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# *Analysis of changing factors of Grain system based on Mathematical Modeling*

**Wanling Yang[1], Jinyan Zhang[1], Honghui Zou[2]**

[1]*School of Geological Engineering and Surveying and Mapping, Changan University, Xi'an, Shaanxi, 710000*

[2]*School of Transportation Engineering, Changan University, Xi'an, Shaanxi, 710000*

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***Abstract:*** At present, the global food market is in a very fragile stability: even in a wealthy area, there will be food shortages. It is important for us to optimize the existing food system. In this paper, the food system is simplified to a system composed of five food structures $\{x_1, \dots, x_5\}$ such as soybeans, cereals, milk, pork, and vegetables. We establish a multi-obje ctive optimization model from the four aspects of efficiency, profitability, fairness and sustainability; Then, using the historical data, the average value of the total population, rural population, an d agricultural land area of each country in the next five years is predicted through the gray predic tion model. Import the predicted data into the calculation of the multi-objective optimization mod el, when the objective function reaches the global optimal solution F=208.322, the optimal food structure $\{x_1^*, \dots, x_5^*\}$ of each country in the next five years can be obtained. For example, the opti mal food structure in China is $\{1668.6, 13557.8, 12514.9, 3128.7, 16686.5\}$( Unit: 10,000 tons ) , w hich increase or decrease 30.2%, 3.0%, 19.5%, -15.8%, 45.6% compared with the current food structure. Finally, a multiple linear regression model was established to consider the five influencing factors of each countries' agricultural input, pesticide residues, chemical fertilizers, farmers' arable land area, and national GDP (all predicted by the gray prediction model) to calculate the future annual changes in the food structure $v_i$, and thus calculate the change time T (The time of China is 4.79 years)

## 1. Introduction

At present, the global food market is in a very fragile stability: even in a wealthy area, there will be food shortages. How to optimize the existing food system model to meet the food needs of different regions and reduce the probability of the occurrence of food crises is a problem we are committed to solving.

## 2. Multi-Objective Planning Model

We use the known data (the total population of some countries, the area of agricultural land, the number of rural population, etc.) to calculate the unknown relevant information for the next five years according to the gray forecast model GM(1,1). Take the average of the data for the next five years and bring it into a multi-objective optimization model to calculate the optimal food structure configuration.

## 2.1 Profitability Analysis

Relative profitability = (domestic food demand * food unit price + export food volume * food unit price-imported food volume * food unit price-food planting cost) / global food production.

$$P=\sum_{i=1}^{5}\ \sum_{j=1}^{n}\frac{k\left(x_{ij}+k\times\max\left\{d_{ij}-x_{ij},0\right\}-k\times\max\left\{d_{ij}-x_{ij},0\right\}\right)-cx_{ij}}{m}$$

## 2.2 Fairness Analysis

In the 1960s, the fairness theory was put forward by the American scholar J.S. Adams, based on the synthesis of the fairness concept of distribution and cognitive dissonance. In 2 019, Chinese scholar Zhang Xingwen [1] used Adams' fairness theory in the multi-objective planning model of emergency supplies deployment. In the fairness theory, the fairness of each country comes from the ratio of the expected value of food to the actual value of btned and the expected value of food in other countries. The smaller the ratio, the more unfair it feels; the larger the ratio, the higher the degree of fairness. Fairness = (Food Expected Quantit y-Actual Food Obtained Quantity)/Total Expected Quantity of Global Food = (Food demand -(food production + food import-food export) / global food demand.

$$Eq=\sum_{i=1}^{5}\ \sum_{j=1}^{n}\frac{d_{ij}-(x_{ij}+\max\{d_{ij}-x_{ij},0\}+\max\{x_{ij}-d_{ij},0\})}{d_{ij}}$$

## 2.3 Model Building

*Table 1: The Optimal Solution of Several Countrise (unit: ton)*

| country | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ |
|---|---|---|---|---|---|
| ***China*** | 16686480.53 | 135577654.27 | 125148603.94 | 125148603.94 | 166864805.25 |
| ***India*** | 16121885.38 | 130990318.75 | 120914140.39 | 30228535.10 | 161218853.85 |
| ***United States*** | 3910985.09 | 31776753.86 | 29332388.18 | 7333097.04 | 39109850.90 |
| ***Brazil*** | 2502920.93 | 20336232.56 | 18771906.98 | 4692976.75 | 25029209.31 |
| ***Russia*** | 1738785.85 | 14127635.02 | 13040893.87 | 3260223.47 | 17387858.49 |

The weights of the four objective functions are determined by the entropy weight method. First, the objective functions are all forwarded to obtain the forwarding matrix. Calculate the probability of each element in the matrix, apply the information entropy calculation formula, and obtain the weights of the four indicators.

Multi-objective planning is transformed into single-objective planning through linear weighting of the objective function.

$$\max F=0.327Ef+0.184P-0.283Eq+0.206S$$

$$
s.t.\begin{cases}
\sum_{j=1}^{n}\sum_{i=1}^{5} x_{ij} \geq \sum_{j=1}^{n}\sum_{i=1}^{5} d_{ij}\,, j = 1, \ldots, n \\
\sum_{j=1}^{n}\sum_{i=1}^{5} max\{d_{5j} - x_{5j}, 0\} \leq \sum_{j=1}^{n}\sum_{i=1}^{5} max\{x_{5j} - d_{5j}, 0\}\,, j = 1, \ldots, n \\
\sum_{i=1}^{5} (x_{ij} + max\{d_{5j} - x_{5j}, 0\} - max\{x_{5j} - d_{5j}, 0\} \geq \sum_{i=1}^{5} d_{ij}, j = 1, \ldots, n \\
max\{d_{ij} - x_{ij}, 0\} \leq 0.3 * d_{ij}, i = 1, \ldots, 5, j = 1, \ldots, n \\
max\{x_{5j} - d_{5j}, 0\} \leq 0.1 * d_{ij}, i = 1, \ldots, 5, j = 1, \ldots, n \\
\sum_{i=1}^{5} k_j * x_{ij} \leq S_j * y_j, j = 1, \ldots, n \\
(1 - \lambda) * S_j \leq S_j \leq (1 + \lambda) * S_j, j = 1, \ldots, n
\end{cases}
$$

Based on the data algebraic multi-objective programming model, the optimal solution of the model is F=208.322

## 3. Difference Between Model And Real System

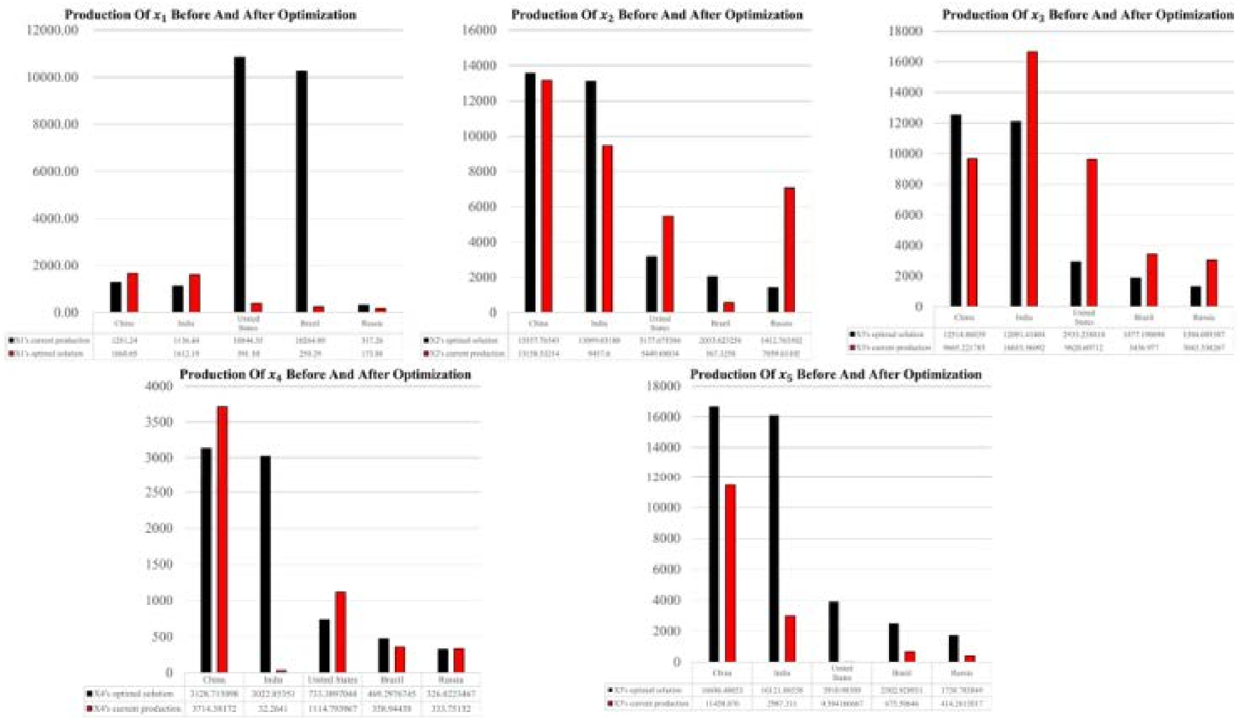


*Figure 1: Comparison of optimization results in some countries around the world with existing annual output*

(In the calculation of the model, the global average ratio of import and export is taken as 0.1 and 0.3, the ratio of food and diet structure demand is taken as 0.7, and the land area weight λ is taken as 0.1, which is calculated.)

In the optimization model, we solve the optimal values of soybean, cereals, milk, pork, vegetable and fruit yields in 20 different countries.In order to more clearly describe the difference between the optimized grain yield structure and the existing grain yield, we draw the following five graphs to show the comparison of the changes of the above five grains before and after.Due to the limited space, we have only selected data from five countries to present: China, India, the United States, Brazil and Russia. 3.4 Food System Transformation Time

## 4. Multiple Linear Regression

For countries with different levels of development, it is necessary to steadily transition from the existing food structure $\{x_1, \ldots, x_5\}$ to $\{x_1^*, \ldots, x_5^*\}$, the speed of agricultural reform υ different. In order to solve when the system can complete the transformation this question is particularly important as to how to obtain the speed of agricultural reform υ. Here, the speed of agricultural reform can be regarded as the annual increase in food production. In this way, as long as it can be based on the social and economic development of different untries and the policy attitude towards agriculture As well as the external environment conditions of agricultural development and other factors to quantify the country's annual food growth in the next five years, use the formula $T = \max\{\frac{|x_1^* - x_1|}{v_1}, \ldots, \frac{|x_5^* - x_5|}{v_5}\}$.The time required for the transition from the existing system to an optimized system for fair and sustainable development can be obtained.

In order to correctly show the relationship between the annual growth of food and the five factors, we use spss to analyze the data of China from 2008 to 2013, and use the linear regression method to fit the six-year data, where the variables involved and their meanings are as follows:
In the final report generated by SPSS, we can see:

*Table 2: Model Summary*

| Model | R | $R^2$ | Standard Estimate Error | Degree of Freedom1 | Degree of Freedom2 |
|---|---|---|---|---|---|
| 1 | 1.00 | 1.00 | 0.00 | 5 | 0 |

a. Predictor variable:(constant),$A_1, A_2, A_3, A_4, A_5$

b. Dependent variable: $Z$

From the third coefficient graph, we can see that the results of the entire regression analysis are very good. The significance level in the t-test is 0.00<0.05, indicating that the coefficients of the regression equation are significant and statistically significant. In order to unify the unit of each independent variable, standardized coefficients are used here to express, then the regression equation of this regression analysis is:

$$Z = 1.435A_1 - 1.258A_2 + 1.6741A_3 - 7.371A_4 + 5.608A_5$$

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