Evaluation Model of Grain System Based on AAQN Index System

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Abstract-According to UN FAO, global food production in 2019 reached 2.722 billion tons, showing high profitability and efficiency levels[1]. However, while we enjoy fresh and nutritious food, people in Africa and Central Asia are suffering from starvation and nutritional deficiencies. Despite the high profitability and efficiency levels, the existing food systems are challenged by equity and sustainability problems. In order to assess the current food system and propose a rational optimization approach, we propose a linear and hierarchical food system based on the priorities of food flow and distribution. To quantify food security based on food systems, we develop the AAQN Index system to measure the affordability, availability, quality& safety, and natural resources& resilience of a food system based on the Global Food Security Index (GFSI). We select 68 indicators and calculate the indicator weights by combining the entropy weight method (EWM) with GFSI. By systematically clustering the calculated results, we classified the food systems of 113 countries/regions into: excellent, normal, and poor. Then, we adjust the priorities of the Indian food system, a poor food system, to reveal the differences before and after optimization. Finally, by predicting the future AAQN Index of Indian through Grey Relational Analysis.

1. Introduction
The current global food system is facing major challenges, including how to feed a growing world population, how to reduce rural poverty in the world, and how to manage ecosystem goods and services in light of global environmental change.

The food system is a complex web of activities involving production, processing, distribution, and consumption. Issues concerning the food system include the governance and economics of food production, its sustainability, the degree to which we waste food, how food production affects the natural environment, and the impact of food on individual and population health[2].

The current food safety system plays a role in allowing food to be produced and distributed relatively cheaply and efficiently. But the food system has strong insecurity, even in some areas where food systems are functioning well. At the same time, it faces challenges such as equity and sustainability.

Hence, it is necessary to optimize the food system to address equity and sustainability issues. In this paper, we analyze what impact will it have on the food system if the current food system is optimized for equity and sustainability, and estimate when this system can be implemented.

2. AAQN Index: an evaluation model
Researchers define the food system as the chain of activities connecting food production, processing, distribution, consumption, and waste management, as well as all the associated regulatory institutions and activities[3]. Based on the food flow and the priorities assigned, we propose a linear and
hierarchical food system.

Why we need an evaluation model? In order to quantify food security according to the food system, we develop the AAQN Index, which measures a country’s ability to ensure affordability, availability, quality & safety and natural resources & resilience of food. When formulating the evaluation system, we referred to the Global Food Security Index, which comprehensively measures the food security of 113 countries/regions from three aspects, affordability, availability, quality & safety. The index is a dynamic quantitative and qualitative benchmark model constructed from 34 unique indicators that can measure the food security drivers of developing and developed countries.

However, GFSI has certain drawbacks. It does not take into account the impact of the food system on the environment. In order to make up for GFSI’s ignorance of the environment, we introduce adjustment factors for natural resources and resilience. These dynamic and quantitative factors assess a country’s ability to withstand the effects of climate change, its sensitivity to natural resource risks, and how the country adapts to these risks.

2.1 Data Description
When calculating GFSI, the researchers preprocessed the collected data, that is, scored each indicator with a 100-point system (100 is the best). We absorbed the advantages of the GFSI calculation method and selected 68 indicators in 113 countries/regions in order to prepare for the establishment of evaluation model in the next step.
2.2 The Establishment of AAQN Index

2.2.1 Affordability
To evaluate the affordability of a country’s food system, we selected 6 levels of indicators, including changes in average food costs, the proportion of the population under the global poverty line, per capita GDP (US$ PPP), agricultural import tariffs, presence and quality of food safety net programmers, access to financing for farmers. We have added 4 indicators to the existence and quality of the food safety net plan, the operation of the food safety net plan. This increases the accuracy of the indicator.

2.2.2 Availability
To evaluate the availability of a country’s food system, we selected 8 levels of indicators: Sufficiency of supply, Public expenditure on agricultural R&D, Agricultural infra-structure, Volatility of agricultural production, Political stability risk, Corruption, Urban absorption capacity, Food loss. We have added 2 indicators to the sufficiency of supply, including average food supply, change in dependency on chronic food aid. We also add 6 indicators to agricultural infrastructure, including existence of adequate crop storage facilities, Road infrastructure, Port infrastructure, Air transport infrastructure. Rail infrastructure, Irrigation infrastructure. This increases the accuracy of the indicator.

2.2.3 Quality and safety
To evaluate the quality and safety of a country’s food system, we have selected 5 levels of indicators: dietary diversity, nutritious standards, micronutrient availability, protein quality, food safety. We have added 3 indicators to nutritious standards: national dietary guidelines, national nutrition plan or strategy, nutrition monitoring, and surveillance. We have added 3 indicators to micronutrient availability: dietary availability of vitamin A, dietary availability of iron dietary availability of zinc. We also added 3 indicators to food safety. This increases the accuracy of the indicator.

2.2.4 Natural resources and resilience
In evaluating the natural resource situation and resilience of a country’s food system, we selected 7 levels of indicators: exposure, water, land, oceans, sensitivity, Adaptive capacity, Demographic
stresses. Corresponding indicators are added to supplement each level.

It should be noted that the selection of the above indicators and the source of the indicator data are obtained by referring to many documents, drawing on the relevant data of the Global Food Security Index, and having a certain degree of credibility. This increases the accuracy of the indicator.

2.3 Determining the weight

2.3.1 Entropy weight method

With the evaluation indicators defined above, we further determine the weights of these indicators, resulting in the combination of primary indicators. Recalling on the Entropy Weight Method (EWM), we will carry out the standardized treatment, making the optimal and worst value of each variables after alternation be 1 and 0, respectively. The evaluation indexes are \(X_1, X_2, X_3, \ldots, X_k\), where \(X_i = x_{i1}, x_{i2}, \ldots, x_{in}\). Among there, \(k\) and \(n\) are the number of defined evaluation indictors and sovereign countries/regions throughout the world, where \(k = 68, n = 113\).

For the consideration of cost-type indicators, the food system is directly proportional to the value of the indicators. However, in terms of profit indicators, the higher the value, the lower the food system of the country or region. Therefore, we have carried out a positive treatment on the benefit index.

\[
\tilde{z}_{ij} = \max \{x_{i1}, x_{i2}, x_{i3}, \ldots, x_{in}\} - \min \{x_{i1}, x_{i2}, x_{i3}, \ldots, x_{in}\}
\]

where \(z_{ij}\) is the standardized value of each evaluation indicator of each country, \(\max(x_i)\) and \(\min(x_i)\) are the maximum and minimum value of the evaluation indicator. \(\max(x_i) = \max\{x_{i1}, x_{i2}, \ldots, x_{in}\}\), \(\min(x_i) = \min\{x_{i1}, x_{i2}, \ldots, x_{in}\}\).

After standardization, we succeed in substituting \(z_{ij}\) for \(x_{ij}\) to implicate the Food system of a country.

Calculate the probability matrix \(P\), where the calculation formula for each element in \(P\) is as follows:

\[
p_{ij} = \frac{\tilde{z}_{ij}}{\sum_{i=1}^{n} \tilde{z}_{ij}}
\]

It is easy to verify that the sum of \(P_{ij}\) is 1.

Calculate the information entropy of each indicator, calculate the information utility value, and normalize to obtain the entropy weight of each indicator. For the \(j\) indicator, the information entropy calculation formula is

\[
e_j = -\sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \quad (j = 1, 2, 3 \ldots n)
\]

Information utility value:

Normalize the information utility value to get the entropy weight of each indicator:

\[
W_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \quad (j = 1, 2 \ldots m)
\]

2.3.2 Objective weights

To be more objective, we calculate the final weight by assigning weights to the results of EWM and the weights calculated by researchers of GFSI.

The equation is as follows:

\[
\omega = \alpha \omega_{Ej} + (1 - \alpha) \omega_{Gj}
\]

\(\omega_{Ej}\) represents the weight of \(i_{th}\) indicator calculated by EWM, while \(\omega_{Gj}\) represents the weight of \(i_{th}\) indicator calculated by researchers of GFSI. We suppose \(\alpha = 0.5\) and get the final weights. As the final
weights take up a lot of space, we attach the document to the Appendices.

2.4 Validation test
In order to measure the validation of AAQN Index, we draw a scatter plot and find that there is a strong correlation between AAQN Index and FGS1, indicating that our model is validate.
In order to solve the equity and sustainability issues in the current food system, the Indian government has taken measures and formulated national budgets. Measures include but not limited to ensuring food availability and accessibility to below poverty line (BPL) candidates, improving purchasing power through employment generating schemes, establishing food grain banks and promoting household gardening, raising community awareness through IEC activities and social marketing, monitoring and timely evaluating nutritious programmers, increasing community participation and intersect coordination. In this way, the priority of the food system has changed, and these measures cover every aspect of the food system. Instead of focusing on the profitability and efficiency of the production and processing links like the original food system.

2.5.2 How it differs from the current food system
We calculate the AAQN Indexes of the current food system and the optimized one to show the differences between them. We assume that Indian government’s efforts in improving equity and sustainability will increase the scores of relevant AAQN indicators by 1% every year.

If the improvement measures progress smoothly, the AAQN Index of India will be gradually improved. This means that the production and processing of the food system will produce less pollution, food loss in supply chain will be reduced, and everyone has access to affordable and nutritious food, and cultivate the habit of not wasting food.

2.5.3 How long does it take to optimize the food system
In the above, we calculated the AAQN Index of 113 countries/regions in 2018. We systematically clustered the calculation results and divided the food systems of all countries into: excellent, normal, and poor.

Theoretically, a country has a poor food system if its AAQN Index is lower than 0.5. If AAQN Index is between 0.5 and 0.8, the country has a normal food system. If AAQN Index is higher than 0.8, it has an excellent food system.

It can be seen from the results above that India has a poor food system, so how long does it take for India to have a normal food system or even an excellent one?

Taking the optimized food system into account, we assume that the Indian government will continue to take measures and even make breakthroughs to tackle with food insecurity. Therefore, we use Grey Relational Analysis to predict the future AAQN Index and determine when the improvements will happen.
As can be seen from Figure 5, if India is committed to improving the food system, it will take 11-12 years to develop a normal food system. If India is not satisfied with the performance and continues to take measures to ensure equity and sustainability. It may create an excellent food system within 20 years.

3. Model Evaluation

3.1 Strengths
(1) AAQN Index has a strong objectivity. When calculating the indicator weights, we combine the entropy weight method and the weights calculated by GFSI experts.
(2) AAQN Index passes the validation test by being compared with GFSI.
(3) The linear and hierarchical food system and AAQN Index have certain scalability and adaptability.

3.2 Weakness
(1) In our model, the indicator scores are consistent throughout the whole food system, but the indicator scores vary in different parts of a food system in real life.
(2) We acquiesced that governments and citizens are committed to building a equitable and sustainable food system, which can hardly be achieved in real life.

3.3 Further discussion
If the indicators are inconsistent in a large area, we may divide the area into small parts, calculate the AAQN Indexes respectively, and add up the results.

We can introduce time-series analysis to reflect the dynamic changes of government policy implementation and citizen participation and predict the future food system.

4. Conclusion
In order to assess the current food system and propose a rational optimization approach, we propose a linear and hierarchical food system based on the priorities of food flow and distribution. To quantify food security based on food systems, we develop the AAQN Index system to measure the affordability, availability, quality& safety, and natural resources& resilience of a food system based on the Global Food Security Index (GFSI). Through our model, we divide the world's national food systems. We applied it to India, a developing country, to verify the feasibility of our model by adjusting the priorities of the Indian food system, comparing the differences before and after, and predicting its future AAQN index.
References
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