# A New Evaluation Scheme for Food Systems

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Abstract—Considering that the existing food systems only pay attention to profit and efficiency and ignore sustainable development and equity, we decide to design a new evaluation scheme to improve and optimize the existing food system. Therefore, we decide to use the Entropy TOPSIS method based on factor analysis to screen more and comprehensive indicators to score the security of the food system. The food system changes priorities and optimizes equity as well as sustainability. This could lead to a more balanced and sustainable development of food security in the future, but it also comes at a cost. However, we strongly believe that such a system will eventually lead to a more balanced and sustained slow increase in global food security.

Index Terms-food security, factor analysis, entropy TOPSI

# I. ESTABLISHMENT OF FOOD SECURITY ASSESSMENT MODEL

# A. Background

The existing food system gives priority to profitability and efficiency, but lacks attention to fairness, sustainability and environmental protection. However, such a system will bring serious disasters and problems such as poverty and famine. Therefore, we need to check and evaluate the existing food system in order to optimize and get a more coordinated system.

# B. Model Establishment

# 1) Calculation of four first-level indicators

Factor analysis method is used to screen the lowest level index, so the entropy weight TOPSIS method can be used to calculate the value of the first level index.

2) Food security assessment value

On the basis of the calculated first-level index value, the entropy weight TOPSIS method was used to calculate the food security evaluation value. [1]

3) Model assumptions

In order to ensure the rigor of the mathematical model and to simplify the conditions, we make the following basic assumptions:

It is assumed that the food system security assessment value is determined by only four first-level indicators (efficiency, profitability, sustainability and equity).

Assuming that there will be no disruptive economic or scientific and technological innovation in the grain field in the future. What's more, the influence of time factor and environmental change is not considered, and the error caused by them is ignored.

# II. EMPIRICAL ANALYSIS BASED ON FACTOR ANALYSIS AND ENTROPY TOPSIS

# A. Food Security Assessment of China

1) Calculation of secondary indicators of China

The grain production conditions and capacity of the main grain producing areas have strong consistency, so the probability of abnormal values of the indicators related to food security is small. [2] This characteristic can effectively avoid the problem of excessive bias in determining ideal solution and negative ideal solution by entropy weight TOPSIS method.

We take the total grain yield, food production index, crop production index and average dietary energy supply sufficiency degree as the subordinate index of efficiency, and try to screen representative indexes through factor analysis, so as to achieve the purpose of dimension reduction. Then input the data into SPSS software and select factor analysis. The software output results are as follows:

TABLE I. KMO AND BARTLETT'S TEST

Kaiser-Meyer-Olkin Measure	e of Sampling Adequacy	0.794
	Approx. Chi-Square	166.704
Bartlett's Test of Sphericity	df	6
	Sig.	0.000

Table I indicates that this data is very suitable for factor analysis.

TABLE II. TOTAL VARIANCE EXPLAINED

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.960	99.005	99.005	3.960	99.005	99.005
2	0.023	0.585	99.589			
3	0.015	0.369	99.958			
4	0.002	0.042	100.000			

Extraction Method: Principal Component Analysis.

We can view the total variance interpretation as the contribution rate of each factor to the interpretation of the

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variable. As can be seen from above Table II, we only need one factor to express more than 99% of the variable, indicating that the expression is very good.



Figure 1. The broken stone diagram.

The broken stone diagram (Fig. 1) can also be verified that the broken line does flatten out after the first factor.

Year	Efficiency	Profitability	Sustainability	Fairness
2001	11431.29	16.88	2593309.73	-14.70
2006	12586.43	14.73	3515298.25	-9.94
2010	13806.11	13.88	4192286.54	-6.15
2014	15337.13	13.44	4674645.43	-7.95
2015	15699.22	13.32	4642706.83	-10.65
2016	15570.59	13.24	4573230.06	-9.83
2017	15613.03	12.55	5120450.60	-10.90
2018	16617.28	12.30	5272700.70	-11.98
2019	16767.38	12.17	5424950.80	-13.06

TABLE III. CALCULATION RESULTS OF CHINA'S FIRST LEVEL INDICATORS

Therefore, we can use crop production index to express efficiency index. The same is true for other first-level indicators. Finally, we choose crop production index, percentage of agricultural added value in GDP, percentage of agricultural land, proportion of forest area and Gini coefficient as the sub-indexes of efficiency, profitability, sustainability and fairness. Some of the results are presented in Table III above.



Figure 2. Indicator trend chart of China.

As can be seen from the above Fig. 2, the grain equity in China had a trend of first increasing and then decreasing 20 years ago with the best grain equity in 2012.

The efficiency of grain (including distribution efficiency and utilization efficiency) was on the rise about 20 years ago, which shows that the innovation of technology and the optimization of theoretical methods have a positive impact on the improvement of efficiency. Food profitability has been declining for 20 years.

Combined with the result that food sustainability has continued to rise over the past 20 years, it can be proved that China has put more emphasis on environmental protection and sustainable development in the past 20 years. [3] The state has invested a lot of money, while keeping food prices stable, which has led to a slight decline in profitability.

2) Determination of weight by entropy weight method

Through entropy weight method, we can determine the weight of China's grain efficiency, profitability, sustainability and fairness. The results are shown in Table IV below.

TABLE IV. WEIGHT TABLE

	efficiency	profitability	sustainability	equity
Weight proportion	0.2478 +	0.2320 +	0.2479 +	0.2723 -
	0.0033i	0.0031i	0.0033i	0.0097i

#### 3) TOPSIS method to get the final score

We divided each number by 10 in Fig. 3 but now we multiply it by 10 for interpretation. It should be noted that the figures in the table uniformly retain two decimal places.

It can be seen from the table above that China's food security score reached its highest point in 2012, at 0.86. Since 2005, the food security score has remained above 0.5, indicating that China's food system is relatively mature, but it has declined in the past decade.



Figure 3. Evaluation score of China's grain system.

#### B. Food Security Assessment of the United States

1) Calculation of secondary indicators of the United States

Because the method of index extraction by factor analysis is the same as that of second-level index

calculation in China, the process is omitted here. [4] Some of the results are shown in the following Table V:

TABLE V. CALCULATION RESULTS OF AMERICA'S FIRST LEVEL INDICATORS

Year	Efficiency	Profitability	Sustainability	Fairness
2001	8241.37	5.12	3365617.12	-14.70
2006	8579.14	4.85	2577865.54	-9.96
2010	10158.89	4.86	3308477.10	-6.16
2015	10934.38	4.87	3228700.90	-10.69
2016	12044.81	4.85	3194173.05	-9.86
2017	11143.72	4.83	3197419.25	-10.94
2018	11719.83	4.81	3188849.73	-12.01
2019	11918.05	4.86	3180280.21	-13.08

As can be seen from Fig. 4 below, food equity in the United States showed a trend of increasing and then decreasing 20 years ago. In 2012, food equity was the highest. The efficiency of grain (including distribution efficiency and utilization efficiency) was in a state of continuous rise about 20 years ago, which indicates that technological innovation and optimization of theoretical methods have a positive impact on the improvement of efficiency. [5]

Food profitability has remained almost constant for 20 years. Food sustainability is the same in the 20 years, indicating that the United States has not invested more money in environmental protection in the past 20 years, and has made less contribution to sustainable development.



2) Determination of weight by entropy weight method Through the entropy weight method, the weights of the four first-level indexes of food efficiency, profitability, sustainability and equity in the United States can be determined. [6] The results are shown in Table VI below.

TABLE VI. WEIGHT TABLE

	efficiency	profitability	sustainability	equity
Weight proportion	0.2545 +	0.2115 +	0.2545 +	0.2795–
	0.0035i	0.0029i	0.0035i	0.0098i

# 3) TOPSIS method to get the final score

We divided each number by 10 for Fig. 5, but now we multiply it by 10 for interpretation. It can be seen that China's food security score reached its highest point in 2012, at 0.86. Since 2005, the food security score has remained above 0.5, indicating that China's food system is relatively mature, but it has declined in the past decade.



Figure 5. Evaluation score of America's grain system.

As you can see from the chart, the food security score of the United States peaked at 0.64 in 2012. From 2005 to 2014, when the U.S. food system was relatively mature, the food security score remained above 0.5. But the score has fallen since 2014, to less than 0.5.

#### Comparative Analysis of Scores between China and С. the United States

We divided each number by 10 in Fig. 6, now let's multiply it by 10 to explain. By comparing the scores of the food security system of China and the United States, it can be seen that before 2012, the food security system of the United States was more secure and mature than that of China.



Figure 6. Comparative analysis chart.

But since then, China's food system has surpassed that of the United States in both security and sophistication.

This shows that the gap between developed and developing countries in the food system has begun to narrow or gradually blurred, but also shows that China has developed rapidly in recent years in the aspects of technology, personnel training, especially in the field of food major inventions and innovations. [7]

# III. CONCLUSION

# A. The Difference between Old and New Systems

1) Indicators vary in type and quantity

We choose efficiency, profitability, sustainability and fairness as first-level indicators which are different from the current one. It is more reasonable to take imbalanced development level in reality into account. Besides, we choose much less second-level indicators than the current one. As for the 5 second-level indicators, valid data can be easily collected. Therefore, the system we build has a lower requirement of data on quality and timeliness. What's more, the standards to judge these second-level indicators can be wildly applied.

#### 2) Different focuses

The current systems focus on the result and effect of food security such as nutritional health. Not only that, our system faces the possible impacts of development directly. For example, in reality, rapid development of a country may bring about sustainability problem like damaged ecological environment and the problem of fairness such as imbalanced development level varied in regions. [8]

#### B. Strengths and Weaknesses of the System

#### 1) Strengths

The final index system determined by factor analysis method is more scientific and effective. And the Entropy TOPSIS method can make full use of the information of original data to reflect the differences between schemes. This method has no special requirements on the number of samples, and is not disturbed by the selection of reference sequences. It has the advantages of more intuitive geometric meaning, less information loss and more flexible operation.

As it is based on local index data, the model is scalable and is well suited to both large and small food systems. In addition, this model has strong adaptability and can be fully applied to other regions. In this paper, both China and the United States can use this model for evaluation and analysis.

As an evaluation system, food system can display a country's macro level of food security, spurring the country to improve further. The optimized food system can raise all countries' attention to notice global issues and solve them together. Specifically, the equity index can expose the food security situation with great disparities among different countries and regions.

For developed countries, the optimized system can help them focus on internal areas of insecurity. Therefore, developed countries are encouraged to improve more balanced development and ultimately further improve food security.

Since most food insecurity occurs in developing countries, most of them focuses on increasing their food supply capacity. This optimized system can remind them to increase food supply without causing irreversible damage to the environment because of rapid development. At the same time, they should avoid unbalanced development among regions and widening gap between the rich and the poor.

#### 2) Weaknesses

The effect of changes in factors such as time and environment is not taken into account.

# IV. FUTURE WORK

Researchers can include more indicators and select indicators with real significant impact as explanatory variables of the model to establish a more effective and more precise food system evaluation model.

In the future, researchers can consider using ARIMA model to study the influence of changes in time, environment and other factors, which can make the model more consistent with the actual situation and make more accurate and reasonable prediction and analysis.

#### CONFLICT OF INTEREST

The authors declare no conflict of interest.

#### AUTHOR CONTRIBUTIONS

Tianran Liu conducted the research and analyzed the data; Yimiao Zhang wrote the paper; Yunhan Zhong search for the data and select it; all authors had approved the final version.

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