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Food system evaluation model based on Analytic Hierarchy Process

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Abstract: *Food safety has always been a global hot topic. So we establish a food system evaluation model. Based on the GDP data of 140 countries in the past 50 years, we determine the malicious competition factors, science and technology factors, external assistance factors, planting structure factors, food price factors, human factors and food health factors as indicators, and calculate the environmental factors by analytic hierarchy process. The results show that food price factors, environmental factors and malicious competition factors have a greater impact on fairness and sustainable development. Finally, we predict the time of policy implementation based on the time series prediction model and conclude that it will take ten years to complete the implementation.*

Keywords: *Food Safety, Food System Evaluation Model, Time Series Prediction Model*

1. Introduction

Food is a necessary item to maintain people's living needs, it is now important for a country's development, and food supply systems are vulnerable even in well-served regions of the world. With the passage of time, the uneven distribution of food, the increase of population and the deterioration of the environment have made more and more people without food security, and the challenges we face are becoming more and more serious. Therefore, it is very urgent and important to solve the food problem under the premise of maintaining the environment is not destroyed.

After consulting the data of 140 countries in the past 40 years, our team mainly used analytic hierarchy process, time series prediction model. In order to calculate the similarities and differences after fair and sustainable development and the time required, we use the analytic hierarchy process and the time series prediction model to solve them respectively. In the model, we also quantify important indicators of sustainability, fairness, profitability, and efficiency. Finally, we carried out advantages and disadvantages evaluation and summary.

2. Model Establishment

2.1 Model Preparation

Food security is not just simply sufficient food supply, but also related to regional accessibility, purchasing power of residents, food quality, food security and political and socio-economic stability. Therefore, we first consider the impacts of sustainability, fairness, profitability and efficiency on global food safety.

We set up a food system evaluation model. First, we standardized the data of range standardization. Secondly, we adopt the mean square deviation to determine the weight of each indicator, and the weight coefficients of the three indicators of efficiency, profitability, sustainability and fairness in each country. Then establish the secondary index evaluation model to evaluate the efficiency, profitability, sustainability and fairness of each country.

2.1.1 The Standardization of Data Processing

(1) We will use range standardization issued to standardize the index data.

(2) Positive indicators are: $X_{ij}^{'} = (X_{ij} - \min X_{ij}) / (\max X_{ij} - \min X_{ij})$

(3) Negative indicators are: $X_j = (\max X_0 - X_0) / (\max X_0 - \min X_0)$,

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$(i=1,2,\cdots\cdots 172;\ j=1,2,\cdots\cdots 12.)$

2.1.2 Weight Determination

We adopt mean square deviation to determine the weight of each indicator.

(1) We first determine the mean square deviation of the evaluation system based on standardized data sets: $\partial=\sqrt{\frac{\sum_{i=1}^{n}(X_{ij}^{'}-\bar{X}_{ij})^2}{n}}, i=1,2,\cdots\cdots 172;\ j=1,2,\cdots\cdots 12$

(2) Secondly, based on the mean square deviation, we calculate the weight coefficients of the three indicators of efficiency, profitability, sustainability and fairness in each country.: $\omega_{mkj}=\frac{\partial_{mkj}}{\sum_{k=1}^{K}\partial_{mkj}}$

(3) Finally, we calculate the mean value of the weight coefficient of each three-level index: $\omega_j=\sum_{m=2000}^{2014}\omega_{mkj}/15, k=4,2,3,3; j=1,2,\cdots\cdots,12$

2.1.3 Secondary Index Evaluation

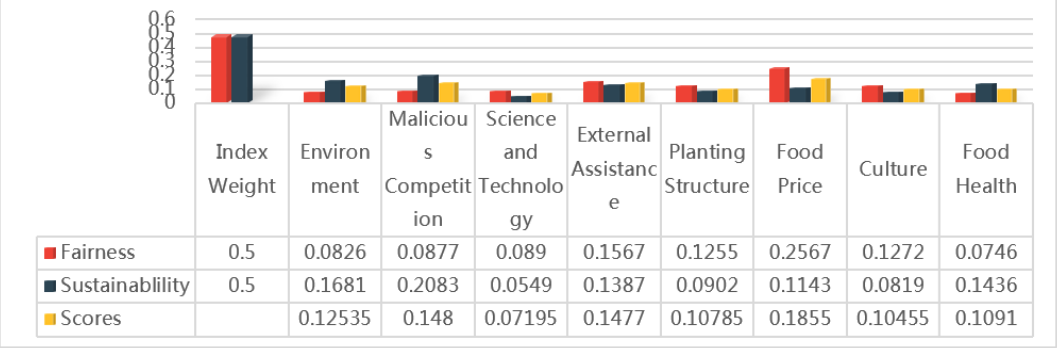
In order to establish a secondary index evaluation model, we will evaluate the efficiency, profitability, sustainability and fairness of each country.

$$Y_1=a_1X_1+a_2X_2+a_3X_3+a_4X_4;$$
$$Y_2=b_1X_5+b_2X_6;$$
$$Y_3=c_1X_7+c_2X_8+c_2X_9;$$
$$Y_4=d_1X_{10}+d_2X_{11}+d_3X_{12};$$

2.2 Analysis and Solution Based on Analytic Hierarchy Process

By analyzing the data of Food and Agriculture Organization of the United Nations, we find that the main factors affecting the fairness and sustainability of the food system are environmental factors, malicious competition factors, scientific and technological factors, external assistance factors, planting structure factors, food price factors, human factors and food health factors. Then we use the analytic hierarchy process to analyze and evaluate the weights. When the weights of fairness and sustainability are the same, the scores of the above factors can be obtained respectively. Thus we can get the three factors that affect the fairness and sustainability of the food system are environmental factors, malicious competition factors and food price factors. Therefore, we need to optimize the fairness and sustainability of the food system in these three aspects.The results are shown in Figure 1.

By analyzing the scores, we concluded that the environment, malicious competition factors and food prices have a greater impact on fairness and sustainable development. In order to verify our results, we compiled data on food safety in five continents through access to information and compared them according to historical and realistic reasons. This proves the correctness of our calculation score and provides a theoretical basis for our modeling.



	Index Weight	Environment	Malicious Competition	Science and Technology	External Assistance	Planting Structure	Food Price	Culture	Food Health
Fairness	0.5	0.0826	0.0877	0.089	0.1567	0.1255	0.2567	0.1272	0.0746
Sustainablility	0.5	0.1681	0.2083	0.0549	0.1387	0.0902	0.1143	0.0819	0.1436
Scores		0.12535	0.148	0.07195	0.1477	0.10785	0.1855	0.10455	0.1091

Figure 1 Score Analysis of 8 Factors

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2.3 Establishment and Solution of Prediction Model Based on Time Series

In this paper, we will use the ARIMA model to predict the grain output of countries that have changed the priority of the current food system for 15 periods from 2007 to 2020

First, we need to determine whether the data meet the stability requirements of the model, After ADF test, when the difference order is 1, can be calculated p=0.121, The t = -2.479 can be calculated to meet the stability requirements of the model. Next, the time sequence diagram of order 1 can be drawn.

Figure 2: The time sequence diagram of order 1

Under the condition that the model is stable, the ACF autocorrelation coefficient is analyzed. With the data included, we can get the following Figure 3:

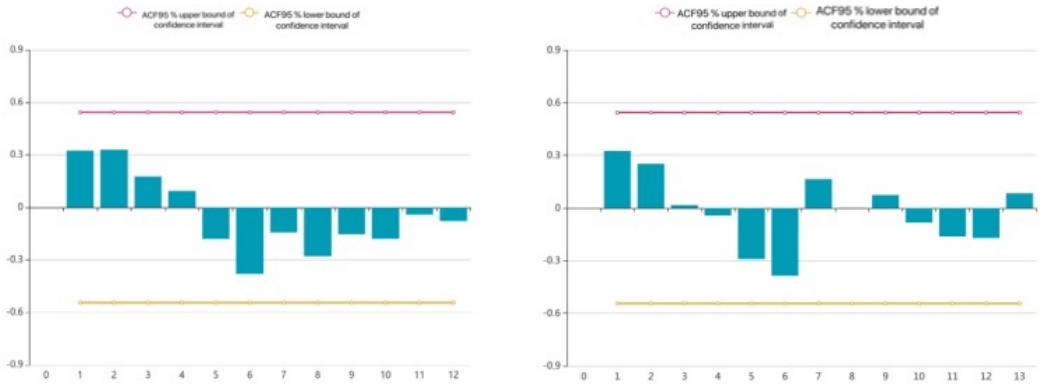

Figure 3: Left graph is ACF analysis, right graph is PACF analysis

According to ARIMA (0, 1, 0), based on the field yield, we can obtain from the analysis of statistics:Q_6 The assumption that the residuals of the model are white noise sequences cannot be rejected. At the same time, the goodness of fit R_2 of the model is 0.941, the model is excellent, and the model basically meets the requirements. With the data included, we can get the following Figure 4:

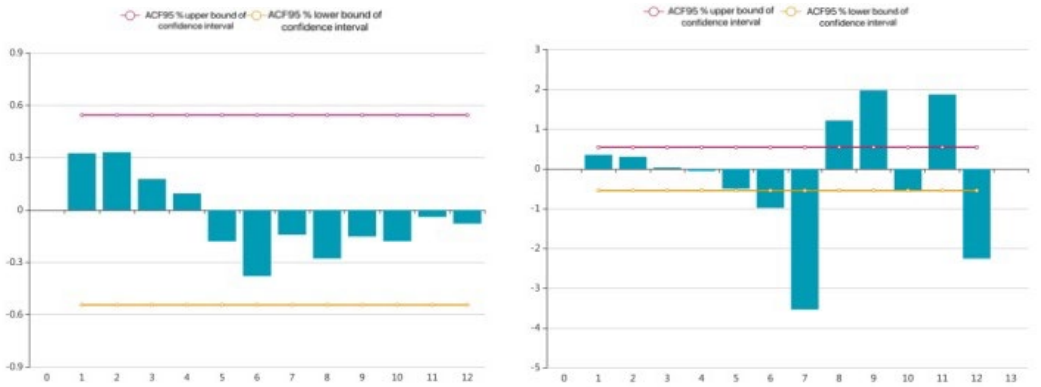

Figure 4: Left graph is ACF analysis, right graph is PACF analysis

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Table 1: Time series prediction analysis

Constant	Coefficient	Standard Deviation	t	p>|t|	0.025	0.975
	254.385	61.326	4.148	0.0001	134.188	374.582

Based on field yield, ARIMA (0,1,0) and d-difference data, the model formula is as follows : y (t) = 254.385. We then forecast the 15-period data as follows Table 2:

Table 2: Time series prediction results

Predicted Value	
Order (time)	Forecasting Results
1	13644.385
2	13898.769
3	14153.154
4	14407.538
5	14661.923
6	14916.308
7	15170.692
8	15425.077
9	15679.462
10	15933.846
11	16188.231
12	16442.615
13	16697
14	16951.385
15	17205.769

Similarly, according to food demand over the years, food demand by 2035 is analyzed and predicted as follows Figure 5:

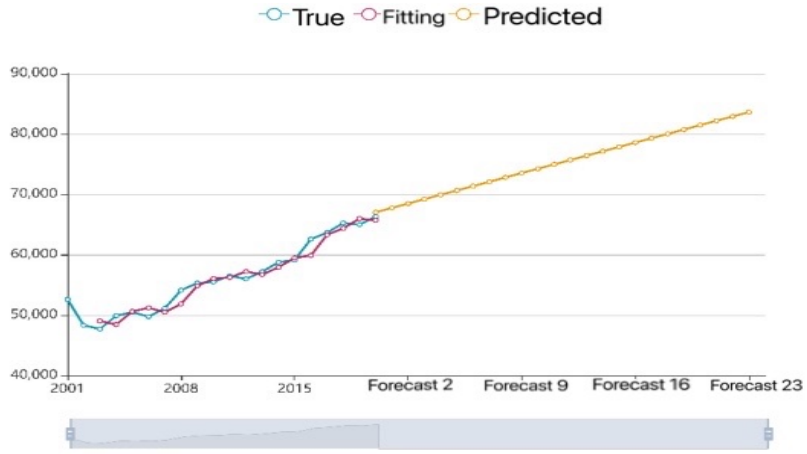

Figure 5: Final results of time series prediction

According to the proportion of the population of the changed country to that of the world, expanding the proportion of grain production can be obtained in 2031, and the implementation of the policy will be completed completely. So we need 10 years to complete the implementation.

3. Model Evaluation

In this paper, the time series model can fully analyze the change trend of past grain production, and predict the future development of grain production according to the development law of objective things. Here, we take the data of 140 countries in the world in the past 50 years as an example, and comprehensively consider the important impacts of land population, climate and topography, agricultural mode, import and export. Based on the principles of sustainability, fairness, profitability and efficiency, we use Python data visualization to evaluate the food system to verify the scalability and adaptability of the model. As shown in the Figure 6 below.

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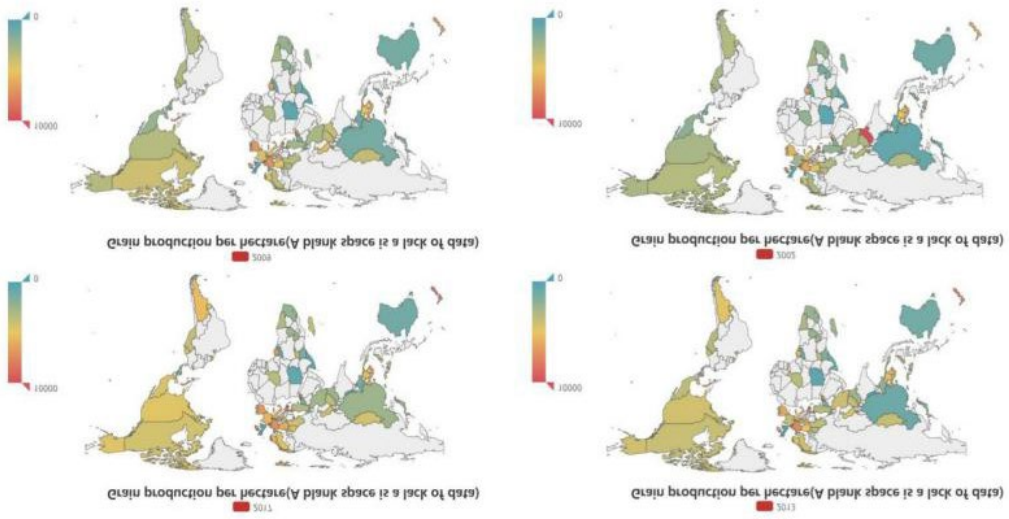

Figure 6: Analysis results of world map based on Python

However, the focus is on the change of time and food production. Since the future grain production will also be affected by many unpredictable things with complex diversity, the time series analysis and prediction cannot consider the influence of external specific factors when predicting grain production, so there are still some errors in the prediction.

4. Conclusion

Global food security is not caused by any single factor. It is an interdisciplinary problem composed of a series of variables. In this paper, we established a food system evaluation model. Our model shows that improving global food security is possible, and the most important intervention factors are fairness and sustainability.

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