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Optimization Model Based on Food System

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Abstract: *The current global food system is unstable. Even if the food produced is enough to feed everyone in the world, many people still go hungry and cause tremendous damage to the environment. Therefore, it is very important to optimize the current food system.*

We have established an EESPE model to evaluate the current food system and an optimized OESPE model. Through the comparison of the two models, our OESPE model is based on optimizing the current food system in terms of fairness and sustainability, and also makes profits and efficiency maintains a high level, and has a faster implementation time.

We used 16 separate indicators to measure these four aspects. We adopted the AHP and entropy method to determine the weights of indicators at all levels of the system. Rely on indicators at all levels to quantify the impact on the food system.

We specifically analyzed the differences in the system before and after the optimization of the food system and the impact on various indicators, and predicted the relevant time of the system through the time prediction model. Based on the OESPE model, EESPE model, to solve the problems of developed and developing countries.

Finally, we discussed the advantages and disadvantages of the model and summarized it.

Keywords: *EESPE model, OESPE model, entropy method, data mining, AHP*

1. Introduction

At present, the global food system generally focuses on efficiency and profitability, and uses low-cost and high-efficiency methods to produce food to meet people's needs for food.

Data shows that there are still many people facing food shortages all over the world[1]. They cannot get enough food and nutrition, causing malnutrition and even death.

In these few years, people in food production time, abuse of environmental resources, cutting down trees, open land farming, land overuse of water resources, as well as the use of chemical fertilizers and so on, have on the environment caused huge big damage.

In order to reduce the number of people facing food shortages, while ensuring a reasonable yield of food and rational use of environmental resources, we need to establish a food system model that can be adjusted and optimized for efficiency, profitability, fairness, and sustainability.

2. Assumptions and Notation

2.1 Assumptions

We make the following assumptions for the OESPE model:

1) The normal food trade between countries

2) The food of each country gives priority to its own supply and then exports

3) The risk of extreme weather events increases with global climate change [2]

4) The food reserves of each country are sufficient to deal with various situations, and there is no coup problem caused by food problems [3]

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2.2 Notation

Our food system-based optimization model is OESPE. The name is four indicators: fairness, sustainability, profit, and efficiency optimization.

We use the symbols in Table 1 to represent the indicators in the O ESPE model equation. Symbols that are used only once are not included in Table 1. They will be introduced in some sections later.

Table 1: Symbol naming

Symbol	Definition
E_{sfp}	Stable food prices
E_{iopm}	The incidence of people's malnutrition
E_{gcfc}	Per capita food consumption
S_{fer}	Amount of chemical fertilizer used per unit of arable land
S_{poap}	Proportion of agricultural population
S_{pcala}	Per capita arable land area
S_{water}	Water resources per unit area of cultivated land
P_{nat}	Natural disaster
P_{apc}	Agricultural production conditions
P_{cop}	Cost of production
E_{flr}	Food loss rate
E_{dofw}	Degree of food waste
E_{gpp}	Grain production per unit of arable land

3. Models

3.1 Food System Evaluation Model

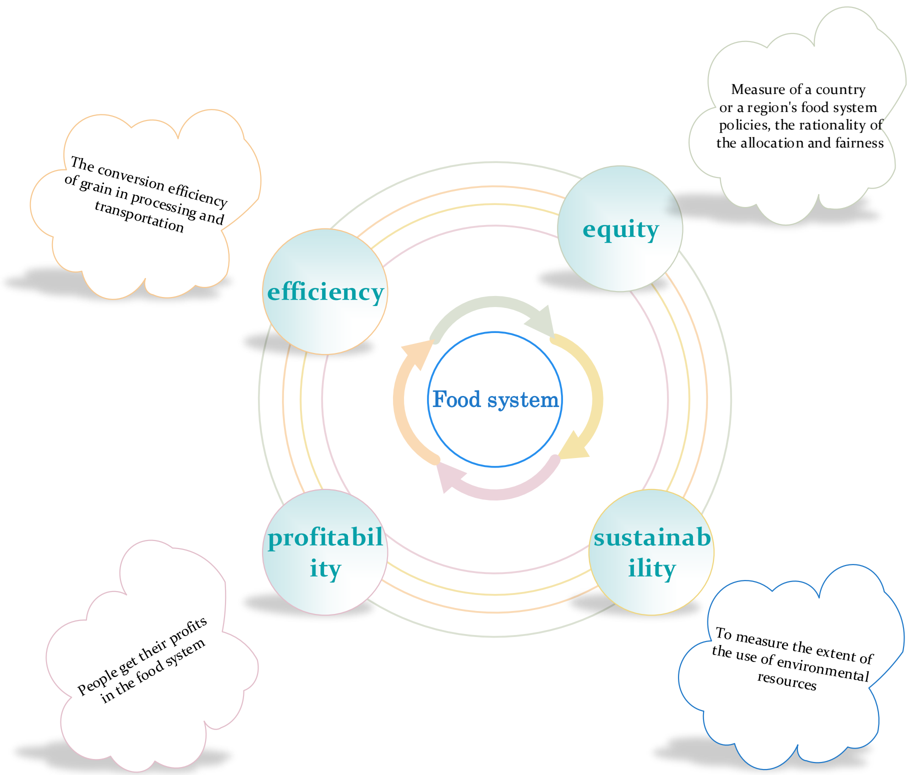

Figure 1: EESPE model and sub-indicator framework diagram

We have established a food system evaluation model to evaluate the current food system. When we

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evaluate the food system, we divide the indicators for evaluating this system into four parts: fairness, sustainability, profit, efficiency, and different Factors in the field affect the food system in different ways. We then introduce the quantification of the influence from various factors in subsections.

3.1.1 Equity

In the field of fairness, we use three indicators, namely price stability, incidence of malnutrition, and per capita food consumption. These three indicators measure the policy, rationality and fairness of the food system of a country or a region.

● **Food prices are stable**. Indicates the rationality of food- related policies designated by a country or region. For specific data, we refer to the food prices of the United Nations Food and Agriculture Organization over the years, and take the variance of the price as the stability factor.

● **The incidence of people's malnutrition**. Defined as the ratio of the total number of undernourished people in the world (or country) to the total number of people in the world (or country).

● **Per capita food possession**. The index is a measure of the region's level of food has an index, it can express the importance of fairness regional food systems degree.

The mathematical expression of the equity index in the OESPE model equation is in the form

$$equity = \alpha_1 E_{sfp} + \alpha_2 E_{iopm} + \alpha_3 E_{gcfc} \tag{1}$$

We will later (4.6) section assign weights$\lambda_1, \lambda_2, \lambda_3$to these indicators.

3.1.2 Sustainability

We use four indicators in the area of sustainability. These widely used indicators are an important aspect of our determination of the sustainable development of the food system.

● **The amount of chemical fertilizer used per unit of arable land**. To measure the use of chemical fertilizers in a country and region, the greater the amount of chemical fertilizer used per unit of arable land in a region, the higher the damage it will cause to the environment [4]. The Food and Agriculture Organization of the United Nations gives all the data.

● **Proportion of agricultural population**. Indicate the development and importance of agriculture and measure the development trend of agriculture in a country or region. The World Bank provides the same data set.

● **Per capita arable land area**. A small area of arable land per capita will prevent a country or region from supplying its own food, and the sustainability of the food system will be overly dependent on food imports to maintain it, and its uncertainty will increase substantially. Global macroeconomic data provides all data sets.

● **Water resources per unit area of cultivated land**. The amount of water resources per unit area of arable land indicates the abundance of available water resources for arable land. the mathematical expression of the sustainability index in the OESPE model equation is

$$sustainability = \beta_1 S_{fer} + \beta_2 S_{poap} + \beta_3 S_{pcala} + \beta_4 S_{water} \tag{2}$$

We will be back (4 .15) section assign weights$\beta_1, \beta_2, \beta_3, \beta_4$ to these indicators.

3.1.3 Profitability

We have three indicators when we measure profit areas. These three indicators directly or indirectly affect the profits of the food industry. Have a major impact on the food system

● **Natural disasters**. The frequent occurrence of natural disasters will have a serious impact on agricultural food, such as floods and droughts, directly reduce its output value and have a significant impact on the profit of the agricultural food industry. The World Bank provided all the data.

● **Agricultural production conditions**. Conditions for agricultural production is a strong indicator of the agricultural food industry in support of government policies, soil fertilizer production conditions factor extent fertile, the climate and environment will affect agricultural food situation, it will directly affect the profits of the food industry.

● **Production costs**. The cost of food production directly affects the profits of the relevant food industry. The World Bank provided the same data set.

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The mathematical expression of the profit index in the OESPE model equation is in the form

$$profitability = \gamma_1 P_{nat} + \gamma_2 P_{apc} + \gamma_3 P_{cop} \quad (3)$$

We will be back (4 .15) section assign weights $\gamma_1, \gamma_2, \gamma_3$ to these indicators.

3.1.4 Efficiency

There are three indicators. These three indicators can show the conversion efficiency of grain through processing and transportation.

● **Rate of food wastage**. According to the definition, the food loss rate is the proportion of food loss in processing and transportation. The degree of industrialization and transportation system are relatively complete, and the food loss rate is also Will be reduced accordingly, which is a direct indicator of the efficiency of the food system[5].

● **The degree of food waste**. The high degree of food waste indicates that the utilization of food in the consumption process is low.

● **Grain production per unit of arable land**. The low grain yield per unit of arable land indicates the low output rate in the grain planting process.

The mathematical expression of the efficiency index in the O E SPE model equation is in the form

$$efficiency = \lambda_1 E_{flr} + \lambda_2 E_{dofw} + \lambda_3 E_{gpp} \quad (4)$$

We will be back (4 .15) section assign weights $\gamma_1, \gamma_2, \gamma_3$ to these indicators.

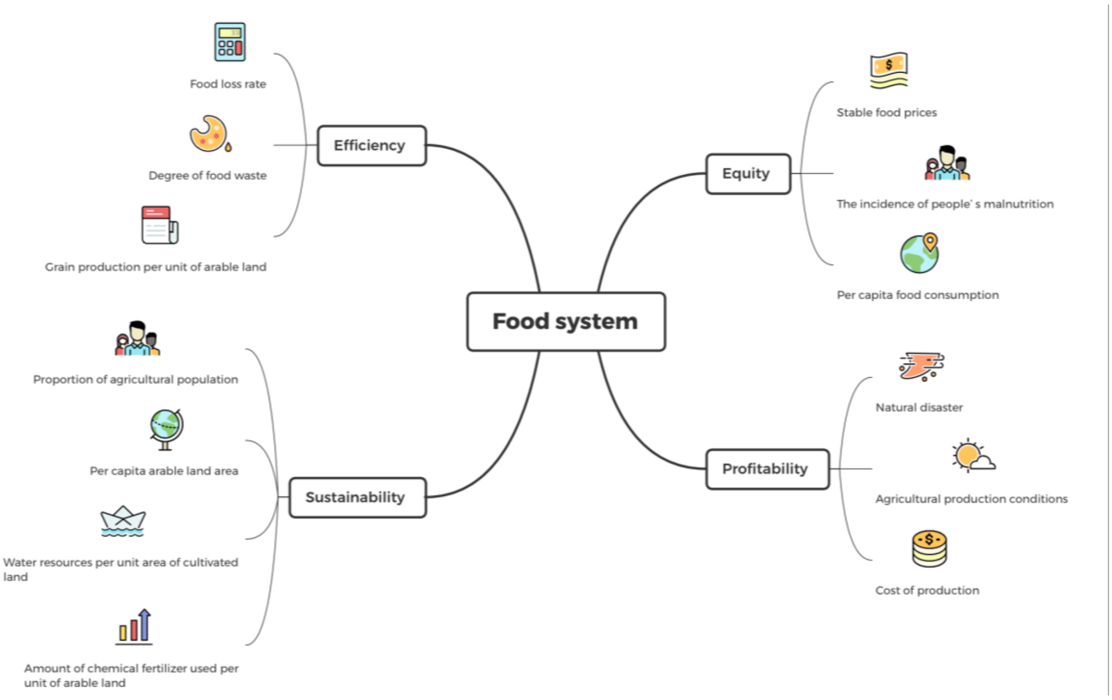

Figure 2: EESPE model and sub-indicator models at all levels

3.1.5 AHP Method for Single Index Data

We have used the AHP to determine the coefficients before each index.

Use the AHP to determine the weights of the sub-indicators for fairness, sustainability, profit, and efficiency, as shown in Figure 2.

1) The three index coefficients of fairness are 0.5954, 0.2764 and 0.1283 respectively

2) The three sustainable index coefficients are 0.1365, 0.2385, 0.6250 respectively

3) The three index coefficients of profit are 0.5825, 0.2495, 0.1062, 0.0618 respectively

4) The three index coefficients of efficiency are 0.6337, 0.1919, 0.1744 respectively

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Table 2: The weight of each indicator

Subsystem	Weight	Individual indicators	Unit	Weight
Equity	0.0445	E_{sfp}	/	2.629%
		E_{iopm}	%	1.229%
		E_{gcfc}	kg	0.571%
Sustainability	0.0670	S_{fer}	kg ħm^{-2}	3.902%
		S_{poap}	%	1.671%
		S_{pcala}	hm^{2}	0.711%
		S_{water}	m^{3} ħm^{-2}	0.414%
Profitability	0.5340	P_{nat}	/	33.839%
		P_{apc}	/	10.247%
		P_{cop}	$	9.313%
Efficiency	0.3544	E_{flr}	%	4.837%
		E_{dofw}	%	22.150%
		E_{gpp}	kg ħm^{-2}	8.452%

The more complex units in the icon are replaced by '/'

We have determined the weight of each indicator through the AHP, the current four indicators food system is coefficient are 0.5340, 0.3544, 0.0445, 0.0670 We then construct a weighting function to weight by weight of index levels, This weighting function is used to calculate the evaluation index of the food system, which is used to measure the current food system. In our model, each part has a specific index composition. Indicators in each area will be appropriate weights to evaluate food systems-based system. We will current food system model named EESPE model

$$EESPE_{score} = \sum_{n=1}^{4} \sum_{m=1}^{j} (X'_{nm} \times weight_n) \tag{5}$$

3.2 Grain System Optimization Model

We have established a grain system optimization model and named the system as the OESPE model. This model is optimized on the basis of the existing grain system. In addition to optimization in terms of fairness and sustainability, it also takes into account the quality of the grain system. Profit and efficiency can face various levels of adjustment and make appropriate optimizations.

3.2.1 Determination of Weight

We used entropy analysis to determine the levels of the food system optimization coefficient index model, Entropy Law is an objective weighting method, entropy analysis of the algorithm can be used to determine the degree of dispersion entropy of an indicator, and its entropy smaller value represents the index's weight greater rights. Therefore, we use the information entropy of this tool specifically calculated for each grade index weights. The main calculation steps are as follows.

When there are i samples and j indicators, X nm′and X nm are the standardized values and original values of the m individual index in the n year, and Y nm ′and Y mn are the m individual index in the nth year, respectively Standardized value and original value, max X m and min X m are the m item in all years, j is the number of evaluation years, and i is the number of indicators.

The two types of indicators, positive indicators and negative indicators, are standardized and calculated. Since the dimensions and magnitudes of the indicators at all levels are not uniform, the indicators are also divided into positive indicators and reverse indicators. Positive indicators and negative indicators have different meanings. The higher the positive indicator value, the better, the lower the negative indicator value, the better, so before we use the indicator for calculation, the first steps we need to take are:

For positive acting indicators:

$$X'_{nm} = \frac{X_{nm} - minX_m}{maxX_m - maxX_m} \tag{6}$$

For negative indicators:

$$X'_{nm} = \frac{minX_m - X_{nm}}{maxX_m - maxX_m} \tag{7}$$

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Calculate the proportion of the m index in the n year:

$$Y'_{nm} = \frac{X'_{nm}}{\sum_{n=1}^{j} X'_{nm}} \tag{8}$$

$$Y'_{nm} = X'_{nm} / \sum_{n=1}^{j} X'_{nm} \tag{9}$$

Calculate the index information entropy:

$$entropy_m = -A \sum_{n=1}^{j} Y_{nm} \times lnY_{nm} \tag{10}$$

Order = A, there are $0<entropy_m<1$, and when $Y_{nm}=0$, the order $Y_{nm} \times lnY_{nm} = 0$

Calculate the entropy redundancy: $R_m = 1 - entropy_m$

Calculate the index weight:

$$weight_n = R_m / \sum_{m=1}^{i} R_m \tag{11}$$

3.2.2 Calculation of Food System Evaluation Index

We passed the entropy weight analysis method to determine the weights, and then we constructed a weighting function through the weights of indicators at all levels, and used this weighting function to calculate the evaluation index of the optimized food system to measure the food system.

$$OESPE_{score} = \sum_{n=1}^{4} \sum_{m=1}^{j} (X'_{nm} \times weight_n) \tag{12}$$

Table 3: The weight of each indicator of the OESPE model

Subsystem	Weight	Individual indicators	Unit	Weight
Equity	0.0445	E_{sfp}	/	2.629%
		E_{iopm}	%	1.229%
		E_{gcfc}	kg	0.571%
Sustainability	0.0670	S_{fer}	kg hm^{-2}	3.902%
		S_{poap}	%	1.671%
		S_{pcala}	hm^2	0.711%
		S_{water}	m^3 hm^{-2}	0.414%
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Efficiency	0.3544	E_{flr}	%	4.837%
		E_{dofw}	%	22.150%
		E_{gpp}	kg hm^{-2}	8.452%

4. Application of the model

Through the comparison between the EESPE model and the OESPE model established above, we can find that through the comparison, we can find that the fairness and sustainability of the system have increased significantly, while taking into account the profit and efficiency, and the profit and efficiency can still be maintained. A good standard. The secondary index fan chart of the EESPE model is shown in Figure 3, and the secondary index fan chart of the OESPE model is shown in Figure 4.

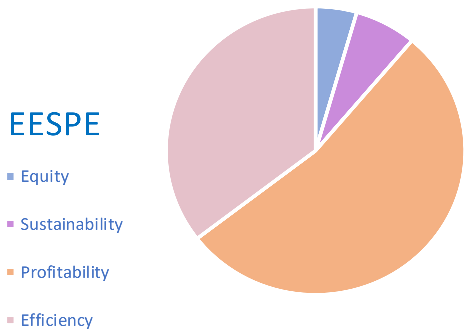

Figure 3 Fan chart of secondary indicators of EESPE model

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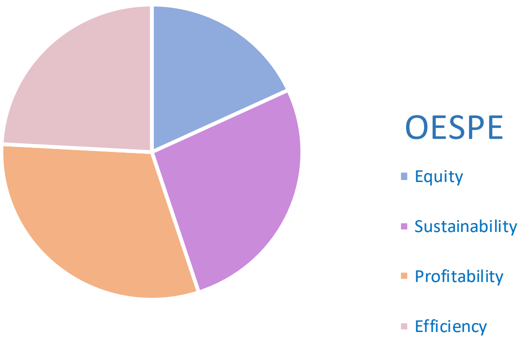

Figure 4 The secondary index fan chart of the OESPE model

The optimized food system has greatly improved the stability of food prices. The reason is that the state has introduced relevant policies and measures to stabilize and regulate food prices. Grain prices need to be maintained at a correspondingly stable price. Grain prices rise too high or too low. well, when food prices are too high , foodrelated upstream and downstream industry will be dramatic effect , for example, food processing , seeds pesticides,fertilizers, food service and other industries will certainly follow up. It also affects the related industries of theseindustries. This series of reactions will cause many commodities to increase in price. However, high food prices willreduce farmers' enthusiasm for production, which will greatly affect farmers' production efficiency. Therefore, theoptimized food system improves fairness.

Optimized in food systems unit of arable land area fertilizer use significantly reduced on the food system beforeoptimization, after the chemical fertilizer, the active ingredient of fertilizers less than half absorbed by crops, theremaining parts are wasted up . Among the many chemical fertilizers, the loss rate of nitrogen fertilizer has evenreached an extremely high level of more than 70% , and it also pollutes the soil, water, atmospheric environment, andagricultural products. The optimized grain system reduces the use of chemical fertilizers, and uses chemical fertilizersat a reasonable time and quantitatively, which improves the use efficiency of chemical fertilizers, reducesenvironmental pollution, improves soil fertility, and also increases grain production per unit area to a certain extent ,Thereby reducing the incidence of people's malnutrition. The optimized model also adjusts the priority of agricultureto ensure a sustainable environment . Thereby improving the sustainability of the agricultural system.

The optimized food model should reduce the global food loss by half in accordance with the sustainabledevelopment goals. The optimized food adopts various solutions in the food supply chain , such as technologicalimprovement, etc. , relying on the inclination of public policies . In a process for the improvement of links to includetraining and equipment manufacturers and collaboration in the supply chain and so on . Improve the efficiency andprofit of the food system, so that while optimizing fairness and sustainability, it can also ensure profit and efficiency.

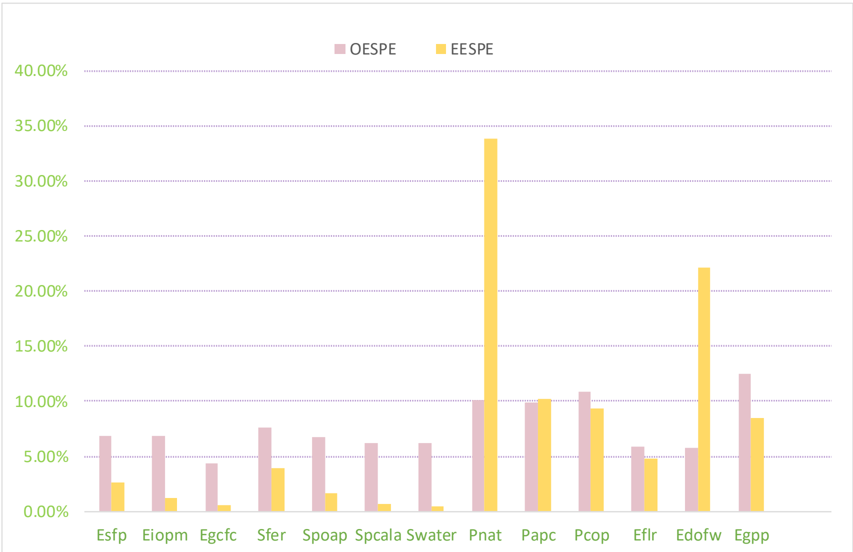

Figure 5: Comparison Chart of three-level indicators of EESPE model and OESPE model

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5. Strength and Weakness

5.1 Strength

Our O E SPE model uses four secondary indicators and thirteen primary indicators to measure the food system of a country or region. Many indicators can avoid the impact of emergencies. Therefore, the OESPE model Relatively stable, the results are relatively comprehensive.

We applied three data processing methods (entropy weight method, weighted average method and AHP), analyzed the characteristics of each indicator, and made our OESPE model more reasonable and scientific.

Universality and scalability: As long as the relevant data is given, and with slight adjustments, our OESPE model can be applied to the food system of various countries or regions.

5.2 Weakness

We use appropriate methods to deal with unfound and missing data, which will affect the accuracy of our model.

6. Concluding Remarks

Considering fairness, sustainability, efficiency and profit, we established OESPE model to analyze and optimize food system. The entropy method and analytic hierarchy process are used to quantify various indicators, and the benefits and costs of developed and developing countries under the food system optimized by OESPE model are discussed. So as to ensure that it is more extensible and adaptable.

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