Research on the Sustainability of the Global Food System

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Abstract: As the basic guarantee for the stable development of the country's economy and society, the food system has always been the focus of studies. Based on the perspective of sustainability, this paper constructs a comprehensive evaluation model of the food system for sustainability. We select a large number of representative indicators to establish a comprehensive index evaluation system for the carrying capacity of the food system , with arable land support, ecological support and socio-economic support as the criterion level, and quantitatively analyze the comprehensive carrying capacity of the global food system. According to the characteristics of carrying capacity and the results obtained, we classify the carrying capacity of the food system and explain its meaning in reality. Through data analysis and processing, we find that the carrying capacity of food resources under the global system is showing a steady upward trend. Although resource shortage and environmental problems such as climate warming are becoming more and more serious, the reduction in ecological support caused by this is not enough to reduce the carrying capacity of food system. Thanks to the improvement of food planting technology and the rapid economic development, the support of arable land and social economy have greatly increased. Therefore, the carrying capacity of food resources has been showing a steady upward trend.

1. Introduction

Combing domestic and foreign literature on the subject of carrying capacity, we can find that some scholars study the development status [3] and limit level of the overall area based on the dimensions of the city [1] or space [2]. Based on the perspective of resources and environment [4], some scholars choose water resources system [5], land resource system [6] or mineral resource system [7] to construct a comprehensive index evaluation system [8] to study the development level and time-space evolution [9], of the carrying capacity and analyze the problems in development. We noticed that most of the literatures focus on the qualitative analysis of the food system. However, this article focuses on the quantitative analysis. Based on a macro perspective, we establish an evaluation model of the global food system, taking sustainability as the starting point, deeply study the development state and existing problems of the food system. Furthermore, we propose solutions and improvement plans based on the actual situation. Based on the research of Yang Jin et al. [9], this paper constructs an comprehensive evaluation index system for the carrying capacity of food resources from three aspects including the carrying capacity of farmland , ecological environment and social economy. By processing nine index data to calculate and classify the bearing capacity. Therefore, the established model is more comprehensive and objective, which improves the accuracy and practicability of the model.

2. Data Processing and Model Assumptions

2.1 Data Sources

The food system assessment model uses nearly 20 years of data, such as total food output value, agricultural population, and agricultural water use. We obtained relevant data through the International Food Agency, and obtained the data by searching the World Bank database and the China Statistical Yearbook and China Energy Yearbook from 1999 to 2020. The required values were obtained through post-formula processing.

2.2 Model Assumptions and Symbol Description

The food system includes agriculture, forestry, animal husbandry, fishery and other crops. The water and energy consumption data for food production can approximately equals to the number of the fresh water and energy consumed by agriculture. The population participating in the food production can be approximated by the proportion of the agricultural population to the total population. The output value of the system can be obtained from the ratio of the GDP of agriculture, forestry, animal husbandry and fishery to the gross national product.

The meanings of the symbols are shown in Table 1.

Table 1 Symbol Description

symbol	symbol description
GFS	Global food system
E	Comprehensive carrying capacity of food resources

3. Model Construction and Analysis

In order to quantitatively analyze the development status of the food system, Figure 1 establishes a food evaluation model for us, and builds an indicator system for the carrying capacity of food resources from the perspective of sustainability.

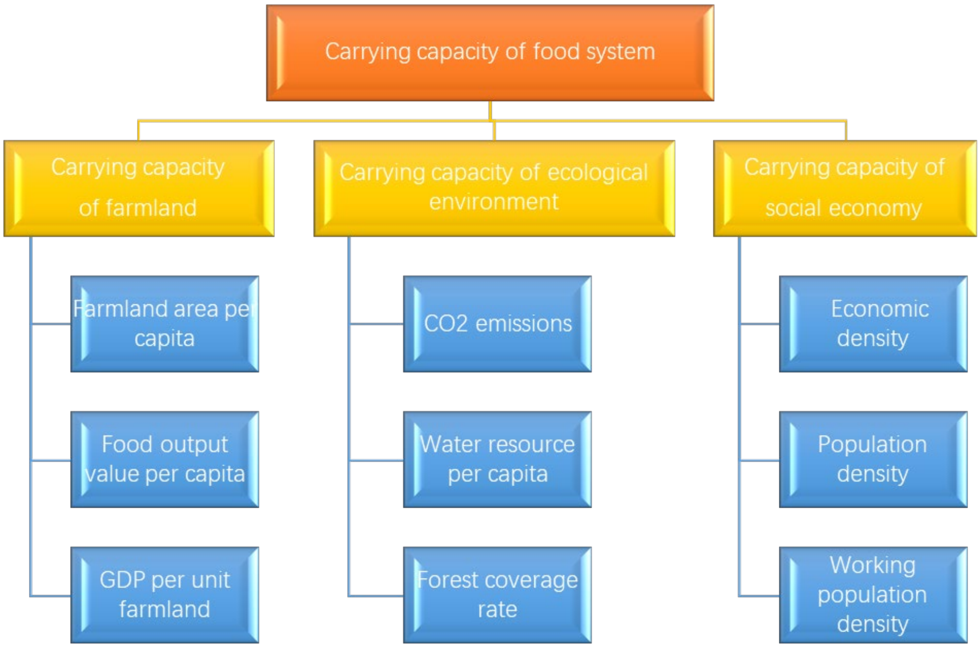

Fig.1 The Comprehensive Evaluation Index System for the Carrying Capacity of Food System

The construction of the comprehensive evaluation index system for the carrying capacity of food resources should not only consider the factors of the food resources themselves, but also include the economic and social development. Based on various influencing factors, we selected 9 indicators from the three aspects of the carrying capacity of farmland, ecological environment and social economy to establish an comprehensive evaluation index system for the carrying capacity of food resources. Also, we classified them according to the characteristics of carrying capacity, as shown in table 2.

Table 2 Classification of Food Carrying Capacity

Grade	range	meaning
1	[0,0.375]	crisis state
2	[0.376,0.625]	pre-alarm state
3	[0.626,0.875]	equilibrium state

4	[0.876,1]	rich state

We use range standardization to process the data. The positive index is listed as follows.

$$Z_{ij} = \frac{C_{ij} - \min_j C_{ij}}{\max_j C_{ij} - \min_j C_{ij}}$$

The negative index is listed as follows.

$$Z_{ij} = \frac{\max_j C_{ij} - C_{ij}}{\max_j C_{ij} - \min_j C_{ij}}$$

Among them, Cij is the sample value j of the index i. minCij is the minimum value of the sample j in the index i. maxCij is the maximum value of the sample j in the index i. Zij is the standardized data of the sample j of the index i. The index weight is determined by the entropy method, and the specific algorithm is listed as follows.

$$P_{ij} = \frac{Z_{ij}}{\sum_{i=1}^{n} Z_{ij}}, k = \frac{1}{\ln n}, \quad E_i = -k\sum_{j=1}^{n}(P_{ij} \cdot \ln P_{ij}), W_i = \frac{1 - E_i}{\sum_{i=1}^{m}(1 - E_i)}$$

However, the value of each food resource index and its influence on the comprehensive carrying capacity are not linear. When the index value is low, its impact on the comprehensive bearing capacity is small; when the index value is at the middle level, the impact on the comprehensive bearing capacity increases with the increase of the index value; when the index value is large, the impact on the comprehensive bearing capacity increases. The influence of bearing capacity gradually decreases and tends to be saturated. Therefore, we use the optimized rising half Γ-type distribution index formula to more accurately reflect the relationship between the two.

$$E_i = \begin{cases} 0, & x_i \le 0 \\ 1 - e^{-0.6827 x_i}, & x_i > 0 \end{cases}$$

Ei is the carrying capacity of the index i. xi is a sample value of the index value of the food resource carrying capacity after standardization. Then the comprehensive carrying capacity of food resources is listed as follows.

$$E = \sum_{i=1}^{n} E_i W_i$$

Table 3 Comprehensive Carrying Capacity of Global Food Resources from 2009 to 2018

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Carrying capacity level	V1	V2	V2	V2	V2	V2	V2	V2	V2	V3

It can be seen from the data in Table 3, With the increase of time, the carrying capacity of food resources under the global system has shown a steady upward trend. The main reason is that the improvement of food planting technology and rapid economic development have greatly increased the support of farmland and social economy. The reduction of water resources and the reduction of ecological support, such as greenhouse gas emissions are not enough to make carrying capacity of food resources drop. Therefore, From Figure 2 there is an upward trend.

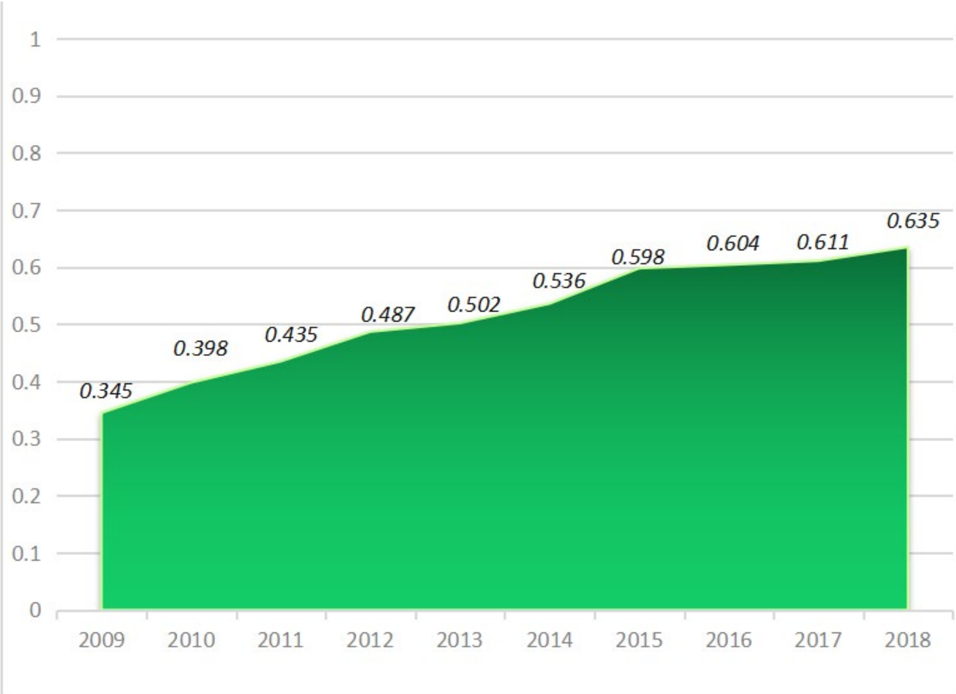

Fig.2 Comprehensive Carrying Capacity of Global Food System from 2009 to 2018

4. Conclusions and Recommendations

4.1 Conclusions

This article quantitively analyses the evolution trend and characteristic law of the global food carrying capacity by constructing a comprehensive index evaluation system. This research and model comprehensively and objectively assess the development status of the food system. The current resource and environmental situation is becoming increasingly severe, and research has strong academic value and social significance. We draw the following conclusions: Based on the obtained results and index characteristics, this article constructs a comprehensive index evaluation system for the carrying capacity of food resources and classify the comprehensive carrying capacity. When using the ecological carrying capacity to analyze the sustainability of the food system, the result data shows that the carrying capacity of food resources has been increasing. For the criterion level, the support capacity of farmland and social economy have increased significantly. However, with the increasingly serious problems of resource shortage, climate warming, and raging epidemics, the pressure on the ecosystem is increasing, so the ecological support continues to decrease. It is urgent to take strong measures to strengthen the stability of the ecosystem and promote the sustainable development of the food system.

4.2 Recommendations

Based on the above conclusions, the following suggestions are made. Firstly, continue to consolidate the food system and increase the overall carrying capacity. All regions around the world should focus on strength complementary resources and complementary advantages for win-win cooperation. Besides, it is necessary to accelerate institutional updates and exchanges, and promote sustainable use of resources and sustainable economic growth.

Secondly, it is essential to promote the use of advanced technologies and promote cross-regional cooperation. The state should increase the state's investment in food production science and technology, strengthen environmental protection technology and equipment updates, and reduce the emission of resource metabolites.

Thirdly, push development and promote regional coordination. It is recommended to promote the multi-level allocation of food and establish a recycling resource system. Enhance departmental management coordination, thus improving resource management and utilization efficiency.

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