Problem Chosen	2021 MCM/ICM Summary Sheet	Team Control Number
E		2100419

Better food system& better world

Abstract:

Before the Covid-19 epidemic, nearly 690 million people around the world faced food insecurity in 2019, and 2 billion people did not have enough food or did not have access to human nutrition. Owing to the influence of locust plague, Covid-19 and other factors, the global food crisis in 2020 will be further intensified. Further exposure of the shortcomings of the global food system shows that we must act quickly to improve the food system, or the situation will deteriorate further.

Firstly, in order to analyze and evaluate the existing grain system, a multi-factor grain system evaluation model based on fuzzy evaluation method was established. Taking China and the United States as examples, the data from 2016 to 2019 were calculated, and it was concluded that the system evaluation values of some grain systems in both countries showed a decreasing trend year by year. In 2019, the grain system score of China was 2.72, while that of the United States was 2.81, indicating that the grain system of developed countries is better.

On this basis, we predict the grain system evaluation value in the next few years through the existing data, and find that the stability of the current grain system is not good by combining the predicted evaluation value with the existing evaluation value. Therefore, three scenarios are set by the control variable method to improve the model. They are to maintain the current trend, put forward the compensatory policy and pay attention to environmental protection, and obtain the optimal change order of factors by using the fuzzy analytic hierarchy process, so as to transform the orientation of the existing grain system. At the same time, we find it is necessary to reduce economic growth to improve social equity and sustainable food systems.

Second, in order to better research guided by fairness and sustainability of the stability of the food system, we based on system dynamics is established "Food - Water - Energy - Economy - Society" PSR model, from the micro-level analysis of the dynamic behavior of the food system, and examines the interaction relationship of indicators, again confirm the above conclusion.

Thirdly, we use SPSS software to obtain the completion time of grain system-oriented transformation through time series prediction algorithm, and apply the model to small regions and the world to discuss the scalability and adaptability of the model.

Finally, we think about the influence of Covid-19 on food supply, tack into account the nonlinear influence of irresistible factors such as natural disasters and wars on the model, optimize the established evaluation model, and put forward suggestions to improve the discourse power of developing countries and give full play to the role of food evaluation system.

Key words: multi-factor, PSR, fuzzy evaluation

Contents

1. Introduction

1.1 Background

In 2015, the world pledged to end hunger, food insecurity and all forms of malnutrition. However. Five years later, we are still lagging behind in achieving our goals [1]. In 1983, the World Food and Agriculture Organization (WFO) pointed out that the goal of food security is to "ensure that all people can buy and afford the basic food they need at all times" [2]. According to current estimates, 8.9 per cent of the world's population is hungry, an increase of 10 million in one year and nearly 60 million in five years. In 2019, nearly 690 million people around the world faced food insecurity, and the outbreak has exposed weaknesses in the global food system. While our world is capable of producing enough food to feed all its people, there are still more than 1.5 billion people scattered around the world who cannot afford to eat a diet that meets essential nutritional needs. At the same time, with the increase of the global population, the damage to the environment is also increasingly severe, and the existing food system is putting forward a greater challenge. The figure below shows the aspects that are relevant to the food system.

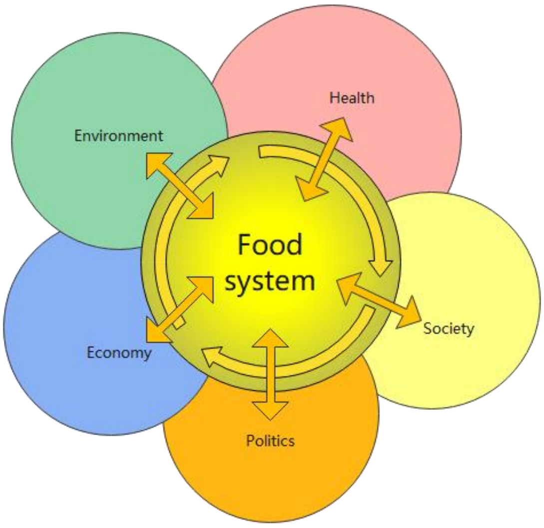

Figure.1 Food system

1.2 Restatement of problems

To address the current instability of the food system, we need to overhaul our current food system and build our own system.

What we need to do is:

- Food system optimization into in order to realize the fairness and sustainability as the guidance, and to explore what will happen and points out the difference between the current system.
- Priorities change the food system, discuss the benefits and costs, and predict the time.
- On the basis of the above research, the model is applied to at least a developed country and a developing country.
- Discuss our model of the larger or smaller food system scalability and adaptability to other regions.

1.3 Our work

First, we build a multi-factor food system evaluation model. Using the data, we score and predict the economic and efficiency-oriented food system in China as an example.

On this basis, we discuss the benefits and costs of changing food system priorities by changing three scenarios for various parameters of the food system: maintaining the current trend, adjusting the equity-related indicators in the model, and the environmental sustainability indicators in the model.

Secondly, in order to better study the food system oriented by fairness and sustainability, we established the "food-water-energy-economy-society" PSR model. After analyzing the optimized food system model, the correctness of Model 1 was also verified.

We then apply the model to the United States and China, predict when to implement fair and sustainable policies, and extend the model to the world, and discuss the model's scalability and adaptability

Finally, we consider the impact of the epidemic on the global food system, taking into account the occurrence of major emergencies such as the epidemic, optimize the food system evaluation model, and give suggestions.

2. Symbol Description

2.1 Notation

The symbols used in this article are listed in table 1

Table.1

Symbol	Notation
P_j	The weight of the j^{th} index in the criterion layer
B_j	The j^{th} index in the criterion layer
A	The target layer
W_j	The weight of each indicator is the j^{th} indicator
X_j	The j^{th} index in the index layer

2.2 Assumptions

- No crop losses before it goes on the market.
- Health and economic conditions are stable, such as no epidemics and economic crisis.
- Social stability, such as there is no conflict.
- Suppose the data we find is correct.
- In order to simplify the model and highlight the difference between the two, in the activities of the food that is associated with people we consider only plant, distribution, sales between countries.

2.3 Noun explanation

Major grain producing areas: the areas dominated by grain industry.
Climate change: Refers to changes in precipitation, temperature, etc.
PSR: Full name is "pressure-state-response" model.
FCA: Fuzzy Comprehensive Appraisal.

3. Food System Evaluation Based on FCA's Multi-factor Evaluation Model

3.1 Model building

To better study the differences between existing and optimized food systems, we first need to consider a standard food system evaluation system. In view of the complexity and uncertainty of the food system evaluation, this paper uses the multi-factor evaluation model, takes China as an example, selects 11 representative indicators from three aspects of economic system, social system and environmental system to calculate the national food system evaluation status.

(1) Index weighting

Based on the process of combining qualitative and quantitative methods and quantifying complex systems, we decided to adopt the fuzzy comprehensive evaluation method, which is a multi-level and multi-objective decision-making analysis method. This method combines the model theory with subjective experience, analyzes the non-sequential relationships among hierarchical systems, and makes an effective evaluation of the model. The basic idea is to adopt the three-level structure, determine the single order weight of the factors in the hierarchy and the total ranking among the layers, and finally calculate the weight ratio of the lowest level to the highest level, so as to get the ranking of the scheme. This method has the advantages of high reliability and small relative error.

(2) Establishment of hierarchical structure

The food system evaluation system is taken as the first objective layer of level. Taking economy, environment and society as the second criterion layer of level; On the basis of the system layer, the representative evaluation indexes are screened out, and the correlation is combined as the third index layer of the analytic hierarchy. The existing food system is ultimately oriented by efficiency and profit. Although the system is highly efficient, it comes at the cost of unsustainable development of the environment and unfair distribution among people. Global food production can be divided into three categories: importing countries (those with little food), exporting countries (those with plenty of food) and countries that are self-sufficient in food. Therefore, when we study and set up the evaluation model, we take the import and export volume of food as the quantified index of benefits.

For example, although the exporting country is rich in food, there are still people starving in the country. However, because the export benefits are greater, we give priority to export rather than distribution. To find and food produce the efficiency of the level of greenhouse gas emissions as a quantitative index, because of the high grain yield without a large amount of fertilizer applied, to produce more food at the same time, in the production processing and so on in the way to produce greenhouse gas levels will rise.

In addition, the burning of a large number of crops also can lead to greenhouse gas emissions, the former and the latter are to some extent reflect the relationship of positive correlation. Due to the final optimization model need to environmental sustainability and social equity as a guide, so appropriate amount and grain fertilizer use level of greenhouse gas emissions as quantitative indicators of environmental system, although fertilizer and a large number of processing will enhance efficiency, will damage the environment, so consider appropriate amount and grain fertilizer to produce the lower the level of greenhouse gas emissions or the less, the better for the sustainable development of environment.

The problem of social equity is quantified by the per capita food production and the net population growth rate, because the change of the per capita net growth rate can represent the hunger mortality rate in the region to some extent, and the per capita food availability can also reflect the food distribution in the region to some extent, thus reflecting the social equity.

The model we have established now is an evaluation model of the existing grain model oriented by benefits and efficiency. The grain model is decomposed into three systems and 11 impact indicators by layers, as shown in the figure 2:

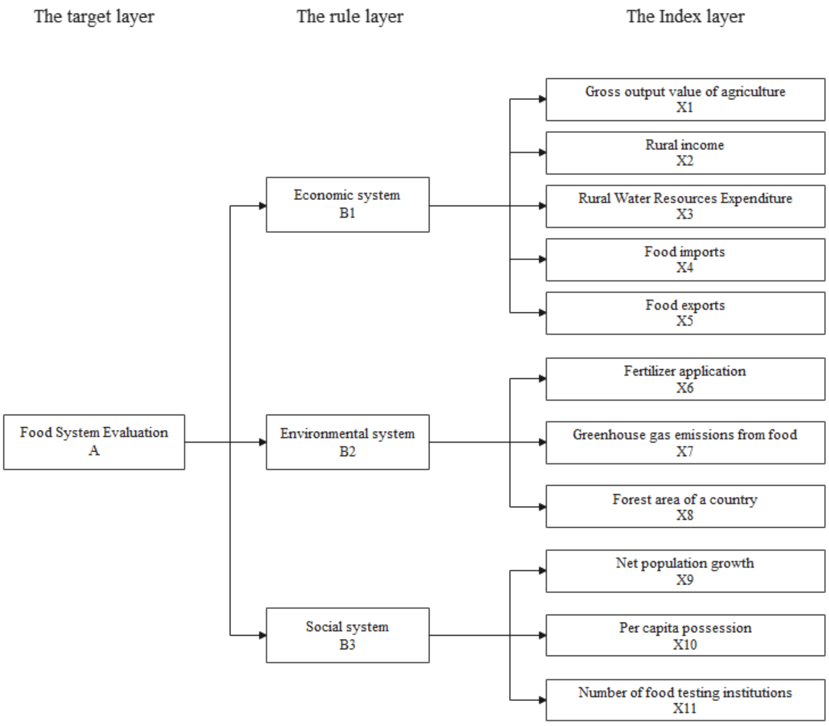

Figure.2

(3) Constructing judgment matrix

Due to the different influence of evaluation indexes, the judgment matrix was constructed by using expert consultation and 1-9 Saaty scale method.

$$c=\begin{bmatrix}\frac{v1}{v1} & \frac{v1}{v2} & \cdots & \frac{v1}{vn}\\ \frac{v2}{v1} & \frac{v2}{v2} & \cdots & \frac{v2}{vn}\\ \cdots & \cdots & & \cdots\\ \frac{vn}{v1} & \frac{vn}{v2} & \cdots & \frac{vn}{vn}\end{bmatrix}(i=1,2,\ldots,n;j=1,2,\ldots,n) \qquad (1)$$

Among them, (1) $\alpha_{ij}=1,\alpha_{ij}\geq 0(i=1,2,\ldots,n)$; (2) $\alpha_{ij}=1/\alpha_{ij}(j=1,2,\ldots,n)$

(4) Calculating index weight

(i) Single level sorting

$$\lambda_i=\left(\prod_{j=1}^{n}\alpha_{ij}\right)^{\frac{1}{n}} \qquad (i=1,2,\ldots,n) \qquad (2)$$

$$V_i=\frac{\lambda_i}{\sum_{i=1}^{n}\lambda_i} \qquad (3)$$

Repeat the above calculation formula to calculate the weight value Vi

of each evaluation index. This weight value represents the relative importance ratio of this level to the previous level, that is, single-level ranking.

(ii) Multi-level sorting

$$\theta_i=\sum_{j=1}^{m}\alpha_j\theta_{ij} \qquad (i=1,2,\ldots,n) \qquad (4)$$

where， $k \in n$； θ_{ij} is the single ranking weight value of the k-layer to the j factor in the k-1 layer， α_j is the total ranking weight value of the j factor in the k-1 layer, θ_i is the total ranking weight value of the factors in the k-1 layer, and m is the factor contained in the k-1 layer.

(5) Check consistency

The consistency test of judgment matrix includes the consistency test of single ranking and the consistency test of hierarchical total ranking. The general condition of the test is that when the random consistency ratio， it means that the single-ordering structure of the judgment matrix meets the consistency requirements. The consistency index $CR = \frac{CI}{RI} \leq 0.1$, μ is the maximum eigenvalue of the judgment matrix, and the average random consistency index is shown in the figure below:

Table.2 Average random consistency index

n	***RI***	***n***	***RI***	***n***	***RI***
1	0.00	6	1.24	11	1.52
2	0.00	7	1.32	12	1.54
3	0.58	8	1.41	13	1.56
4	0.90	9	1.45	14	1.58
5	1.12	10	1.49	15	1.59

(6) Comprehensive evaluation model

The evaluation of food system is related to many fields and belongs to multi-factor evaluation of multi-level and cross-system. There are many models available for evaluation, such as AHP, fuzzy comprehensive evaluation, neural network and other methods. In this paper, the multi-factor evaluation model in the fuzzy evaluation method is adopted to comprehensively evaluate the system layer and factor layer in the hierarchical structure. The calculation formula is as follows:

$$X_a = \sum_j^n V_j P_j \qquad (a = 1，2，3) \qquad (5)$$

$$Y = \sum_j^{11} \theta_i P_i \qquad (i = 1，2，3，…，11) \qquad (6)$$

Where, X_a is the evaluation result value of class A system, and n is the order of the constructed judgment matrix. V_j is the weight value of single-level sorting; P_i is the evaluation coefficient of the corresponding factors of the matrix; Y is the comprehensive evaluation value of the system, and θ_i is the total ranking weight value of factors in the factor layer. P_i is the evaluation coefficient of the corresponding index of the matrix. The ideal standard level is defined according to the characteristics of the food system, and the evaluation result of the food system is compared with the ideal standard level to illustrate the actual grade range of the food system. The evaluation index system is built on the basis of the existing data, and the specific grade is shown in table 3.

Table.3 Classification of evaluation index system

System	**Indicators**	**Grading**				
		5	4	3	2	1
Economic system	**Gross output value of agriculture**	>7600	7200~7600	6800~7200	6400~6800	<6400
	per farming capita income	>7200	6800~7200	6400~6800	6000~6400	<6000
	Water Expenditure on Agriculture	<18000	18000~19000	19000~20000	20000~21000	>21000

	Food imports	<10000	10000~11000	11000~12000	12000~13000	>13000
	Food exports	>300	250~300	200~250	150~200	<150
Social system	**Net population growth**	>4.5	4~4.5	3.5~4	3~3.5	<3
	Per capita possession	<478	476~478	474~476	472~474	<472
	Number of food testing institutions	>3450	3400~3450	3350~3400	3300~3350	<3300
Environmental system	**Fertilizer application**	>5850	[5700,5850]	[5550,5700]	[5400,5550]	<5400
	Greenhouse gas emissions from food	>1000	500~1000	100~500	10~100	<10
	Forest area of a country	>23000	22500~23000	22000~22500	21500~22000	<21500

3.2 Calculation of model

Through the following table, we can calculate the weight diagram of each index as shown in the table 4.

Table.4 Evaluation of figure

Scale	Meaning
1	Equally important
2	Slightly important
3	Obviously important
4	Strongly important

Table.5 Weight chart of each index

	Economic system	Environmental system	Social system	Weight
Pj	0.55560	0.33330	0.11110	
Gross output value of agriculture	0.41180	0.41180	0.41180	0.4118
Rural income	0.17650	0.17650	0.17650	0.1765
Water Expenditure on Agriculture	0.29410	0.29410	0.29410	0.2941
Food imports	0.05880	0.05880	0.05880	0.0588
Food exports	0.05880	0.05880	0.05880	0.0588
Net population growth	0.55560	0.55560	0.55560	0.5556
Per capita possession	0.33330	0.33330	0.33330	0.3333
Number of food testing institutions	0.11110	0.11110	0.11110	0.1111
Fertilizer application	0.55560	0.55560	0.55560	0.5556
Greenhouse gas emissions from food	0.33330	0.33330	0.33330	0.3333
Forest area of a country	0.11110	0.11110	0.11110	0.1111

The data from 2016 to 2019 were analyzed through the multi-factorial grain system evaluation model. The data are shown in the figure below, and the weight obtained in the figure above is substituted to calculate the score of grain system structure from 2016 to 2019 as follows:

Table.6 Data of each indicator from 2016 to 2019

Indicators	Data				
	2019	2018	2017	2016	Unit
Gross output value of agriculture	73567.1	67558.7	64660	62451	Billion CNY
Rural income	7118	6543	6325	5707	CNY
Water Expenditure on Agriculture	22862.8	21085.59	19088.99	18587.4	Billion CNY
Food imports	10609	11555	13062	11468	10 kilo-tons
Food exports	366	280	190	164	10 kilo-tons
Net population growth	3.34	3.81	5.32	5.86	‰
Per capita possession	474.95	472.38	477	479	kg
Number of food testing institutions	3389	3456	3365	3353	Individual
Fertilizer application	5403.59	5653.42	5859.41	5984.41	10 kilo-tons
Greenhouse gas emissions from food	2734.33	67.94	61.69	13.35	Megaton
Forest area of a country	22044.62	22044.62	22044.62	22044.62	10 kilo-hectares

Table.7 Food system structure score

Year	Evaluation of food system value	Evaluation of social system value	Evaluation of environment system value	Evaluation of economic system value
2019	2.70209	3.2724	3.1213	2.3333
2018	2.7275	2.1816	2.6667	3.0001
2017	3.50536	2.2756	3.6667	4.3333
2016	3.67706	2.3634	3.3334	4.6666

3.3 Results of the model

In the current grain production system, which is mainly oriented by efficiency and benefits, the efficiency and benefits are on the rise year by year, but the total score of the system is on the decline year by year, indicating that our current grain system is becoming more and more dangerous and can only reach the level of basic security by 2019. If the food system is optimized to achieve fairness and sustainability, we weaken the indicators of the economic system in the model, while improve the social system and environmental system, we find that the total score of the optimized food system is increased, indicating that the optimized system is more conducive to human survival and sustainable development.

After the optimization of the system, the total variance of the per capita share of grain in each region is reduced, and the fairness of grain distribution is achieved to the maximum extent. But at the same time, the per capita income of farmers will decrease, which may cause more farmers to choose to work outside the country instead of growing food. For the sustainable development of the ecosystem, the application of a large amount of chemical fertilizer will cause soil hardening, plunder the land, and degrade the quality of the land. The amount of chemical fertilizer applied and the area used to grow food will be reduced to extend the service life of the existing land and increase the forest area of the country.

Under the existing grain system, the production elasticity and contribution rate of grain production factors in China are significantly different between developed and moderately developed regions [4]. In order to optimize the existing food system, we will redistribute the amount of food in all parts of the country, so as to maximize the social equity of the distribution of food. The following figure 3 shows the color difference of grain output in some countries in 2005.

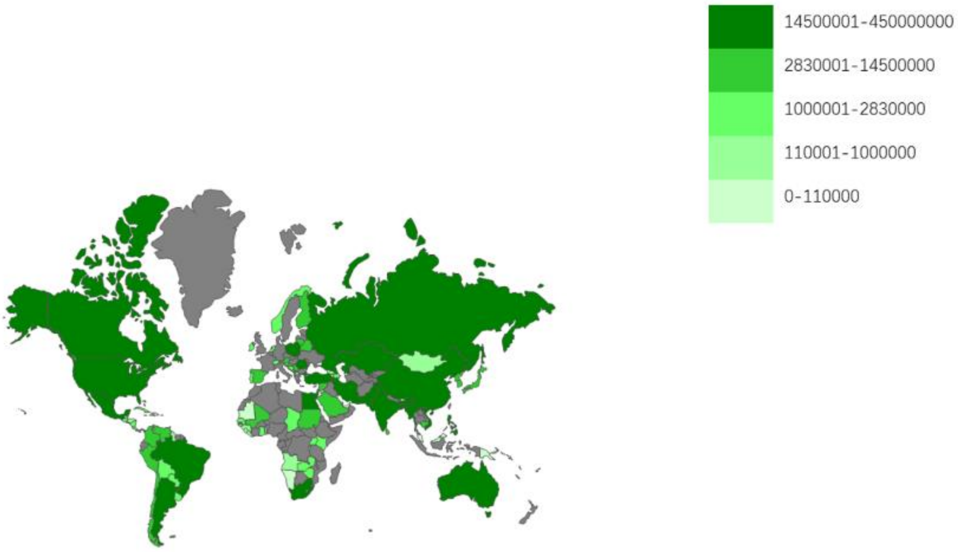

Figure.3 Color difference diagram of grain output in some countries in 2005

We have used China, where the data sets are relatively easy to collect among developing countries, for analysis in our previous model building. After the analysis, we collected data sets for the food system evaluation model through official websites such as USDA and National Bureau of Statistics. According to the data analysis, the forest area and vegetation coverage rate of the United States is always larger than that of China, and also ranks top in the world. According to the statistics on Wikipedia, the forest area of developed countries is larger than that of developing countries in the world. The output of grain crops in the United States is basically the top three in the world all the years, and the amount of grain exports far exceeds the amount of imports. In terms of agricultural added value, the United States also ranks among the top three in the world with its huge amount of grain exports.

First of all, the data we bring to the United States is used to evaluate its food system. After obtaining the system evaluation value from 2016 to 2020, we continue to use the ARIMA (1,0,0) prediction model to predict the evaluation value of the food system in the United States within 5 years. By comparing the system evaluation values of China and the United States in the past 10 years, we found that the system evaluation values of the American food system are higher than that of the Chinese food system.

By the United States and China's data analysis and comparative analysis of the food system evaluation, we draw the conclusion: the developing country economic development level is the overall downturn in the developed countries, so the developing countries are to develop the economy, but most are based on the destruction of the environment and the big difference of per capita in exchange for economic take-off. Therefore, in the process of future development, changing the food system from the benefit and efficiency-oriented approach to the environmentally sustainable development and equity-oriented approach will help developing countries to improve the degree of environmental damage to a certain extent, and also help developed countries to maintain a high ecological level. However, for developing countries, the result of the change of orientation is likely to be a large decline in the national economic growth rate. For developed countries, it is necessary to sacrifice the economy of the rich people within the acceptable range, so as to narrow the gap between the rich and the poor and make society in a more fair and just state.

3.4 Analysis of the model

The judgment matrix is established according to the existing model evaluation (X1), and the system priority is as follows: economy (benefit) > environment (efficiency and sustainable development) > society (fairness). If the food system is optimized to achieve equity and sustainability, then the system priority should be adjusted to environment (efficiency and sustainable development) > society (equity) > economy (benefit). When setting up the judgment matrix of optimization evaluation model (X2). Through the comparison of two final evaluation values with different priorities, we find that the evaluation value guided by social equity and environmental sustainability is higher than the evaluation value guided by benefit and efficiency.

Compared with the current profit-oriented and efficiency-oriented food model, the food model based on social equity and environmental sustainability pays more attention to the environmental changes caused by food production or processing, as well as the distribution of areas with a wealth gap. Although economic development should be a regional priority, it should not come at the cost of environmental sacrifice and social injustice.

3.5 Scenario projections for changing parameters of food system priorities

We take China as an example and use the multi-factor grain system evaluation model to analyze and forecast.

3.5.1 Scenario 1: Maintain current trends

This scenario refers to the 10-year prediction of ARIMA (1,0,0) model in SPSS according to various factors of the multi-factorial food system evaluation model mentioned above, and we get Figure 4- Figure 10. We find that in this efficiency and profit-oriented food system, the per capita income of rural residents increases and the overall economic situation is better. The increase of expenditure on agriculture, forestry and water resources will cause further pollution of water resources to some extent. The increase of grain import and export volume is conducive to the adjustment of domestic and foreign grain markets, but the research found that a restrictive factor of China's grain export is the low level of national inspection, and through the forecast, we found that the number of food inspection institutions is declining, will restrict China's export volume. Carbon dioxide emissions tend to be stable, but they are high. The overall food system score is predicted for five years (Figure 11), and we find that the overall score is getting lower and lower under the existing food system, indicating that the existing food system is not conducive to the sustainable development of human and environment.

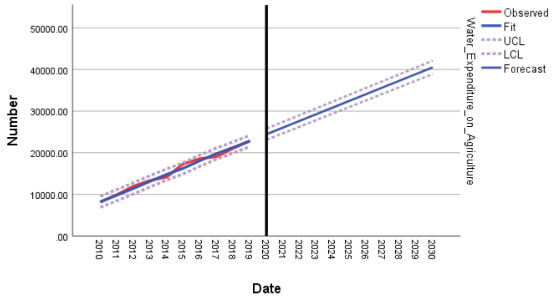

Figure.4

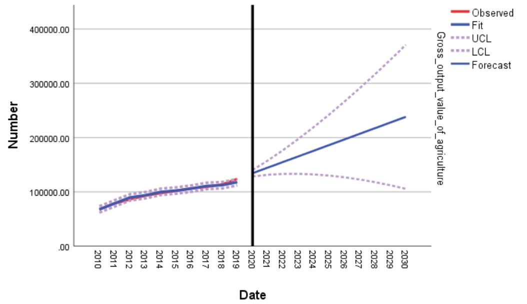

Figure.5

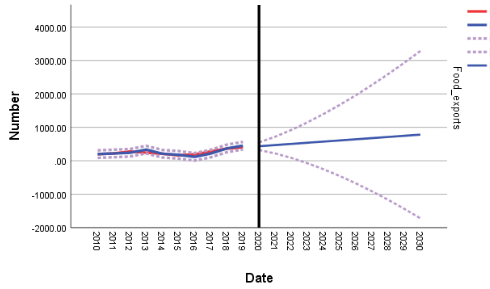

Figure.6

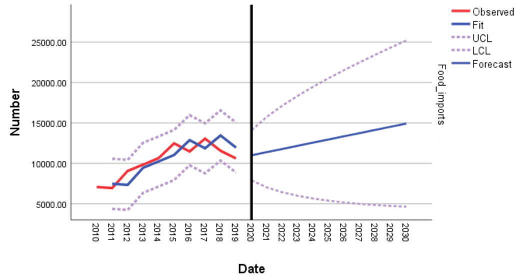

Figure.7

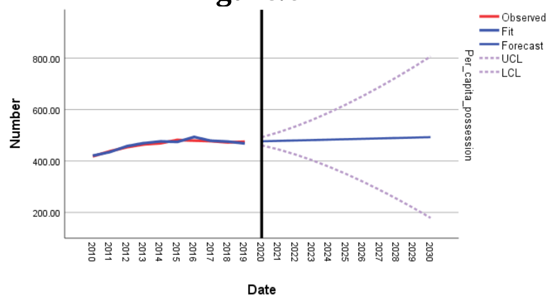

Figure.8

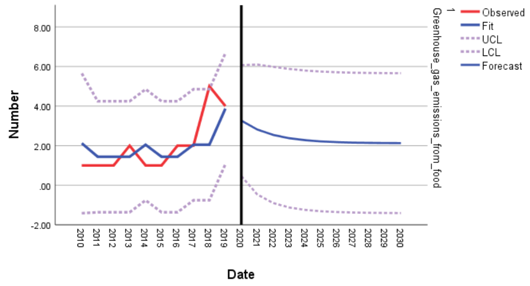

Figure.9

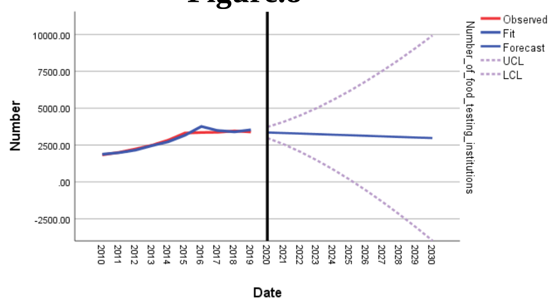

Figure.10

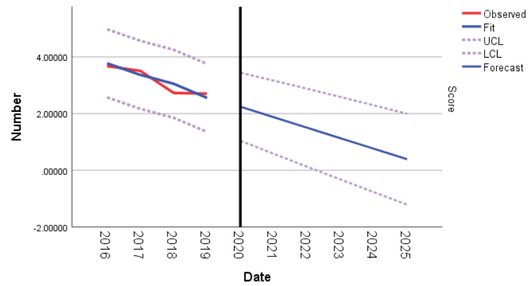

Figure.11

At a time when we are considering is the national average condition, when we compare to different parts of the farmers' income, as shown in figure 8, found that the regional difference is larger, compared with urban living standards, the per capita income of urban and rural residence and regional grain supply and demand situation is different, (as shown in figure 12), you can see the low level of overall life in the countryside. From this point of view, the inequality is more serious.

Table.8 The income of farmers in different regions

province	Jilin	Henan	Inner Mongolia	Anhui	Zhejiang	Guangdong	Beijing	Shanghai
rural per capita net income	8598.2	7524.9	7611.3	7160.5	14551.9	10542.8	16475.7	17803.7

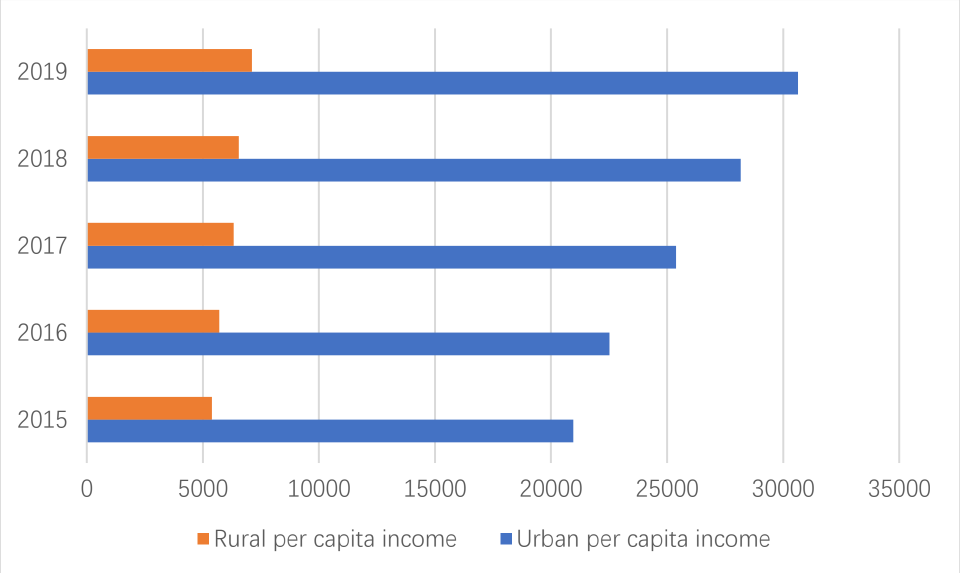

Figure.12 The per capita income of rural and urban residents

3.5.2 Scenario 2: Optimize the food system to achieve equity

China's main grain-producing areas are characterized by large arable land area, large grain volume and stable production, and most of them are rural areas. Economic development in rural areas is relatively backward and income growth is slow. Due to the low price of grain in the US, China will import some grain from the US, resulting in the continuous low price of grain in China. Chinese farmers cannot meet the basic living expenses of their families only by farming the land. Figure 13 shows the comparison between the total wages of agriculture, forestry, animal husbandry and fishery and those of other industries in recent years. On the other hand, while overall food production is increasing, a good food system should not only eliminate hunger, but also combat food insecurity and all forms of malnutrition. In addition to carbohydrates, lipids, proteins and other macronutrients, human health needs calcium, iron, zinc and other 16 mineral elements and 13 vitamins. If the intake of essential micronutrients is insufficient or unbalanced for a long time, the body will not feel hungry, but the health will be impaired, which is called "hidden hunger". A number of studies have shown that "hidden hunger" can lead to birth defects and developmental disabilities, increase child and maternal mortality, and seriously affect the quality of a country's population and economic development.

Figure.13 Wages in different industries

In order to change this unfair situation, on the one hand, we need to improve the rural per capita income and expenditure in each region even if the income is fair, on the other hand, we need to meet the food supply and demand in each region.

Income fair also called fair income distribution, mainly refers to make social members in income distribution is relatively fair, that is to say, the income gap between social members cannot too wide, while under the condition of market economy, because resources distribution is different, different industries, regional income gap between people will be but if we don't regulate, let its development will greatly harm the healthy and stable development of society. The income equity we refer to is not absolute, but there is a moderate-income gap in meeting the basic needs of individuals. Moderate income gap can stimulate people's competitiveness and enthusiasm, without affecting social stability, but also can make the social economy with efficiency and vitality.

For a long time, influenced by many factors such as resources, policies and income distribution mechanism, there has always been a serious inequality or even an insurmountable gap between urban and rural areas. Grain crop production is a typical inefficient industries, if only to grow food in the region rely on food this one, both development efficiency and finance can't compared to is given priority to with other industries in the region, in the long run, there will be less and less people to grow food, causing substantial decline of agricultural development, for example, now there are more and more people choose to give up farming and choose to go out to work, thus appeared the phenomenon of large areas of land planting [5].

In order to guarantee the safety of the food, the major grain producing areas is restricted in the field of food production, but grain output efficiency is much lower than other industry, so the development of major grain producing areas compared to the major grain-producing areas, comprehensive social and economic development lag behind, so the output of grain big province of fiscal income is low, the phenomenon of poor, weak industrial production and people's life (table 9).

Table.9 Comparison of main and non-main producing areas

Province	The total food (Tons)	Food consumption (Tons)	External adjustment of commodity grain (Tons)	Population (Ten thousand)
Beijing	113.77	827.6	-713.83	2069
Tianjin	161.76	565.2	-403.44	1413
Jilin	3343	1100	2243	2750
Heilongjiang	5761.49	1533.6	4227.89	3834
Henan	5638.6	3762.4	1876.2	9406
Anhui	3289.1	2395.2	893.9	5988
Inner Mongolia	2528.5	996	1532.5	2480
Zhejiang	769.8	2190.8	-1421	5477
Guangdong	1396.33	4239.8	-2842.47	10594
Shanghai	122.39	952	-829.61	2380

Note: grain consumption = total population * per capita annual grain consumption

In order to solve this problem, we should give play to the regulation role of the government and make up for the deficiency of the market mechanism by means of laws and welfare policies. On the one hand, we should emphasize the operation efficiency of the grain industry and on the other hand, emphasize the role of government regulation in the development of the grain industry. The supply of food should be guaranteed without undermining the market economy. According to the data of National Bureau of Statistics in 2012, we can get Table 10.

Table.10 Major grain producing and marketing areas in 2012(Unit: yuan)

Province	Rural per capita net income	Per capita consumption expenditure of farmers	The ratio of farmers' consumption to income	Urban per capita gross income	Urban per capita consumption expenditure	The ratio of Urbans' consumption to income
Jilin	8598.2	6186.2	71.95%	21659.6	14613.5	67.47%
Beijing	16475.7	11878.9	72.10%	41103.1	24045.9	58.50%
Shanghai	17803.7	11971.5	67.24%	44754.5	26253.5	58.66%
Guangdong	10542.8	7458.6	70.74%	34044.4	22396.4	65.79%
Inner Mongolia	7611.3	6382	83.85%	24790.8	17717.1	71.47%
Anhui	7160.5	5556	77.59%	23524.6	15011.7	63.81%
Zhejiang	14551.9	10652.7	73.20%	37994.8	21545.2	56.71%
Henan	7524.9	5032.1	66.76%	21897.2	13733.0	62.72%

We can see that the per capita net income of farmers in major grain-producing areas is lower than the per capita total income of urban areas. Based on the per capita gross income of urban residents in the same region. And according to the same region with the level of urban and rural consumer prices, can calculate the relatively fair income level of farmers, the formula is as follows:

$$\frac{A}{B} \cdot T \qquad (7)$$

Where, A is the per capita consumption expenditure of farmers, B is the per capita consumption expenditure of cities and towns, and T is the per capita total income of cities and towns. The following table is obtained: Table 11.

Table.11 The theoretical per capita relative fair income of farmers in the same region in 2012(Unit: yuan)

Province	Per capita consumption expenditure of farmers	Urban per capita consumption expenditure	Urban-rural price ratio	Urban per capita gross income	Rural per capita net income	Farmer theory per capita relative fair income
Jilin	6186.2	14613.5	42.33%	21659.6	8598.2	9186.51 (+570.31)
Beijing	11878.9	24045.9	49.40%	41103.1	16475.7	20304.93 (+3829.23)
Shanghai	11971.5	26253.5	45.60%	44754.5	17803.7	20408.05 (+2604.35)
Guangdong	7458.6	22396.4	33.3%	34044.4	10542.8	11336.79 (+793.99)
Inner Mongolia	6382	17717.1	36.02%	24790.8	7611.3	8929.65 (+1318.35)
Anhui	5556	15011.7	37.01%	23524.6	7160.5	8706.45 (1545.95)
Zhejiang	10652.7	21545.2	49.44%	37994.8	14551.9	18784.63 (+4232.73)
Henan	5032.1	13733.0	36.44%	21897.2	7524.9	7979.34 (+454.44)

It can be seen that the per capita net income of farmers in the main grain-producing areas is lower than the per capita total income of cities and towns. On this basis, it is more reliable to calculate the theoretical per capita relative fair income of farmers by referring to the ratio of urban and rural consumer price levels.

Then, we can calculate the relatively fair income level of farmers in the main grain producing areas based on the per capita relative fair income of farmers in the main grain producing areas and compare it with the inter-regional consumer price level. The formula is as follows:

$$\frac{C}{D} \cdot S \qquad (8)$$

Where, C is the per capita consumption expenditure of farmers in major grain producing areas, D is the per capita consumption expenditure of farmers in major grain marketing areas, and S is the theoretical per capita relative fair income of farmers in major grain marketing areas. Get the following table: Table 12

Table.12 The per capita income of farmers in major grain-producing areas in 2012 should be relatively fair (Unit: yuan)

Province	Per capita consumption expenditure of farmers	The price of production and marketing of farmers	Farmer theory per capita relative fair income	With Jilin farmer per capita actual income contrast difference
Jilin	6186.2	--	9186.51	--
Guangdong	7458.6	58.07%	11336.79	+804.53
Beijing	11878.9	82.94%	20304.93	+1976.61
Shanghai	11971.5	52.08%	20408.05	+1946.64
Zhejiang	10652.7	51.67%	18784.63	+2310.03

According to the above calculation, we find that there are income gaps between urban and rural areas in both main grains producing areas and main grain selling areas. In order to achieve fairness, farmers should be compensated to different degrees.

3.5.3 Scenario 3: Optimize for sustainability

Adjust the indicators related to environmentally sustainable development in the model. The sustainable development of the environment means to leave a good ecological environment for future generations on the premise of meeting the development needs of the present people. According to China Statistical Yearbook 2019, we know the existing forest area in China, the amount of chemical fertilizer applied and the carbon dioxide emissions generated in the process of grain processing and transportation. According to the suggestions of experts, the carbon dioxide emissions have been quantified. The data of relevant indicators are shown in the figure below. At the same time, the existing data from 2016 to 2019 are used to forecast by using the ARIMA (1, 1, 0) model, and then the forecast data for 2020-2030 are obtained.

Table.13 Forecast data for 2020-2030

Year	Forest area about China (Unit: Hectares)	Fertilizer application amount (Unit: Ten thousand tons)	Carbon dioxide emissions from food (Unit: One million tons)
2016	22186.36	5403.59	13.35
2017	22186.36	5653.42	61.69
2018	22186.36	5653.42	67.94
2019	22186.36	5403.59	2734.33

Through the forecast data, my team found that with the increase of years, although the forest area increased, the amount of chemical fertilizer and grain-related carbon dioxide emission level remained at a relatively high level. The predicted data were put into Vensim5.6 simulation to finally get the annual environmental carrying capacity. The analysis showed that the annual environmental carrying capacity increased slightly and gradually approached the theoretical limit of environmental carrying capacity, which was roughly the same as the predicted value trend of the existing grain system oriented by efficiency and profit.

Therefore, we believe that on the premise that other conditions remain unchanged by default, indicators related to environmentally sustainable development in the model should be optimized, and the value of the indicators should be reduced by reducing the application of chemical fertilizer and artificial afforestation, so as to occupy a low weight in the final model.

3.6 Optimal order of change

As shown in the above three scenarios, each scenario represents in the case of other parameters constant, change one of the parameters, based on this we use the fuzzy analytic hierarchy process (AHP), to calculate the rule layer relative to the total target weights of W_D, then use the same method to calculate index X_1, X_2, X_3on weights of criteria B_1 ,W_{B1}, indexX_1, X_2, X_3 on weights of criteria B_2,W_{B2}, calculated the change of the optimal sequence, tectonic W_B weights of indexes of criterion layer, calculate the n by the normalization processing proposed schemes to get the parameter values of The weights and index values obtained from these calculations were used to calculate the comprehensive evaluation value of each scheme, $S = YW_B W_A$. The comprehensive evaluation value was ranked from the largest to the smallest, and the scheme with the largest comprehensive evaluation value was the optimal scheme.

The optimal scheme is as follows:

First of all, when we increase financial investment in rural areas through compensatory policies, on the one hand, we will intensify efforts to control pollution in rural areas and on the other hand, improve the level of scientific and technological innovation in rural areas. This not only ensures food security, but also improves environmental sustainability.

At the same time, in the treatment of pollution should also focus on improving the farmers in the production of food environmental protection awareness, improve the utilization rate of water resources, reduce water pollution, avoid the waste of water phenomenon.

Then, through the compensation of individual farmers' wages, the per capita income of farmers will be increased, the income gap between urban residents and rural residents will be reduced, and the social equity will be improved. Thus, the number of farmers will be increased, the labor force will be increased, and the grain reserve will be increased. This series of compensatory investment will reduce the capital investment in other aspects in the whole region, affecting the current economic development and slowing down the level of economic growth.

How long it will take for each country to implement a fair and sustainable system is now projected.

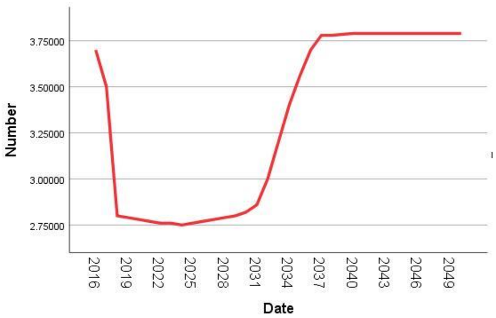

Figure.14 America

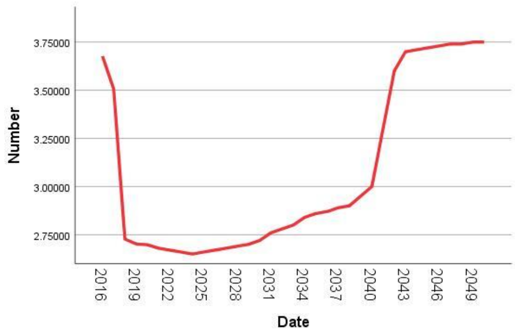

Figure.15 China

As the chart shows, assuming that countries start to make the transition in 2021, it will theoretically take China at least 30 years to do so using SPSS projections. In the US it takes 20 years.

3.7 Model checking and sensitivity analysis

First of all, we make $\overline{w}_j$ $(j = 1,2,..,6)$as the original weight coefficient and $\sum_{j=1}^{11} \overline{w}_j = 1$, X_i for solution on the index j i original value after normalization, assuming that $\overline{w}_r$ into w_r, only cause $\overline{w}_s$ into w_s, while other $\overline{w}_j$ are constant, then $\overline{w}_r + w_r = \overline{w}_s + w_s$, when w_s and w_r values to make the optimal scheme and time equal to the optimal scheme of comprehensive evaluation, we call the weight of the weight. The marginal weight can be calculated by the following formula:

$$\begin{cases} W_r' = \overline{w_r} - \frac{f(\bar{s}_p) - f(\bar{s}q)}{[\overline{x_{pr}} - \overline{x_{qr}} - (\overline{x_{ps}} - \overline{x_{qs}})]} \\ W_s' = \overline{w_s} - \frac{f(\bar{s}_p) - f(\bar{s}q)}{[\overline{x_{ps}} - \overline{x_{qs}} - (\overline{x_{pr}} - \overline{x_{qr}})]} \end{cases} \quad (9)$$

It can be seen from the hierarchical model of grain evaluation established in this paper that, when carrying out sensitivity analysis on the weight of index layer relative to criterion layer, because each criterion layer has a weight relative to the total target layer, the calculation formula of its marginal weight should be adjusted as:

$$\begin{cases} W_r' = \overline{w_r} - \frac{f(\bar{s}_p)-f(\bar{s}q)}{[\overline{x_{pr}}-\overline{x_{qr}}-(\overline{x_{ps}}-\overline{x_{qs}})]w_{B_k}} \\ W_s' = \overline{w_s} - \frac{f(\bar{s}_p)-f(\bar{s}q)}{[\overline{x_{ps}}-\overline{x_{qs}}-(\overline{x_{pr}}-\overline{x_{qr}})]w_{B_k}} \end{cases} \qquad (10)$$

Where, w_{B_k} is the weight of the criterion layer relative to the total target A

Analysis of marginal weight can be obtained, if:

1. When neither W_r' nor W_r' belongs to, it indicates insensitivity;
2. $|\overline{w}_r - W_r'| = \delta$ the delta as the delta is less than a tolerance, it is a sensitive weighting[5].

Here, we use the weight index to carry out sensitivity analysis on the three indicators of chemical fertilizer application amount, forest area and greenhouse gas emissions under the environmental system. First of all the weight of the target of total to criterion layer and then calculate a scheme attribute values of relative criteria, plug 9 type obtained optimal solutions and suboptimal equal marginal weight and the integrated evaluation, reoccupy 10 type to sensitivity analysis layer weights are calculated the optimal solutions and subprime index, relative criterion the marginal weight of environmental system, through calculation and analysis, marginal weight in each group, there is a number greater than 1, negative or up, or marginal weight are not the actual weight allowed values within the scope of known the above three weight are not sensitive to weight.

4. "Food - Water - Energy - Economy - Society" PSR Model

System dynamics can combine qualitative and quantitative, construct the basic structure of the total system from the microstructure of the total system, and then analyze and simulate the dynamic behavior of the system.

We divide the total system into five interrelated subsystems, which can be described by a set of state variables that change over time, as

$$X = (x_1, x_2, x_3, x_4, x_5) \qquad (11)$$

The subsystem is a first-order feedback loop, which includes rate variables, state variables and auxiliary variables. It is a multivariate first-order differential equation. The future development of the system depends on the initial conditions and its own structure, as

$$C, f(x, c, t) \qquad (12)$$

Food, water and energy are the material bases necessary for human survival and development [6]. In order to better study the food system oriented by fairness and sustainability, we introduce the "Food - Water - Energy - Economy - Society" PSR model to analyze. Food is inextricably linked to water, energy, economy and social systems, and the relationship between them is shown in the figure 16.

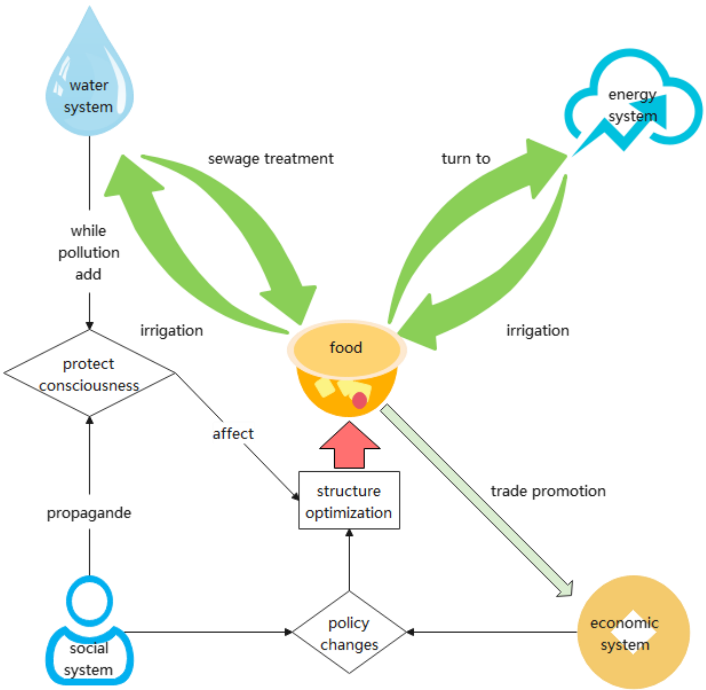

Figure.16 System diagram

Water is used to irrigate crops, and the resulting sewage is returned to the water system. Growing food requires energy, and food can be turned into energy through a series of processes. Food trade can promote economic development, bring social progress and human prosperity. When energy is in short supply, the social system can reduce the waste and pollution of resources and optimize the structure of resource utilization through policy adjustment. When water resources are scarce or polluted, social systems can promote environmental awareness and adjust industrial structure through publicity.

Assumptions

- Grain can replace each other, among which the proportion of grain in grain is the largest.
- Water resources are used only for food irrigation and domestic water.
- The industrial use of grain is mainly for fermentation, such as the production of wine.
- We believe that energy sources can be substituted with each other.

4.1 Dynamic model construction of subsystem

4.1.1 Grain subsystem model

（1）Grain reserves. The calculation method is as follows：

$$\frac{A}{B \cdot e^{-\frac{t}{n}} + C} \qquad (13)$$

where A, B and C represent coefficients and t represent years.

（2）Industrial grain usage. The calculation method is as follows:

$$B \cdot P \qquad (14)$$

where B represents the coefficient, and P is the amount of the product used in the industry for fermentation.

（3）Water-saving awareness. The calculation method is as follows:

$$\frac{B}{C \cdot e^{-\frac{m}{n}} + D} \qquad (15)$$

where m stands for publicity intensity. With the increase of publicity intensity, the awareness of water saving will be strengthened along with the development of science and technology and the spread of the network. However, there is an upper limit, and the process conforms to the change characteristics of the Logistic equation. B, C and D represent coefficients.

4.1.2 Economic subsystem model

（1）Farmers' per capita net income. The calculation method is as follows:

$$\frac{I - O - T}{N} \qquad (16)$$

where I is the total income of the region, O is the total expenditure, T is the local government tax, and N is the local farmer population.

（2）Economic growth rate. The calculation method is as follows:

$$\frac{N - L}{L} \qquad (17)$$

where L is the level of the economy last year, and N is the current level of the economy.

4.1.3 Social subsystem model

（1）Natural population growth rate. The calculation method is as follows:

$$\frac{B - D}{A} \qquad (18)$$

where B is the number of births in A year, D is the number of deaths in A year, and A is the average annual population.

（2）The supply of labor. The calculation method is as follows:

$$\frac{\Delta S}{S} \div \frac{\Delta W}{W} \qquad (19)$$

where $\Delta S/S$ is the percentage change in quantity supplied，$\Delta W/W$ is the percentage change in wages.

4.1.4 Energy subsystem model

（1）The amount of energy a person can consume. The calculation method is as follows:

$$17 \cdot P + 37 \cdot F + 17 \cdot C \qquad (20)$$

where P is the mass of protein, F is the mass of fat, and C is the mass of carbohydrate, both in grams, and the energy unit obtained is kilojoules.

（2）Energy extraction. The calculation method is as follows:

$$A \cdot N + B \cdot T + C \cdot V \qquad (21)$$

where A, B and C are coefficients, N is the number of people employed in various energy sources, T is the investment in science and technology, and V is the investment in fixed assets.

4.1.5 Water resources subsystem model

（1）Water consumption for irrigation. The calculation method is as follows:

$$A \cdot S + W \qquad (22)$$

where A is the irrigation water required per square hectare, S is the land area, and W is the water wasted in irrigation.

（2）Domestic water. The calculation method is as follows:

$$L_{country} + L_{city} - L_{save\ water} \qquad (23)$$

where $L_{country}$ is domestic water consumption in rural areas， L_{city} is urban domestic water consumption, $L_{save\ water}$ is the amount of water saved.

4.2 Validation of the benefits and costs of changing priorities

We still take China as an example, and according to the hypothesis put forward previously, variables are substituted into the corresponding subsystem, in which the various factors interact and feedback, thus affecting the whole system. We put the variables into the formulas of each subsystem, and the results are analyzed as follows: when we increase the financial investment in rural areas through compensatory policies, on the one hand, we will intensify the efforts to control pollution in rural areas, on the other hand, we will improve the level of scientific and technological innovation in rural areas. This not only ensures food security, but also improves environmental sustainability. At the same time, in the treatment of pollution should also focus on improving the farmers in the production of food environmental protection awareness, improve the utilization rate of water resources, reduce water pollution, avoid the waste of water phenomenon. Then, through the compensation of individual farmers' wages, the per capita income of farmers will be increased, the income gap between urban residents and rural residents will be reduced, and the social equity will be improved. Thus, the number of farmers will be increased, the labor force will be increased, and the grain reserve will be increased. This series of compensatory investment will reduce the capital investment in other aspects in the whole region, affecting the current economic development and slowing down the level of economic growth. This conclusion also verifies the correctness of the multi-factor model mentioned above.

5. Scalability and Adaptability of The Model

The model established this time is mainly for the analysis and prediction of the country, but the scope of application of the model can be further narrowed, such as the grain system of a state in the United States or a province in China, as long as the statistical data of that state or province is collected, and the evaluation value can be obtained。

The preliminary establishment of the model is based on the data of China, but it is also applicable to other regions. No matter the three system levels or the 11 factor indexes of the fuzzy comprehensive multi-factor analysis method, there is a strong correlation for the grain system of any region. At the same time, there is no special case index in the index, so it also has strong applicability and reference value for other regions.

Extended our multi-factor-based food system evaluation model to the whole world, we obtained that the total score of the global food system is 2.78029, at the basic safety level, and there is a downward trend, indicating that the existing efficiency and profit-oriented food system is in a safe state as a whole, but it is increasingly dangerous. According to our projections, it is difficult for the world to achieve the goal of zero hunger by 2030. Moreover, under such trends, the number of hungry people in 2030 is likely to exceed 830 million. "Hidden hunger" is also a thorny issue, with data showing that 21.3 percent of children under the age of five were stunted and 6.9 percent were underweighted in 2019.The global food security situation is critical, so we need to transform the food system to minimize the number of people who do not have enough income to have access to healthy food, while ensuring that the production and consumption of food is environmentally sustainable. Our aim is to reduce the cost of nutritious food and provide decent income for those involved in food production, strengthen the food security situation and focus on the sustainability of the food system. To each country of the world, the governor should formulate corresponding measures according to their own specific situation, in order to realize the transformation of the food system.

Governments around the world need to adjust agricultural policies and create incentives for food producers, increase investment in food security, and focus on reducing "hidden hunger" and improving the mix of crops grown. Now is given priority to with high efficient production and distribution of food, giving priority to efficiency and profitability of food system is unfair and unreasonable phenomenon is not conducive to ecological protection, we need from the overall demand, the benefit of farmers, resources and environment conditions into consideration, such as based on people's health, sustainable development of human and the nature harmonious Angle analysis, guarantee food security, science and technology innovation is undoubtedly the most important factor. In the long run, agriculture still depends on science and technology. Countries around the world need to invest more money in agriculture at the cost of delaying economic development, spend more energy on increasing farmers' economic income and improving the status of the primary industry, and also need more scientists and technicians to participate in the process to improve the scientific and technological level of agriculture.

Global food production is geographically concentrated, and human dependence on four key crops makes today's food systems vulnerable to climate change. After the outbreak, we realized that the concentration of global food production is very bad for the stability of the food system. Sixty percent of the world's food production is in just five countries: China, the United States, India, Brazil and Argentina.[7] Within these countries, food production is also highly concentrated. Extreme weather in these regions could severely affect food production around the world. So, we need to diversify the areas where food is grown to make the global food system more stable. At the same time, we should also increase grain reserves. Food stocks represent the capacity of the global food system to cope with food production shortfalls, and while current levels of food stocks are high, they are insufficient after the outbreak. So we need countries around the world to increase their levels of food storage.

6. Conclusions

To sum up, the stability of the food system is not caused by any single factor. Instead, it is an interdisciplinary question, made up of a range of factors.

Our model focuses on raw data and data analysis. Energy, social, and economic factors are also considered for the evaluation and optimization based on the evaluation results. Although the model cannot account for all of these factors, it uses a representative cross-section of available data to show the current state of the food system. Our model shows that the current economic and efficient-oriented food system is not sustainable in the long run, while the optimized sustainable development and equity-oriented system is more conducive to human survival and sustainable development. Therefore, in the future development process, the food system should be changed from the benefit and efficiency oriented approach to the environmentally sustainable development and equity oriented approach, which will help developing countries to improve the degree of environmental damage to a certain extent, and also help developed countries to maintain a high ecological level.

Finally, we offer some suggestions for the food system under the epidemic.

We sincerely hope that our models, results, and recommendations provide valuable information.

7. Strength and Weakness

7.1 Strength

- The model uses accurate data from the government, which is rigorous and reliable, and the research results have high reference value.

- The multi-factor method based on fuzzy comprehensive evaluation fully considers the potential relationship of each evaluation object, the evaluation value of each level and many factors on each level, which reduces the subjectivity of the analytic hierarchy process.
- PSR model can reflect the pressure from human activities, the system state and the response of human, can qualitative quantitative analysis of health food system, from the time scale of the selection of food system stability index for dynamic evaluation, apply more extensive, compared with the traditional evaluation system more practical and operability.

7.2 Weakness

- The multi-factor method based on fuzzy comprehensive evaluation requires each index or each factor to determine the membership degree of the grade, and the process is complicated
- Neither of the two models takes into account the influence of irresistible factors, such as major disasters, wars, financial crises, etc., while the model cannot accurately evaluate the impact of the new epidemic in 2020 if it takes into account the impact of the new epidemic in 2020
- We did not include all the factors that could affect the stability of the food system, so our analysis was biased

8. Optimization of Food System Evaluation Model under Epidemic Situation

The impact of the new global pandemic is multifaceted, such as a shrinking global economy, falling per capita income, and increasing poverty, and affects food systems and nutritional security in multiple ways.[8] According to the Global Food Crisis Report 2020, a total of 135 million people is facing acute and severe food insecurity in 2019, and 55 countries and regions are at the stage of crisis or worse. Africa has the highest number of people in acute and severe food insecurity, followed by the Middle East and Asia. People in a severe food crisis face severe malnutrition or irreversible effects throughout their lives, even death.

8.1 The impact of the outbreak on global food

1. Exacerbate existing levels of malnutrition and increase the risk of malnutrition

Outbreak of the new champions league in addition to directly affect people's health, also indirectly worsened global nutritional status, especially in health, food and social protection of vulnerable countries and regions [9] travel restrictions that affect the consumer demand to meet, and reduced the grain transport between countries in the region, the dependence on imported grain region or country food prices rise, people's healthy diet affordability is reduced, the resulting negative effects on the nutritional intake and diet quality, increase the risk of malnutrition。

2. It disrupted the global food supply chain

Production of major food crops was not affected by the Covid-19 outbreak, and there were no serious food shortages, but the supply chain of the food system around the world was severely disrupted as a result. The resulting economic slowdown leads to a reduction in the demand for jobs and labor, which has a serious impact on the income of the poor people around the world, reduces their food purchasing power, and impacts on food nutrition security and food security.

8.2 Advice

Considering the above situation, we optimized the food system evaluation model and added an emergency stabilization system (figure 17). Among them, the indexes include the fluctuation level of grain price, the total grain reserves and the national stress level, in which the national stress level is judged by the response capacity of each region.

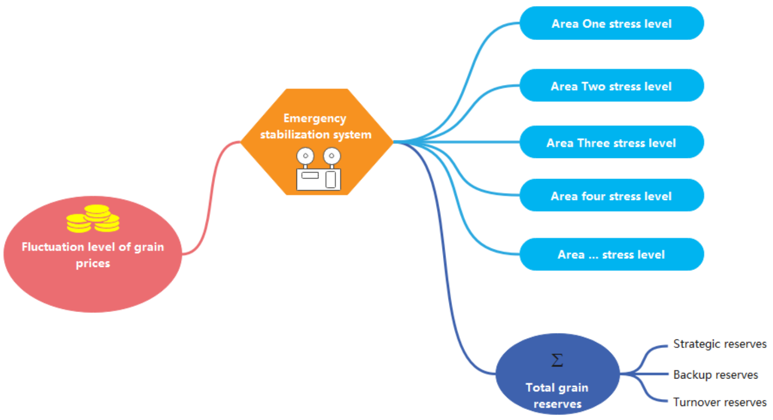

Figure.17 Emergency system description diagram

Based on the calculation method of the previous model, we calculated the score as China >Global >The United States, we therefore make the following recommendations:

1. The global governance system should enhance the voice of developing countries

In the current global governance pattern, developing countries are often in a state of "aphasia". Although the influence of developing countries is gradually rising, it is still dominated by western countries with a very strong historical inertia [10]. The food security system and its related contents are affected by global governance, and the imbalance of food security assessment reflects the imbalance of the global governance system. In order to achieve better food governance and even global governance, special attention should be paid to developing countries in global governance.

2. We should give full play to the function of the grain evaluation system

In general, the food evaluation system can play a guiding role for the improvement of the food system in the world's regions and countries, and can objectively evaluate the advantages and disadvantages of different status and countries in the food system, which has a good reference value for the sustainable development of human beings and the protection of the ecological environment. The results show that although various evaluation systems are being improved, they still do not play a full role. We should update the global information system in a timely manner. In particular, countries facing serious food security problems should have the latest and most realistic data, and the world should agree on food system evaluation indicators. We should not only consider the global average, but pay more attention to the specific situation of each region and country.

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10. Appendix

Code:

```
mux=input('mux=');
[n,n] = size(mux);
[V,D] = eig(mux);
M = max(max(D));
[r,c]=find(D == M , 1);
disp('Result is：');
disp( V(:,c) ./ sum(V(:,c)) )
CI = (M - n) / (n-1);
RI=[0 0.0001 0.52 0.89 1.12 1.26 1.36 1.41 1.46 1.49 1.52 1.54 1.56 1.58 1.59];
CR=CI/RI(n);
disp('CI=');disp(CI);
disp('CR=');disp(CR);
if CR<0.10
    disp('success');
else
    disp('default');
end
```