of the indicators. In order to facilitate the later comparison, the indicators need to be normalized to become a standardized scale. In the following formula, we will use the symbol Ci to represent the main indicators of the food system. Let's take Ci as an example to introduce the process of data normalization.
After normalization, it is:

\[
\tilde{C}_i = \left( \tilde{C}_{i1}, \tilde{C}_{i2}, \ldots, \tilde{C}_{in} \right)
\]  

(4)

4.2. Structure of AHP analysis

Construct a judgment matrix Using the method of pairwise comparison and ranking according to the relative importance of different factors, we can get the judgment matrix

In this step, we need to determine the largest eigenvalue corresponding to matrix \( A \) and the corresponding eigenvector \( W = (w_1, w_2, \ldots, w_n)^T \). After the feature vector is normalized, the elements are the ranking weights of the relative importance of the factors of the same level to the factors of the previous level, that is, the single-level ranking. The formula is as follows:

\[
AW = \lambda \max W
\]

(6)

In order to confirm the ordering of the hierarchical list, a consistency check is required. Define the consistency index as:

\[
CI = \frac{\lambda \max - n}{n - 1}
\]

(7)

We define the test coefficient CR. Generally, if \( 0.1 < CR \), the judgment matrix is considered to pass the consistency test, otherwise it does not satisfy the consistency. The formula of calculating the consistency ratio is as follows:

\[
CR = \frac{CI}{RI}
\]

(8)

5. Establishment of single-objective planning model

Our task is to optimize the current situation where the food system pays more attention to profitability and efficiency, so that the food system can evolve toward the comprehensive evaluation model we described above, thereby improving the sustainability and fairness of the food system. System dynamics models can represent complex systems with interconnected parameters, but it is difficult to provide optimal predictions for model optimization. The single-objective planning can better solve this difficulty. Therefore, in the process of optimizing the model, we combine the single-objective programming model and the system dynamics model to form the SD-SOP model.
Figure 1. Comprehensive evaluation index analysis

In Figure 1, the ordinate is the comprehensive evaluation index, which represents the comprehensive evaluation of the various benefits produced by the food system. The abscissa is the timeline. The blue line in the figure represents the unoptimized system, and the yellow line represents the optimized system. It can be clearly seen that the comprehensive evaluation index of the system before optimization is much smaller than that of the optimized system, that is, the optimized system can generate greater comprehensive benefits than the system before optimization.

The current high efficiency and profitability of the food system have helped some countries solve some difficulties in economic development and promoted the development of other industries. As the food system is optimized towards sustainability and fairness, it will undoubtedly have a certain negative impact on economic development. But the system will also have a beneficial impact on the country in terms of sustainability and social equity.

6. Conclusions

Through our design, we have obtained a model that can more comprehensively and objectively reflect the complex system of the food system. We use this system dynamics-based model, combined with the single-objective programming model, to set the optimal plan for the system to achieve greater fairness and sustainability.

Through this optimization, we found that in the early stage of optimization, it will inevitably have a certain negative impact on the entire system. But with the completion of optimization, the benefits of fairness and sustainability will gradually make up for this loss. In the long run, the country can benefit a lot from it. In the process of optimization, the benefits and costs of developing countries and developed countries are not the same. Generally speaking, developed countries have not made high gains from this process. However, developing countries can obtain various improvements at a small price.

Our model can be expanded through later research and can be applied to more complex systems and a wider range.

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