ISSN 2616-5872 Vol.3, Issue 1: 63-66, DOI: 10.25236/AJEE.2021.030113

A Food System Optimization Model Based on NUFER-AGD

Mingyu Zhao[1], Yujiao Li[2]

[1]*College of Agronomy and Biotechnology, China Agricultural University, Beijing, 100000, China*
[2]*College of Economics and Management, China Agricultural University, Beijing, 100000, China*

Abstract: *The global food system has already been under multiple threats even before the outbreak of the COVID-19, and the epidemic last year has made it even more vulnerable. Therefore, it's never been so important to examine and re-optimize our current food system comprehensively nowadays. In this paper, we established a statistical model termed as NUFER-AGD, which use NUFER model as core model, coupling soil, water and air emissions sub-models to depict the interaction between food system and environment. We reoptimized the current food system from three aspects based on our model: At the upstream of food chain, we must respect the nature, and focus on technological innovation to increase yields and diversity; In the middle of food chain, we should establish a sound infrastructure for food storage and transport, and establish flexible and mobile global and regional food reserves to guarantee the smooth operation of international trade activities; At the downstream of food chain, we need to improve the social security system so that the food system could cover more poor regions. Besides, we are ought to adjust our diets and reduce food waste and loss. By doing so, we could observe a significant increase in the recoverability and fairness index calculated by our model. And finally we can achieve a food system that is highly productive, low-carbon, resilient, sustainable and inclusive.*

Keywords: *Food system optimization; NUFER-AGD; Resilience; Food security*

1. Introduction

1.1 Background

Under the frequent and intense impact of multiple factors, such as economic depression, regional conflicts, climate change and extreme weather, the world has entered an era of complex risks with multiple crises, and the agricultural and food systems have already been vulnerable. In this context, it is urgent to rethink the current food system and try to design a new food system that is more equitable and sustainable. The future food system should be efficient and high-yield, low carbon, healthy and nutritious, resilient, sustainable and inclusive.

1.2 Assumptions

In our model, idealization in some places was adapted.

- The energy and material flow in food system obey certain statistical laws, and could be described.
- Just concentrated on several major food crops and animals, assuming they could represent the whole situation.
- The fairness of food system is based on food production distribution, no matter what and how production is.
- The nitrogen cycle can describe the major changes in the food system.

2. Model Establishment

2.1 NUFER-AGD

Aiming at quantifying the flow of nutrients in food system, NUFER model was adapted as our core model, moreover, in order to take ecological issue into consideration, soil, air and river model were set

ISSN 2616-5872 Vol.3, Issue 1: 63-66, DOI: 10.25236/AJEE.2021.030113

up coupling to NUFER (JIN, 2020), termed as NUFER-AGD model (Nutrient flows in Food chains, environment and resources use model for agricultural green development). The NUFER-AGD model includes four compartments: the crop production compartment, the animal production compartment, the food processing compartment, the household compartment; and four modules: an input module with partitioning and transformation coefficients, a calculation module with equations, an optimization module, an output module.

2.1.1 Crop production Compartment

Crop production is most foundational part in the food system. Crops collect energy and materials from environment, and grow into the food product market. There're so many material and energy input for crop production, such as fertilizer, irrigation, biological fixation, etc. For input module, there're eight categories i and several items for each category j to aggregate.

$$Ic = \sum_{i}^{8} \sum_{j} Ic_{ij} \tag{1}$$

Our model includes 10 outputs in crop production process, such as food production, erosion, residues, grass, air emission, etc.

Besides, the crop production compartment is most related to soil model for upper soil layer, which was the main layer for crop to take nutrients and water.

2.1.2 Animal Production Compartment

The higher level in the food system is animal production, including fishery and stock-breeding,they has two main kinds of input (environment input and crops input) and three kinds of output (back to environment, manure as fertilizer or be as food). Six animal products were included in the model, which were meat, egg, milk, fish, bone, and by-product. Besides, manure is the main source back to environment or crop production. After statistical summary as the same way in the crop production, we can get the flow situation of animal production.

2.1.3 Food Processing Compartment

The food processing compartment comprised the storage, transport, processing, packaging, and retail sectors.

The input of food processing compartment including three main origins: crop product, animal product and import from another region. The intrinsic rule here necessary to explain is that the transport (import and export) of processed food (and residues) between regions was considered to be part of the exchange between food processing compartments of regions, and that the transport (import and export) of unprocessed crop and animal products between regions was considered to be part of direct exchanges between the crop and animal production compartments of these regions.

2.1.4 Household Compartment

Household is the highest level in the food system, which represents the consumption of food by humans, no matter at home or in the restaurant. It also is the goal of food system and nutrition consuming side. The household compartment was subdivided into rural and urban households. The input of household compartment is the same as output of food processing for plant food or animal food, while the output is difficult.

$$\begin{aligned} Ih &= \sum Ih_{plant\,food} + \sum Ih_{animal\,food} \\ Oh &= \sum_{i} \sum_{j} Ih_{ij} \end{aligned} \tag{2}$$

2.2 RAINS Model for Air Environment

RAINS (The Regional Air Pollution Information and Simulation) is to use the atmospheric chemical transformation diffusion model to simulate the distribution of air pollutants in the future, and on this basis, comprehensively consider the cost of emission reduction technology to find the emission control strategy with the lowest cost and the highest benefit(Brink C,2004).It can effectively evaluate and control the emission of SO_2,NOx, NH_3 and PM.

By coupling the RAINS model with the NUFER model, we can better quantify the effects of various links in the food system, especially livestock production and crop fertilization on the contents of N and its compounds in the atmosphere, PM and other indicators.

2.3 Global-NEWS 2 Model for Water Environment

Global-NEWS 2 model (A et al., 2010) is used to quantify the migration of element flow from source to river and lake. Based on the assumption that nutrient elements are in a stable state, it analyzes and calculates the output of different sources, different elements and different forms of salt from land to water in most basins of the world.

In the process of coupling with NUFER model, point sources mainly refer to the wastes discharged into the water body from household activities, processing and transportation activities, etc., which are usually connected with the sewage treatment system and discharged into the stream as a single point source after certain treatment.

While diffuse sources refers to the nutrient elements in agricultural activities (ant) (fertilizer, livestock manure, etc.) and natural activities (nat) (deposition, leaching, etc.) enter into streams in the form of diffusion.

Global NEWS 2 model and NUFER model belong to the same nutrient flow model, so the coupling effect is better, which can well supplement the migration process of nutrient elements from NUFER model to stream, and can be used to determine and evaluate the relationship between food system and water body at the nutrient flow level.

2.4 GLOBIOM Model for Soil Management

Global Biomass Optimization Model (GLOBIOM) is a dynamic equilibrium model integrating agriculture, bioenergy and forestry (Energy Policy, 2011), which mainly studies and analyzes the land use competition among major land production sectors in the world. Its purpose is to make the sustainable and balanced development of national or regional agriculture by planning land use and corresponding processing activities under the constraints of land, resources, policies and other factors. After coupling GLOBIOM with NUFER model, we get the objective profit function as follows:

$$MAX\_Tt = \sum_{r,y} \varphi_{r,t,y}^{demd} - \sum_{r,y} \varphi_{r,t}^{splw} - \sum_{r,y} \varphi_{r,l,t}^{lucc} - \sum_{r,y} \varphi_{r}^{live} - \sum_{r,y} \varphi_{r,m}^{proc} - \sum_{r,y} \varphi_{r,t,y}^{trad} - \sum_{r,y} \varphi_{t,e}^{emit} \tag{3}$$

Where product balance is expressed as:

$$Dr,t,y \le \sum_{c,q,l,s,m} \alpha_{t,c,q,l,s,m,y}^{land} + \sum_{r,t} \alpha_{r,t,y}^{live} + \sum_{r} \alpha^{traded} \tag{4}$$

Land use balance is expressed as:

$$\sum_{s,m} A_{r,t,c,q,l,s,m} \le L_{r,t,c,q,l} \tag{5}$$

We couple GLOBIOM with NUFER model as the land system analysis model in the grain system, which is used to reasonably arrange and guide the land use of each link of the grain system, so as to achieve the goal of maximizing the relevant profits and sustainable development.

3. Solution of Model

The current food system is inefficient, unsustainable and wasteful. Our new food system will be consistent with the 2030 agenda for sustainable development, including the following four aspects: the food system should enable all people to benefit from nutritious and healthy food; the food system should reflect sustainable agricultural production and food value chain; the food system should mitigate climate change and enhance resilience; the food system should encourage the revival of rural areas.

3.1 Optimization of food system

According to our vision, the new food system model will be optimized in the following aspects

(1) At the upstream of food chain (production)

Encourage technological innovation and optimize the priority of agricultural investment. First of all, we need to develop disease resistant and tolerant, so as to improve the stability of the food system. Secondly, we should increase investment in agricultural, give priority to supporting the development of technology to promote the diversification of crop production. Third, we should promote small farmers to better carry out risk management, and enhance the resilience of small farmers through insurance, income diversification and other ways.

(2)In the middle of the food chain (processing and circulation)

Improve storage and transportation infrastructure. Build global and regional grain reserves. The new food system should establish a storage and distribution system that can meet the emergency needs and market circulation. Ensure smooth trade and promote international trade. We should strengthen the resilience of the supply chain and ensure that some countries without comparative advantage can make up the food gap through imports.

(3)At the downstream of food chain (consumption)

Improve the level of institutional innovation and improve the social security system. The first is to expand social protection for the urban poor and the hungry, and to establish a more targeted and effective cross sectoral social protection system. In addition, we can also try to develop food banks and use the wasted food to deal with the problem of hunger.

4. Conclusion

In this paper, based on the method of material flow analysis, the model reveals the rule of nitrogen flow in the food system, and simulates the food production- processing-transportation-consumption process with clear characteristics. The proposed optimization scheme is based on the underlying operation of NUFER-AGD model, quantifying the relevant evaluation criteria, and has mathematical logic.The interaction of atmosphere, water, soil and food system is considered, and the sustainability and resilience of food system are considered from the perspective of ecology. And there are still some disadvantages to improve: A large amount of data is needed to support the application of this model, which is difficult to be collected by small groups; Due to the limitation of time, the model only considers the nitrogen flow and does not consider the footprint of other elements.

References

[1] S. Bretschneider and A. Kimms. A basic mathematical model for evacuation problems in urban areas. Transportation Research Part A Policy & Practice, 45(6):523–539, 2011.
[2] G. Dikas and I. Minis. Solving the bus evacuation problem and its variants. Computers & Operations Research, 70:75–86, 2016.
[3] Marc Goerigk. Branch and bound algorithms for the bus evacuation problem. Elsevier Science Ltd., 2013.
[4] Marc Goerigk, Kaouthar Deghdak, and Philipp Hebler. A comprehensive evacuation planning model and genetic solution algorithm. Transportation Research Part E Logistics & Transportation Review, 71(71):82–97, 2014.
[5] Xiaozheng He, Hong Zheng, and Srinivas Peeta. Model and a solution algorithm for the dynamic resource allocation problem for large-scale transportation network evacuation. Transportation Research Part C, 59:233–247, 2015.
[6] Pamela Murray-Tuite and Brian Wolshon. Evacuation transportation modeling: An overview of research, development, and practice. Transportation Research Part C, 27(2): 25–45, 2013.