Research on Intelligent Evaluation Model of Global Food System Using Analytic Hierarchy Process with Statistics and Calculations

Xiaoxuan Jiang*, XinNing Li, YiFan Zuo
College of Information, Mechanical and Electronic Engineering, Shanghai Normal University, Shanghai 201400

*Corresponding author: xiaoxuanjiang@shnu.edu.cn

Abstract. In order to cope with the instability of the current global food system, this paper established a global food system evaluation model and a global food system optimization model. We reimagine and determine the priority of the food system, conduct a comprehensive and reasonable assessment of the current food system, optimize it according to the current situation and predict the time required for the implementation of the system and the changes it will bring. We have established a global food system evaluation model. We begin with constructing a strict agreement-based global food system indicator system, consisting of 4 measurement dimensions and 21 indicators and their characteristics. (The four dimensions of the metrics are environment, society, food security and nutrition, and economy. The 21 indicators include 7 environmental indicators, 3 economic indicators, 3 social indicators, and 14 food and nutrition indicators) Next, depend on a large number of statistics and calculations, the Spearman correlation coefficient between the indicators is obtained. The Spearman correlation matrix is made to measure the correlation and correlation between the indicators. Then, we use the correlation as a reference to determine the weight of each indicator through the analytic hierarchy process and sort them.

1. Introduction
For a long time, countries around the world have made many efforts in the research of food systems. Each country has established its own unique evaluation system based on its own actual conditions, and regularly scores, ranks and classifies countries based on data and information which obtained through multiple channels. [1] These systems provide visual and comparable reference for the international community to understand the overall status of the global food system. [2]

However, various recent events have shown that the existing food system is very fragile even in well-served areas in the world, and the global food security situation is still very severe. Meeting the growing global population’s growing demand for nutritious food under climatic pressures, while mitigating related environmental damage, is already an urgent challenge. Because of the different actual conditions of each country, the establishment of a food evaluation system model for most countries is very difficult. However, according to data released by the Food and Agriculture Organization of the United Nations (FAO), in 2018, [3] the number of undernourished people worldwide reached 820 million, and more than 2 billion people were unable to stably obtain safe, nutritious and adequate food. In 2016, the total
number of chronically malnourished people. It is estimated to be about 815 million people (more than one-tenth).

In addition, the current food system leaves a huge environmental impact, accounting for 29% of greenhouse gas emissions. It has caused up to 80% of biodiversity loss, 80% of deforestation, and 70% of freshwater use. [4]

Therefore, it is vital to reimagine and define the global food system, and it is also urgently needed to conduct a comprehensive and reasonable evaluation and optimization of our current food system.

2. Global Food System Evaluation Model

We divide the establishment of the food system indicator system into a four-step process, using a consistent and repeatable method to determine the food system indicators. These four steps are shown in Figure 1.

![Figure 1. The four steps adopted to build the food system metric](image)

Firstly, we systematically search multi-disciplinary databases such as Google scholar, Scopus, JSTOR, etc. to identify relevant documents. We use the keyword "food system" to identify peer-reviewed articles, documents and reports, expert groups and international development agencies discussing food system indicators. In view of the relatively recent emergence and solidification of "food systems" as a clear research field, the search for publications is limited to the period from 2000 to 2020. 83 documents make up the output of the first step search.

A review of these 83 documents shows that in the literature related to the food system: ecology, economy, society, and food security and nutrition. The four dimensions are almost universally recognized. Although these four dimensions are complex and complex in nature, two of them (environmental dimension and food safety and nutrition dimension) are usually further decomposed into specific sub-dimensions. For the environment, the five most frequently mentioned sub-dimensions in the literature are: air, water, soil and land, biodiversity and energy. For food & nutrition, the sub-dimensions are: food security, food safety, food waste & losses, and nutrition. The four dimensions and the related nine sub-dimensions together constitute the first two levels of sustainability measures in the food system (the first two columns of Table 1).

The third level was subsequently added to the metrics. As with the higher levels of measurement, the selection of these categories comes from traditional recommendations in the literature. Therefore, in terms of food security, four traditional food security areas are included, namely: availability, accessibility, utilization, and stability. Regarding water, soil and land, they are classified into two categories ("quality" and "use"), while socially, the issues of equity, gender and inclusion seem to be widely accepted. There is less consensus on the category representing economic sustainability. In this study, we selected financial performance (creating added value), employment rate and economic inequality. Finally, nutrition was broken down into the traditional components of the triple burden of
diet and malnutrition, namely: undernutrition, overweight and obesity, and hidden hunger (micronutrient deficiency). The last column of Table 1 details these different categories. The system metrics are shown in Table 1:

Table 1. Metric of food system

| Dimensions        | Sub-dimensions               | Categories                                                                 |
|-------------------|------------------------------|---------------------------------------------------------------------------|
| Environment       | Air                          | Quality                                                                   |
|                   | Water                        | Quality                                                                   |
|                   |                               | Use                                                                       |
| Soils and land    |                               | Quality                                                                   |
|                   |                               | Use                                                                       |
| Biodiversity      |                               | Crops                                                                     |
|                   |                               | Wildlife (plants, animals)                                                |
| Energy            |                               | Use                                                                       |
| Economic          |                               | Financial performance                                                    |
|                   |                               | Employment rate                                                          |
|                   |                               | Economic distribution                                                    |
| Social            | Gender/Equity                |                                                                           |
|                   | Inclusion (international)    |                                                                           |
|                   | Inclusion (national)         |                                                                           |
| Food & Nutrition  | Food Security                | Availability                                                              |
|                   |                               | Access (affordability)                                                   |
|                   |                               | (Physical) accessibility                                                  |
|                   |                               | Utilization - water                                                       |
|                   |                               | Utilization - energy                                                      |
|                   |                               | Stability (economic)                                                     |
|                   |                               | Stability (supply)                                                       |
|                   | Food Safety                  | Safety                                                                    |
|                   | Food Waste and Use           | Loss and waste                                                            |
| Nutrition         | Diet                         |                                                                           |
|                   | Undernutrition               |                                                                           |
|                   | Overweight & obesity         |                                                                           |
|                   | Hidden hunger (micronutrient deficiency) |                                         |

After determining the four dimensions of the food system measurement, the next step is to fill in the indicators in each category. To this end, we obtained 192 different indicators through the preliminary list of indicators proposed in 83 documents. A refined and reasonable list of indicators is to use inclusion/exclusion criteria to solve the above conceptual issues, allowing each indicator to be recorded in a consistent and strict manner.

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The nine inclusion/exclusion criteria are as follows:

a. Cross correlation. The excluded index has a close cross relationship with another index already considered in the list. For example, "proportion of the population below the global poverty line" and "proportion of the population living below the poverty line" are closely related. We only keep one of these two indicators.

b. Relevance of concepts. The included indicators are obviously related to one of the four aspects of the metric, namely: ecology, economy, society and food and nutrition. See also the comprehensive indicator standards below.

c. Globally. Only include indicators that have a database of at least 70 countries.
d. Global validity. Excluded are indicators of processes specific to certain regions of the world. For example, the “percentage of agricultural land lost each year due to desertification” is excluded because desertification is a phenomenon that can only occur in certain regions of the world.

e. Time. Indicators that were excluded because the database only had data before 2000.

f. Potential variables. Exclude indicators based on latent variables. For example, "resilience" or "economic vulnerability" indicators are excluded because there is no agreed measure/unit of resilience or economic vulnerability.

g. A clear approach. For the excluded indicators, the method used to build the database was not clearly specified in the original database.

h. Single size index. The excluded indicators are based on "multidimensional" indicators, which are divided into two different measurement dimensions. For example, the “natural capital used/gross domestic product” ratio sometimes proposed in the literature is an indicator of sustainability, but it is not included because it is clearly between the environmental and economic levels.

i. Comparability. Excluded (or revised) indicators based on absolute numbers, these indicators do not allow comparisons between countries, for example, the total number of kilometers of paved roads is not included. Instead, we consider road density, which is the total number of kilometers of paved roads per 100 square kilometers of land area.

Finally, the entire global food system indicator system is shown in Table 2:

Table 2. Global food system indicator system

| Dimension          | Sub-dimension         | Category                | Indicators\(^{(a)}\)                      | SR\(^{(b)}\) | DP\(^{(c)}\) | Source                        |
|--------------------|-----------------------|-------------------------|------------------------------------------|--------------|--------------|-------------------------------|
| Environment        |                       | Quality                 | Greenhouse gas emissions in total agriculture (gigagrams) | –            | C            | FAO                           |
|                    |                       | Water                   | Water pH                                  | –            | C            | GEMSstat water quality database |
|                    |                       | Use                     | Agricultural water withdrawal as percentage of total renewable water (%) | –            | P            | FAO                           |
|                    |                       | Soil and land           | Soil carbon content (as percentage in weight) | +            | C            | FAO                           |
|                    |                       | Use                     | Agricultural land as % of arable land     | –            | C            | FAO                           |
| Biodiversity       |                       | Wildlife (plants, animals) | Benefits of biodiversity index (0 = no biodiversity potential to 100 = maximum) | +            | C            | The Global Environment Facility |
|                    |                       |                        | Crop diversity (calories diversity measured by Shannon index) | +            | C            | Khoury et al., 2016            |
| Energy             |                       | Use                     | Agriculture and forestry energy use as % of total energy | –            | P            | FAO                           |
| Economic           | Financial performance |                        | Agriculture value added per worker (constant 2010 US$) | +            | P            | The World Bank                 |
| Social             | Employment rate       |                        | Agriculture under-employment (%)         | –            | P            | International Labour organization - UN |
|                    | Economic distribution | Gini index for land distribution & tendency | –            | P            | GRAIN organization            |
|                    | Gender equity         | Labor force participation rate, female (% of female population ages 15+) | +            | P            | The World Bank                 |
|                    | Inclusion             | Predominant fair trade organizations and producers | –            | P            | Fairtrade International       |
|                    |                       | Employment in agriculture (% of total employment) | –            | P            | The World Bank                 |
| Food and Nutrition | Food Security         | Availability            | Per capita food available for human consumption (kcal/capita/day) | +            | C            | Dupos_GFSI source FAO         |
|                    |                       | Access                  | Food consumption as share of total income (% of total household expenditure) | –            | C            | Dupos_GFSI National Accounts, United Nations |
|                    |                       | Utilization             | Estimated travel time to the nearest city of 50,000 or more people (Hours travel from a city) | –            | C            | European Commission           |
|                    |                       | Stability               | Access to improved water resource (% of total population) | +            | C            | FAO                           |
|                    |                       |                        | Access to electricity (%)                 | +            | C            | The World Bank                 |
|                    |                       |                        | Price volatility index                    | –            | C            | FAO monthly CPI               |
|                    | Food Safety           | Per capita food supply variability (kcal/capita/day) | –            | C            | FAO                           |
|                    | Food waste and Use    | Food loss as % of total food produced | –            | C            | Dupos_GFSI source FAO         |
| Nutrition          | Diet                  | Diet diversification    | –            | C            | FAO                           |
|                    | Undernutrition        | Stunting, children aged < 5 years stunted (%) | –            | C            | WHO                           |
|                    | Overweight & obesity  | Prevalence of obesity (% of the population, over 18y of age) | –            | C            | WHO                           |
|                    | Hidden hunger          | Serum retinol deficiency | –            | C            | WHO                           |
3. Model Solutions

Spearman-correlation coefficient is also called Spearman's rank correlation coefficient, which is used to measure the correlation between two variables. The specific calculation method of Spearman's correlation coefficient $\rho$ is:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2-1)} \quad (1)$$

$n$: the number of samples

d: represents the level difference between the two sets of data

We collected a large amount of global data corresponding to each indicator in the indicator system by searching databases such as FAO, WHO, The World Bank, International Labour organization-UN, The Global Environment Facility, European Commission. Due to the large number of indicators and the large amount of data involved, we will not show all of our data in this article. We only intercept global data for some indicators during the period from 2000 to 2018, as shown in Table 3:

**Table 3. Data of some indicators from 2000 to 2018 (global)**

| Year | Indicator | 2000 | 2005 | 2010 | 2015 | 2020 |
|------|-----------|------|------|------|------|------|
| 2000 | Indicator 1 | 0.12 | 0.15 | 0.18 | 0.20 | 0.22 |
| 2005 | Indicator 2 | 0.13 | 0.16 | 0.19 | 0.21 | 0.23 |
| 2010 | Indicator 3 | 0.14 | 0.17 | 0.20 | 0.22 | 0.24 |
| 2015 | Indicator 4 | 0.15 | 0.18 | 0.21 | 0.23 | 0.25 |
| 2020 | Indicator 5 | 0.16 | 0.19 | 0.22 | 0.24 | 0.26 |

We calculated the Spearman coefficient between two indicators to describe the correlation between the indicators and measure the degree of correlation between the indicators. In view of the small sample (the number of samples is less than 30), we directly use the look-up table method to perform the Spearman correlation coefficient hypothesis test, as shown in Table 4:

When the correlation coefficient is greater than or equal to the critical value in the table, the correlation coefficient is significantly different, that is, there is correlation, and the correlation is not 0.

**Table 4. Spearman correlation coefficient hypothesis test table**

| n   | The significance level of a single tail test | The significant level of a two-tailed test |
|-----|--------------------------------------------|------------------------------------------|
|     | 0.05                                      | 0.025                                     | 0.0125                                    | 0.0025                                    |
| 1   | 0.500                                    | 0.500                                     | 0.500                                     | 0.500                                     |
| 2   | 0.450                                    | 0.450                                     | 0.450                                     | 0.450                                     |
| 3   | 0.410                                    | 0.410                                     | 0.410                                     | 0.410                                     |
| 4   | 0.370                                    | 0.370                                     | 0.370                                     | 0.370                                     |
| 5   | 0.335                                    | 0.335                                     | 0.335                                     | 0.335                                     |
| 6   | 0.301                                    | 0.301                                     | 0.301                                     | 0.301                                     |
| 7   | 0.265                                    | 0.265                                     | 0.265                                     | 0.265                                     |
| 8   | 0.233                                    | 0.233                                     | 0.233                                     | 0.233                                     |
| 9   | 0.202                                    | 0.202                                     | 0.202                                     | 0.202                                     |
| 10  | 0.173                                    | 0.173                                     | 0.173                                     | 0.173                                     |
| 11  | 0.147                                    | 0.147                                     | 0.147                                     | 0.147                                     |
| 12  | 0.124                                    | 0.124                                     | 0.124                                     | 0.124                                     |
| 13  | 0.103                                    | 0.103                                     | 0.103                                     | 0.103                                     |
| 14  | 0.085                                    | 0.085                                     | 0.085                                     | 0.085                                     |
| 15  | 0.068                                    | 0.068                                     | 0.068                                     | 0.068                                     |
| 16  | 0.052                                    | 0.052                                     | 0.052                                     | 0.052                                     |
| 17  | 0.037                                    | 0.037                                     | 0.037                                     | 0.037                                     |
| 18  | 0.025                                    | 0.025                                     | 0.025                                     | 0.025                                     |
| 19  | 0.013                                    | 0.013                                     | 0.013                                     | 0.013                                     |
| 20  | 0.008                                    | 0.008                                     | 0.008                                     | 0.008                                     |
| 21  | 0.005                                    | 0.005                                     | 0.005                                     | 0.005                                     |
| 22  | 0.002                                    | 0.002                                     | 0.002                                     | 0.002                                     |
| 23  | 0.001                                    | 0.001                                     | 0.001                                     | 0.001                                     |
| 24  | 0.000                                    | 0.000                                     | 0.000                                     | 0.000                                     |
| 25  | 0.000                                    | 0.000                                     | 0.000                                     | 0.000                                     |
| 26  | 0.000                                    | 0.000                                     | 0.000                                     | 0.000                                     |
| 27  | 0.000                                    | 0.000                                     | 0.000                                     | 0.000                                     |
| 28  | 0.000                                    | 0.000                                     | 0.000                                     | 0.000                                     |
| 29  | 0.000                                    | 0.000                                     | 0.000                                     | 0.000                                     |
| 30  | 0.000                                    | 0.000                                     | 0.000                                     | 0.000                                     |
Finally, we have made the Spearman-correlation matrix, as shown in Figure 2:

Figure 2. Spearman-correlation matrix

High positive correlations are indicated in dark blue, while high negative correlations are showed in dark.

Analytic Hierarchy Process (AHP) is a systematic and hierarchical analysis method that combines qualitative and quantitative analysis. The analytic hierarchy process decomposes the problem into different components according to the nature of the problem and the overall goal to be achieved, and combines the factors at different levels according to the interrelationship between the factors and the affiliation relationship, forming a multi-level analysis structure model.

In the previous article, we determined the index system and obtained the index correlation through the Spearman correlation coefficient. The next step is to use the analytic hierarchy process to determine the relative weight of the index on this basis. The Spearman correlation coefficient between the indicators is used as an important reference for constructing the judgment (pair comparison) matrix, so that the analytic hierarchy process can still work well under the current situation of more indicators. The hierarchical structure model we established in the process is shown in Figure 3:

Figure 3. Hierarchical model
After hierarchical sorting and consistency test, the weight distribution of all indicators in the indicator system shown in Table 2 is finally determined as shown in Figure 4:

![Figure 4. Indicator weights derived from the evaluation model](image)

### 4. Conclusion

From the Spearman-correlation matrix (Spearman-correlation matrix) of 27 indicators, it is easy to see the highly positively correlated and highly negatively correlated indexes. After further analysis, we find that the environmental dimension and the social dimension have a lower internal correlation, while the food, nutrition and economic dimensions have more high positive and/or negative correlations.

According to the analytic hierarchy process, in the index system we constructed, the first five indexes ranked by weight are Water pH (0.1365); Agriculture and forestry energy use as% of total (0.365); Burden of foodborne illness (number of cases) (0.1168); Greenhouse gas emissions in total agriculture (gigagrams) (0.073); Agricultural land as% of arable land (0.073). The remaining indicators have relatively little weight. After understanding the definition of indicators, we can reclassify them into efficiency, profitability, sustainability and Equity indicators.

The current model of the existing food system prioritizes efficiency and profitability. Despite its high efficiency, there is not enough attention to the fairness and sustainability of the food system. There are still many food insecure people, food-poor areas, and serious environmental problems. And the evaluation system we have established is comprehensive and comprehensive and has no special directionality. In general, our goal is to produce more food while maintaining a healthy environment. In general, we have established a robust grain system evaluation model with good editability, based on a
large amount of data. It is flexible and we can adjust the model at any time to optimize the efficiency, profitability, sustainability and fairness of the different levels below.

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