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Research on "Zero Hunger" Based on AHP and TOPSIS Model

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Abstract: To produce more food and maintain or even improve our environmental health, this paper put forward a strategy called "zero hunger" policy by building a better food system is the only way. In order to ensure the fairness of food distribution, the analytic hierarchy process is used to form a one-to-many agricultural cooperative relationship between the food supplier and the food recipient by taking the main grain yield, the transportation cost and the crop category as the criterion layer. Finally, based on the TOPSIS model, this paper build a prediction model of priority factors in grain system.

1. Introduction

Although the efficiency of the current global food systems is high, the main productivity is controlled by agricultural powers and international food producers and distributors. Although there is enough food to feed everyone in the world, uneven distribution causes instability in the food system. There are still 8.21 million people suffering from hunger in the world, and people with food insecurity can’t afford enough nutrients. At the same time, human abuse of the environment has led to the increase of greenhouse gas emissions, the loss of biodiversity, deforestation and the occupation of freshwater resources and other environmental impacts. These factors urge us to rebuild and update the current food system.

2. National Distribution Model

When the GHI score is below 35 and above 20, it can be regarded as severe hunger. The intervals of 35-49 and above 50 indicate vigilance and extreme vigilance respectively. In 2017, the total GHI score of all countries is 8, which belongs to the "severe" level. In 119 countries, 52 are still at the levels of "severe", "alert" and "extreme alert".

Table 1: GHI scores by Region

Area	score
South Asia	30.9
Sub-Saharan Africa	29.4
Near East and North Africa	12.8
East and Southeast Asia	12.6
Latin America and the Caribbean	8.4
Eastern Europe and CIS	7.8

We select 52 countries with GHI index below "severe" level in 2019 as food receiving countries.

The entropy weight method is used to calculate the weight of food supplier.

We choose the top 20 countries with the highest per capita grain output and the total grain output higher than the world average in 2019 as food suppliers. They have the least hunger pressure and most of the grain is used for export. In 2019, the global grain output will be about 2.722 billion tons. According to 7.7 billion people, the per capita grain output will be about 350 kg.

Entropy weight method as an objective weight method, according to the information provided by the data of each index to determine the weight of the index, the smaller the degree of variation of the index, the less the amount of information reflected, the corresponding weight should also be lower (objective = the data itself tells us the weight).

First, calculate the proportion of the j-th indicator in the i-th country.

$$p_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}}, i = 1, \ldots n, \ j = 1, \ldots, m \tag{1}$$

- Represents the serial number of the country.
- Represents the serial number of four indicators.
- Refers to the value of the corresponding index.
- Represents the number of countries, which is equal to 119 in our model.

Then we get the information entropy of the j-th index:

$$E_j = -\ln(n)^{-1} \sum_{i=1}^{n} P_{ij} \ln p_{ij} \tag{2}$$

So, we can get the weight of the j-th index.

$$w_j = \frac{1 - E_j}{k - \sum E_j} (j = 1, 2, 3) \tag{3}$$

Where is the index number, which is equal to 3 in our model.

Finally, the weight of these three indicators is obtained, as shown in the table.

Table 2: weight of indicators

index	weight
per capita grain output	0.45
per capita DGP	0.32
per capita arable land area	0.33

The per capita grain production is highly weighted, which is in line with the expectation of our team. As per capita grain production is the basic index of life support, the weight structure is reliable.

According to the data of the three indicators of these 119 countries, and given the weight, we can calculate the weight of each country's food supply, and get the score and ranking of these 119 countries. Then we select data from the top 20 countries. We believe that these 20 countries should act as food suppliers to meet the food needs of food receiving countries, and reach one-to-one or one to many or even many to many agricultural cooperative partnership with food receiving countries.

3. Partner Selection by AHP

Since there are 52 food receiving countries and 20 food supplying countries, we can't form an agricultural cooperative partnership through one-to-one distribution. There must be one to many or even many to many situations. We choose analytic hierarchy process (AHP) to solve this problem. AHP can combine qualitative analysis with quantitative analysis to solve complex multi-objective problems. We use the experience of decision-makers to judge the relative importance of the standards to measure whether the objectives can be achieved or not, and reasonably give the whole book of each standard of each decision-making scheme, and use the weight to find out the priority of each scheme.

3.1 Establish Hierarchical Structure Model

As the GHI index of food receiving countries is at or below the "serious" level, let's assume that: The level of hunger in 52 food receiving countries was equal.

In this model, we choose the grain supplier as the target layer, the main grain yield, grain transportation cost and crop type as the criterion layer, and the scheme layer is 20 grain suppliers.

3.2 Construct Judgment Matrix

We believe that the importance of major grain production is greater than the transportation cost of grain, and greater than the category of crops. As the grain output directly affects the number of hungry people in the food receiving countries, the main grain output is of the highest importance, and the grain transportation cost directly relates to the economic benefits and affects the agricultural trade between the two countries, so it is more important than the crop category. The judgment matrix is as follows:

$$A = \begin{array}{c} C1 \\ C2 \\ C3 \end{array} \begin{bmatrix} 1 & 1/3 & 1/5 \\ 3 & 1 & 1/3 \\ 5 & 3 & 1 \end{bmatrix} \tag{4}$$

3.3 Hierarchical Total Ranking and Its Consistency Test

According to this, the relatively important weights of the criterion layer and the scheme layer for the target layer are calculated.

The three factors in the criterion layer are mainly grain yield, grain transportation cost and main crop category, and the order of selecting grain supply country is.

The ranking of the 20 items in the scheme layer to the factors in the criterion layer is.

The total ranking of the scheme layer (that is to say, the weight of the ith project in the scheme layer to the total goal is) is:

$$
\begin{aligned}
&B_1 : a_1 b_{11} + a_2 b_{12} + a_3 b_{13}, \\
&B_1 : a_1 b_{21} + a_2 b_{22} + a_3 b_{23}, \\
&\ldots \\
&B_{20} : a_1 b_{201} + a_2 b_{202} + a_3 b_{203},
\end{aligned}
\tag{5}
$$

The consistency ratio is $CR = \dfrac{a_1 CI_1 + a_2 CI_2 + a_3 CI_3}{a_1 RI_1 + a_2 RI_2 + a_3 RI_3}$, When $CR < 0.1$ it is considered that the total ranking of hierarchy has passed the consistency test.

Finally, the agricultural cooperation relationship between food supplier and food recipient countries is obtained.

4. Priority Change Model of Food Systems

From the above analysis, we can see that the existing food system takes food production as the highest priority, but with the increasing environmental pollution, the development of sustainable agriculture is more urgent. Therefore, our team proposed to change the priority of the food system based on the existing food system. We used to increase the weight of sustainable development factors in the output and analyzed the output of the changed system.

Based on the ranking of the global GHI index, we selected four representative countries with GHI scores at different stages, Belarus (<5.0), Suriname (10.2), Nepal (20.0), and Madagascar (36.0). We collected data on pesticide use, fertilizer use, arable land area, and grain production in these four countries from 1961 to 2018.

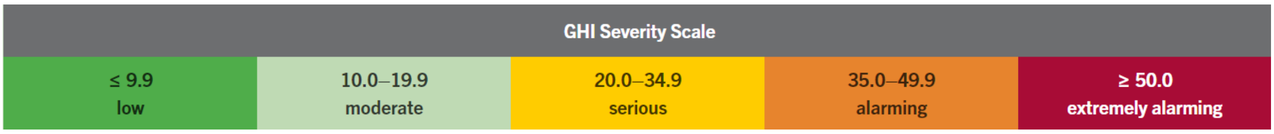

Figure 1: GHI Severity Scale

The data of each country is analyzed.

Step 1: Forward the original matrix.

Step 2: Normalize the forward matrix.

Step 3: Calculate the score and normalize it.

From this we can calculate the unnormalized score of the i-th (i = 1, 2, ... , n) evaluation object as:

$$S_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

Obviously, 0≤Si≤1, and the larger the Si, the smaller the, that is, the closer to the maximum. Regarding the maximum and minimum values, if the maximum and minimum values are maintained, the results obtained by this formula are the same, so there may be insensitivity.

When we prioritize environmental factors first, according to the TOPSIS model prediction results, the United States, which was originally rated as A, will continue to be rated A after considering the most important environmental factors. For Mauritius, when priority is given to sustainable development policies, it has changed from a B-level country that can guarantee national food supply to a C-level country that lacks food supply capacity.

Through correlation analysis, we found that these factors have a strong correlation with grain production. Combining with the world's existing grain system, we can know that all countries are maximizing grain production to ensure their own economic interests.

Based on the consideration of environmental protection, many developed countries have gradually regarded sustainable development as the focus of agricultural development while having sufficient food supplies. In order to predict the impact of countries on agricultural economic benefits after considering the implementation of sustainable development policies. Our team adopted the TOPSIS model and selected a developed country and a developing country to predict the economic benefits of agriculture.

Among them, we selected the United States and Mauritius as representative countries, and selected the pesticide use, fertilizer use, arable land area, total grain output, food import volume, and per capita GDP in the two countries. The TOPSIS model is used to predict the result is divided into four levels, that is:

A: Countries with sufficient food production or the ability to import large amounts of food. GHI<9.9.

B: Countries that basically guarantees food supply. 10.0<GHI<19.9.

C: Countries with insufficient food supply capacity. 20.0<GHI<34.9.

D: Countries with extreme food shortages. GHI>35.0.

We regard the four countries of Belarus (<5.0), Suriname (10.2), Nepal (20.0), and Madagascar (36.0) as the representative countries of the four levels of A, B, C, and D, and the insecticide of these four countries The 6 indicators of the amount of pesticides, fertilizers, arable land, total grain output, grain imports, and GDP per capita are used as reference quantities for each level.

Take Suriname, a country with a GHI score between medium and low hunger as an example. Suriname has a GHI score of 10.2. Its total grain output reached 274,001 tons in 2018 and has been increasing since 1961. At the same time, the use of chemical fertilizers has also increased year by year. , Reached the highest of 12417.12 tons in 2017.

Correlation analysis shows that the amount of fertilizer used, land area and yield are directly proportional, and there is a strong correlation. The land area is more important. From the perspective of stability, to ensure the sustainability of the agricultural system, it is first necessary to ensure sufficient yield. In countries with high levels of hunger, priority can be given to increasing the yield per unit area by increasing the use of chemical fertilizers and pesticides. Areas with relatively low levels of hunger should pay more attention to land pollution caused by the use of chemical fertilizers and pesticides. For all countries, it is very important to ensure the area of arable land. The size and quality of arable land are directly related to grain output.

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