# A Study of the Global National Food Security System Based on the AEG Model

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**Abstract.** At present, although the global food system is highly efficient and functioning well in some parts of the world, it has brought great harm to the environment, and as the number of people worldwide increases, the impact on the environment is getting worse and worse. Therefore, for the global food system to produce more food while being sustainable and to maintain or even improve our environmental health, we will reimagine and adapt the global food system. Our work used the AEG evaluation and prediction model plus the secondary exponential smoothing method to construct the new AEGQ model to make predictions, and then to support our model by scoring forecasts for China and the U.S. food security system. Our team first worked out the weight of the indicators that did not change the priority, and then used the entropy weight method to score the food security system, and then used analytic hierarchy process (AHP) to optimize the weight of each indicator. We change the priority, and get the Chinese and U.S. food security system ratings, then use Matlab gray prediction and SPSS secondary index smoothing method to predict. Compared with the trend of pre-optimization food security system scoring, we can find that the rating of optimized food security system is relatively high, but China's optimized rating is not higher, perhaps because the model is still imperfect, but for most countries the model is still reliable, which can prove that our model is relatively accurate.

**Keywords:** entropy right method · analytic hierarchy process (AHP) · gray prediction · AEG evaluation and prediction model · food system

## 1 Introduction

As far as we know, although our global food system is efficient and works well in parts of the world, our global food system is not perfect enough, and there are two important problems to be solved [1–3]. First of all, although the world has enough food to feed everyone in the world, 821 million people in the world is still starving, and even in some rich areas, some do not even have the most basic food security. Secondly, our global


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food system has caused indelible harm to the environment. "29% of greenhouse gas emissions, up to 80% of biodiversity loss, 80% of deforestation and 70% of fresh water consumption" are angrily declaring the adverse effects of the global food system on the environment [4–6], which will intensify as the global population increases. Therefore, there is an urgent need for an accurate model to assess and predict the current and future global food systems, so as to improve the current global food system, make the current global food system produce more food while sustainable and maintain or even improve our environmental health [7].

Nie Changle analyzed the grain trade relationship data of 231 countries and regions from 2000 to 2018, and used complex network indicators such as network density, average distance, and clustering coefficient to analyze the evolution law and formation mechanism of the global grain trade network. Analyze [8]. The results show that the global grain trade network is gradually becoming more complex, the degree of network development is gradually increasing, and the global grain trade group has always been in a dynamic evolution of continuous differentiation and integration. Ma Xiaohe through the analysis of the characteristics of China's international grain trade, expounds the factors that affect the instability of China's international grain trade, and believes that the unsound national grain production and storage system will cause the national grain supply and demand gap to expand, and the way to supplement the gap Can rely on international trade in food [9]. Wang Jieyong constructed a global grain trade network for the three major staples of wheat, rice and maize by constructing a complex network analysis method, analyzed the overall characteristics and changes of the network pattern, and quantitatively evaluated the influencing factors of the global grain trade network pattern [10]. Research shows that global grain trade has become a complex, orderly and interdependent network system, the network scale is continuously increasing, and the connectivity and tightness are continuously strengthened; the nodes of the global grain trade network are characterized by non-equilibrium structure, and countries with high intensity and high node degree are in The network plays a leading role, showing the characteristics of the network structure dominated by exporting countries; the differences in economic and social development, the consistency of trade policies and the proximity of language and culture have a significant impact on the grain trade network.

## 2 Theory and Method

According to the question, our work designed the AEG (analytic hierarchy process (AHP) -entropy weight method - gray prediction) evaluation and prediction model to make corresponding evaluation and prediction for food security system of a country or a region. In this model, our team used multi-level stratification index method to weight each indicator, so as to get the national food security system score. The higher the score, the safer the national food system.

In the prediction, our work adopts the method combining G(1,1) gray prediction and quadratic exponential smoothing prediction, which has the advantage of better mutual verification and more accurate prediction of a country or region's food security system score.

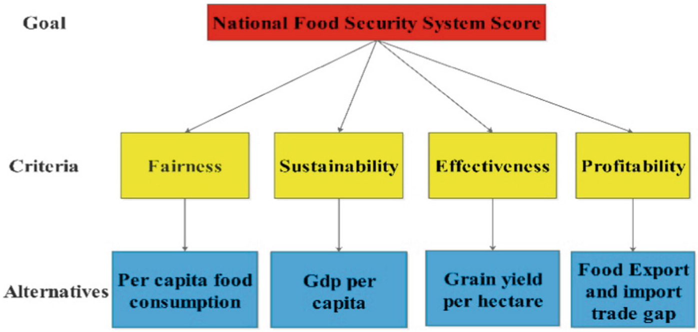


**Fig. 1.** Hierarchical indicator framework

**Table 1.** Discriminant matrix

| | FA | SU | EF | PR |
|---|---|---|---|---|
| FA | 1 | 1/2 | 2 | 5/2 |
| SU | 2 | 1 | 5/2 | 4 |
| EF | 1/2 | 2/5 | 1 | 1/2 |
| PR | 2/5 | 1/4 | 2 | 1 |

The AEG evaluation and prediction model uses data on food production, population, gross domestic product, agricultural land area, Exports and imports of agricultural products (See Fig. 1 and Table 1).

Our work constructs a discriminant matrix for fairness, sustainability, efficiency and profitability in the first-level indicators, respectively, FA, SU, EF and PR. We artificially subjectively give relative values to the indicators, and obtains the corresponding weights of the indicators. Based on this model, the hierarchical analysis method model formulas are:

$$a_{ij} = \frac{1}{a_{ji}} \tag{1}$$

$$CI = \frac{\lambda - n}{n - 1} \tag{2}$$

$$RI = \frac{CI_1 + CI_2 + \cdots + CI_n}{n} \tag{3}$$

$$CR = \frac{CI}{RI} \tag{4}$$

Because the analytic hierarchy process (AHP) is subjective in the indicator assignment, our work used an objective evaluation model combined with entropy weight method to score a country or region's food security system, which is still using the above indicators and plus the average per capita grain possession (AP), average GDP per capita (AG), average grain yield per hectare (AY), average difference between grain export and import trade (AD) and other indicators. Based on this model, the entropy weight method formulas are

$$Y_{ij} = \frac{X_{ij} - \min(X_i)}{\max(X_i) - \min(X_i)} \tag{5}$$

$$E_j = -\ln\left(\frac{1}{n}\right)\sum_{i=1}^{n} p_{ij} \ln p_{ij} \tag{6}$$

$$p_{ij} = Y_{ij} / \sum_{i=1}^{n} Y_{ij} \tag{7}$$

$$W_{ij} = \frac{1 - E_i}{k - \sum E_i} (i = 1, 2, \ldots, k) \tag{8}$$

$$Z_l = \sum\nolimits_{i=1}^{n} X_{li} W_i \tag{9}$$

According to the national food security system score obtained by entropy weight method, our work used the G (1,1) gray prediction model to predict the future trend of national food security system score, which is the basis for predicting the optimized national food security system.

## 3 Results and Discussion

Our work used the AEG evaluation and prediction model plus the secondary exponential smoothing method to construct the new AEGQ model to make predictions, and then to support our model by scoring forecasts for China and the U.S. food security system.

Our work first worked out the weight of the indicators that did not change the priority, and then used the entropy weight method to score the food security system, and then used the analytic hierarchy process (AHP) to optimize the weight of each indicator. Changing the priority, get the Chinese and U.S. food security system ratings, and then use Matlab gray prediction and SPSS secondary index smoothing method to predict. Compared with the trend of pre-optimization food security system scoring, we can find that the rating of optimized food security system is relatively high, but China's optimized rating is not higher, perhaps because the model is still imperfect, but for most countries the model is still reliable, which can prove that our model is relatively accurate (Figs. 2, 3 and 4).

### 3.1 Verification of the Model

For the AEG and AEGQ models established by our team, we used linear regression to verify the results, which showed that the residual distribution was within the 95% confidence interval, and the fitting effect was good, R2 = 1, F = 7.716 × 1030, P = 0, where R squared of 1 represented the accuracy of the regression model, and $P < 0.5$ represented the validity of the fitting equation, Thus, the model is verified to be relatively accurate. The fitting equation is

$$Y_1 = -0.0732 + 0.5121x_1 + 3.6426 \times 10^{-4}x_2 + 4.688 \times 10^{-5}x_3 + 2.250 \times 10^{-9}x_4 \tag{10}$$

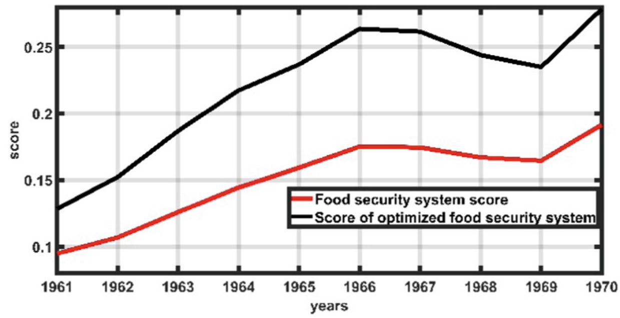


**Fig. 2.** China's food security system score in some years

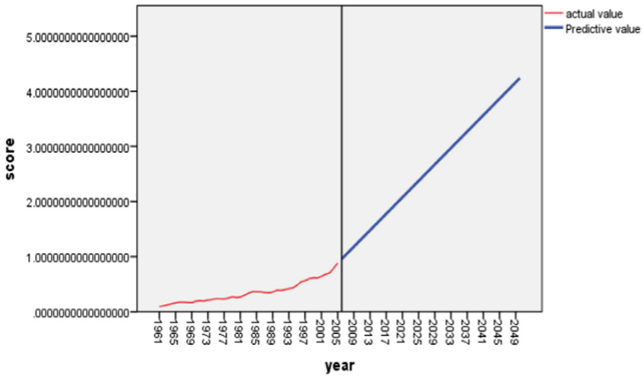


**Fig. 3.** China score and optimized score prediction

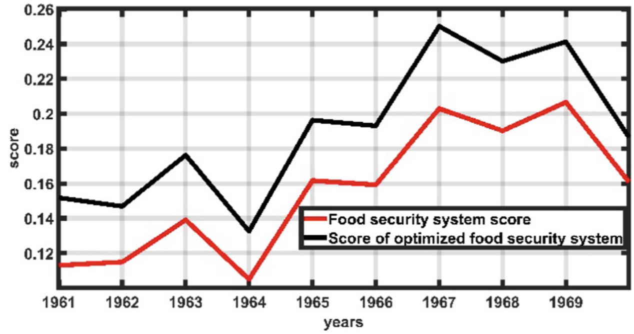


**Fig. 4.** Food security system scores in the United States in selected years

## 3.2 Sensitivity Analysis

For sensitivity analysis of the AEG model, our work performed multilinear regression fitting based on the scores derived from the AEG model, and selected the rating fittings of China, the United States, Japan and Korea. According to the fitting results, all R2 =

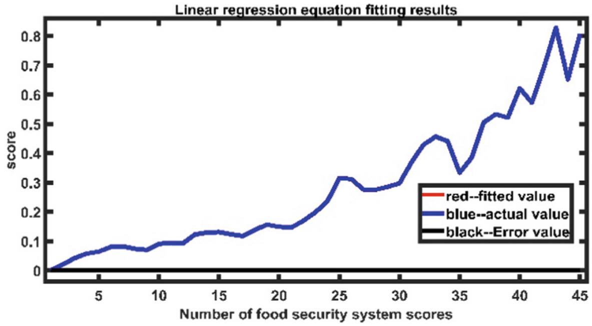


**Fig. 5.** Linear regression fitting

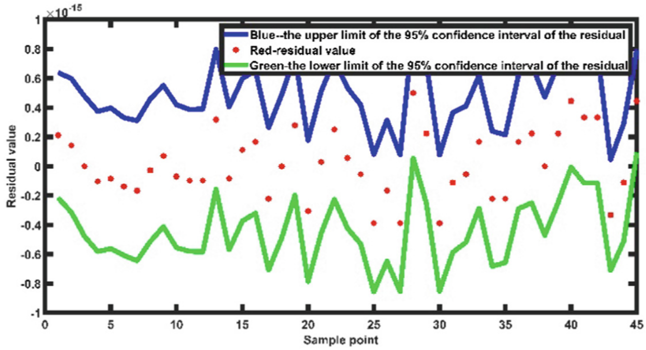


**Fig. 6.** Residual analysis

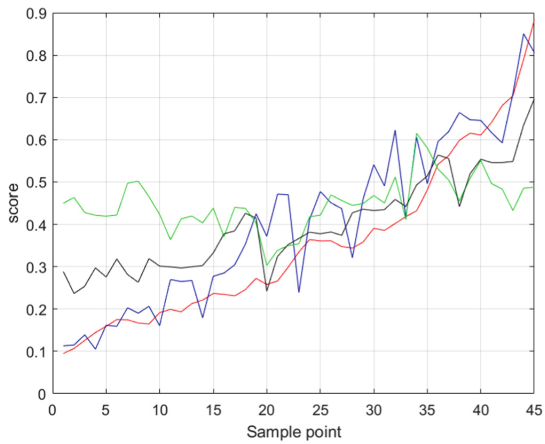


**Fig. 7.** Scatter plot of ratings

1 and P < 0.5 can be known that the regression model is accurate and the fitting effect is pretty good. According to the principle of sensitivity, when the model responds to

linear regression, the regression coefficient is used as a direct measure of sensitivity, thus proving that sensitivity is excellent (Figs. 5, 6 and 7).

The chart is a 45-year national food security system scoring trend chart of four countries, which shows that the scores of all four countries fluctuate within a certain range, and there are no large fluctuations, which can prove that the sensitivity of the model is better.

## 4 Conclusion

On the basis of taking into account the impact of factors such as average per capita grain possession (AP), average GDP per capita (AG), average grain yield per hectare (AY), average difference between grain export and import trade (AD) on food security, we have selected four indicators, equity, sustainability, efficiency and profitability, and established the AEG evaluation and prediction model to evaluate and forecast the food security system of a country or region accordingly. In this model, our work uses a multi-level hierarchical indicator method to weight individual indicators to obtain a national food security system score. The higher the score, the safer the national food system.

In the prediction, our team adopts the method of combining G (1,1) gray prediction and quadratic exponential smoothing prediction, which has the advantage of better mutual verification and more accurate prediction of a country or region's food security system score. The AEG evaluation and prediction model use data on food production, population, gross domestic product, agricultural land area, exports and imports of agricultural products. From these raw data, it can be inferred that the per capita grain possession, GDP per capita, grain yield per hectare, agricultural products import and export trade gap. Changes in per capita food possession can describe changes in food to supply and stability. Changes in GDP per capita can reflect changes in food access. Grain yield per hectare can reflect a country's or region's food self-supply capacity. The difference in agricultural products import and export trade can reflect external food demand and internal food supply capacity.

Food production capacity is the most basic factor influencing the food supply of a country or region. However, the growing demand for food can be addressed through external purchases or food imports, in addition to self-severity through grain production in the country or region. Singapore and Hong Kong, for example, do not have their own advantages in food production, but internal food supplies can be addressed from external purchases or international trade input to achieve food security for their populations. The South Asian country of India, for example, has its peculiar good food production capacity, but its domestic food supply capacity still does not meet the food needs of its fast-growing population. At the same time, it's relatively weak purchasing power limits the regulation of food supplies through external markets.

Therefore, to ensure future food security, on the one hand, we should protect the quantity and quality of cultivated land, prevent soil degradation, increase capital input, carry out technological innovation and upgrading, so as to improve the comprehensive production capacity of grain and ensure the effective supply of grain; At the same time, we will vigorously improve the food circulation and agricultural trade system, regulate the food supply through external markets, actively address climate change, improve the resilience of agricultural production to climate change, and ensure the stability of food production.

Average per capita grain possession (AP), average GDP per capita (AG), average grain yield per hectare (AY), average difference between grain export and import trade (AD). The result shows that food security is the result of a combination of factors. The average per capita grain share, the average per capita GDP, the average per capita grain possession (AP), average GDP per capita (AG), average grain yield per hectare (AY), average difference between grain export and import trade (AD) is the most important factor affecting and crisis food security. Therefore, the evaluation of food security in a country or region requires a combination of multiple factors, and it is clear that the current model prioritizes efficiency and profitability of food security systems with certain limitations. In addition, we modified the model to ensure that it applies to "larger" and "smaller" countries or regions. Finally, we demonstrate the credibility of our model by analyzing its sensitivity and discussing its strengths and weaknesses.

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