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Diet optimization promotes global greenhouse gas emission

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ABSTRACT

Achieving the Paris Agreement's goal of limiting global temperature rise to 1.5°C or 2°C above pre-industrial levels requires global greenhouse gas emission reductions. Currently, most of the global greenhouse gas emission reductions are focused on the energy sector, such as reducing fossil fuel combustion, improving utilization efficiency, and using clean energy. However, studies have shown that decarbonization in the energy sector alone may not be sufficient to meet the goals of the Paris Agreement. Because the global food system accounts for about one-third of global greenhouse gas emissions, reducing emissions from the global food system is also key to reaching this goal. By dividing the world into two camps according to economic levels and using population projection data, individual diet structure data, and food carbon footprint data in each segment, this paper projects human GHG emissions from 2020-2060 due to the consumption of major foods such as grains, meat, dairy products, vegetables, fruits, legumes, and aquatic food groups. The LMDI analysis of GHG emissions due to food production in different regions was also conducted to analyse the magnitude of the driving forces of three factors: population, food structure, and carbon footprint on emissions.

Keywords: Global food system, future emissions projections, Greenhouse gas emissions, diet structure, carbon footprint, LMDI analysis

1. INTRODUCTION

The Paris Agreement set out to limit the rise in global average temperature to 2℃ above preindustrial levels and strive to limit the rise to 1.5℃. To achieve this goal, the global community needs to rapidly reduce greenhouse gas (GHG) emissions in all sectors and think about ways to reduce greenhouse gas emissions in the future. In 2018, A special report on global warming of 1.5℃ released by IPCC pointed out that the recent emission trend has deviated from the limit of global warming of 2℃. If greenhouse gas emissions are not reduced through emission reduction measures before 2030, the global average temperature rise will exceed 1.5℃ in several decades [1]. Much of the current focus on reducing greenhouse gas emissions is on the burning of fossil fuels in industrial production. The use of clean energy, improved fuel efficiency to reduce fossil fuel combustion, and the use of carbon capture technologies (e.g., BECCS) to reduce the amount of greenhouse gases in the atmosphere can effectively reduce the accumulation of greenhouse gases in the atmosphere [2]. Nevertheless, it has been documented that such efforts are not sufficient to achieve a global average temperature limit below 1.5 degrees Celsius [3]. The global food system is also a major source of greenhouse gas emissions, accounting for about one-third of total global emissions [4]. According to a special report on climate change and land published by the IPCC, the global food system emitted an average of 10.8-19.1 Gt of greenhouse gases per year during the period 2007-2016, accounting for 21-37% of total global average emissions [5].

Foods consumed by humans in their daily lives (e. g. grains, meat, vegetables, etc.) produce some amount of greenhouse gases during their regular production and harvest. There are various sources of greenhouse gases from food production and harvesting, such as fertilizer inputs that produce methane and nitrous oxide in agricultural production; methane released from growing rice in rice fields; methane released from intestinal fermentation in ruminants during production; methane released from livestock manure management; and greenhouse gases from burning fossil fuels during food production [6, 7]. Thus, humans produce a significant portion of greenhouse gas emissions simply because of their daily dietary intake. Individual diet structure has an important impact on global food demand because it is strongly influenced by inter-regional economic and

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cultural influences, resulting in regional differences in diet structure. In addition, the Lancet report on healthy eating states that diet is related to human health and environmental sustainability, so individual diet structure needs to be given adequate attention in predicting global food demand and in developing strategies to reduce emissions from food systems [8, 9].

2. MATERIAL AND METHODS

In this paper, population data, diet structure data and food carbon footprint data are obtained to estimate the greenhouse gas emissions due to food production between 2020 and 2060 (Fig.1). It is divided into three main sections as follows:

1. Forecasting future food demand

The future global food demand projected in this paper is derived by multiplying the per capita demand for each food group with population data. Future population data were obtained from World Population Prospects 2019, published by the United Nations Population Division, and were selected by age group, 0-79 years [10]. Data on per capita diet structure are based on the Food and Agriculture Organization of the United Nations' World Agriculture Towards 2030/2050：2012 Revision and per capita food availability data from the Food and Agriculture Database of the Food and Agriculture Organization of the United Nations [11, 12].

Next, the global population demand for each food from 2020-2060 can be calculated by the following equation：

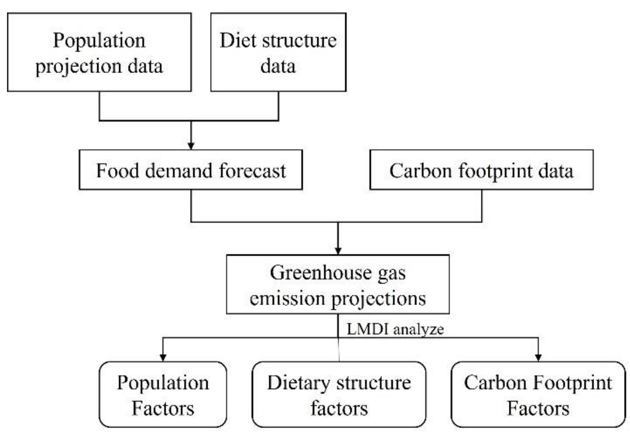
$$D_i = \sum_n \sum_t P_t \times D_n \qquad \text{(eq. 1)}$$

In equation (1), D_i represents the projected total demand for each food for the period 2020-2060; Pt represents the total population of the region each year; and D_n represents the per capita intake of this food in the region. (The population projections by age group in the World Population Prospects 2019 report are tabulated every five years, and for the missing years, this article uses MATLAB software to interpolate and simulate the population data.)

2. Calculating greenhouse gases produced during food production in the global food system

For greenhouse gases emitted in the global food system because of the food production process, this article uses the calculated demand for each food multiplied by the estimated greenhouse gas emissions per kilogram produced for that food. Data on the amount of greenhouse gas emissions (carbon footprint) emitted from the production of each food item were obtained from a recent Life Cycle Assessment meta-analysis [7, 13, 14]

Figure 1 Method flow chart



The calculation of greenhouse gas emissions due to food production in the global food system is given by the following equation:

$$E = \sum_i D_i \times CF_i \qquad \text{(eq. 2)}$$

In Equation 2, E represents the greenhouse gas emissions; CF_i represents the carbon footprint of that food.

3. LMDI analysis for the business-as-usual scenario

Based on the analytical model of LMDI, the following equation illustrates the modeling of GHG emissions from food systems in each region under a business-as-usual scenario.

$$E = \sum_i C_i = \sum_i \frac{C_i}{M_i} \times \frac{M_i}{P} \times P = \sum CF \times Int \times P \qquad \text{(eq. 3)}$$

In Equation 3, E represents the total carbon emission; C_i represents the carbon emission generated by the food i; M_i represents the consumption of the food i; and P represents the population. According to the LMDI method, the change in carbon emissions in period t relative to the carbon emissions in the base period can be expressed in the following equation:

$$\Delta E = E^t - E^0 = \Delta CF + \Delta Int + \Delta P \qquad \text{(eq. 4)}$$

$$\Delta CF = \sum_i W_i Ln \frac{InCF_i^t}{InCF_i^0} \qquad \text{(eq. 5)}$$

$$\Delta Int = \sum_i W_i Ln \frac{Int_i^t}{Int_i^0} \qquad \text{(eq. 6)}$$

$$\Delta P = \sum_i W_i Ln \frac{P_i^t}{P_i^0} \qquad \text{(eq. 7)}$$

In the above three equations, W_i is represented by the following equation:

$$W_i = \frac{C_i^t - C_i^0}{LnC_i^t - LnC_i^0} \qquad \text{(eq. 8)}$$

3. RESULTS AND DISCUSSION

3.1 Description of the prediction context

In this paper we refer to the projected GHG accumulations as the business-as-usual projections. The business-as-usual scenario is a projected scenario of how much food the global food system would need to produce to meet people's needs and how much greenhouse gas is produced in the process of food production during the period 2020-2060, without external intervention and continuing in accordance with the current pattern of changes in world population, economy, and food production efficiency. In the business-as-usual scenario, the data for the population projections are chosen from the medium growth rate projections in the World Population Prospects 2019 published by the United Nations Population Division. Meanwhile, per capita food consumption data were selected from Towards World Agriculture 2030/2050, published by the World Food and Agriculture Organization (FAO), as well as per capita food availability data from the FAO database. In a business-as-usual scenario, this paper further assumes that the composition of individual foods (beef, lamb, pork, poultry meat) in each food group (e.g., meat) remains constant over time in different country regions. By pairing this assumption with our food demand projections for different food categories (predicting how many different food categories will be consumed in the future), we estimated the future per capita demand for individual food products (e.g., beef, lamb, pork, poultry). Next, the carbon footprint data for each food is combined to calculate the global food system GHG emissions.

3.2 Greenhouse gas emissions in the business-as-usual scenario

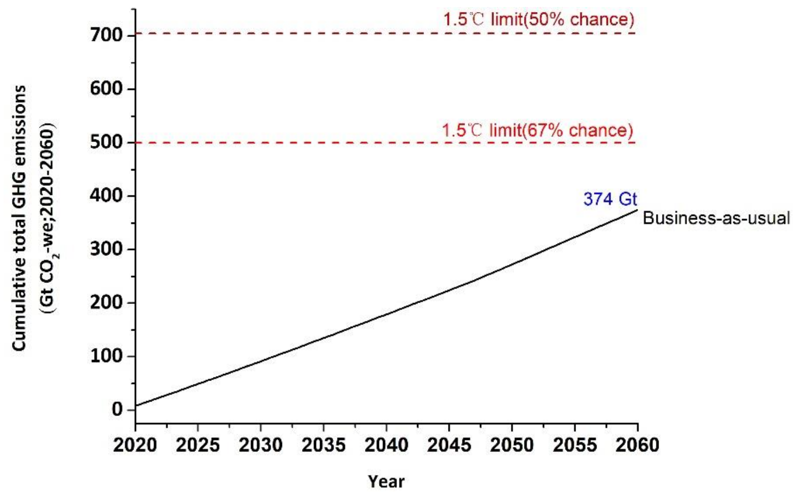


Fig.3. The red dashed lines in Figure 2 show the amount of carbon budget to reach a 50% and 67% probability of global warming of 1.5°C, respectively.

We estimate that cumulative GHG emissions from the global food system due to food production alone are about 374 Gt CO2-equivalent over the period 2020-2060. (Fig.2)

The map shows that in the business-as-usual scenario, the four regions with the highest share of GHG emissions in the global food system are East Asia (29%), Europe and North America (19%), and South Asia (15%) and Latin America and the Caribbean (12%), while all other regions have a share of 10% or less. The high share of GHGs accumulated in food systems in East and South Asia is mainly driven by demographic factors, as countries with large populations, such as China and India, can still generate large amounts of GHGs even if their per capita diet structure is at the level of developing regions; GHG emissions are also higher in Europe and North America, and Latin America and the Caribbean because the meat diet is higher in these two regions compared to other regions. The reason for the higher GHG emissions in Europe and North America, and Latin America and the Caribbean is that in these two regions, the meat diet has a higher share in the per capita diet structure than in other regions (36 kg per capita per year for developing regions in 2030, compared to 87 kg per capita per year in

Europe and North America, and 74.6 kg per capita per year in Latin America and the Caribbean) [11].

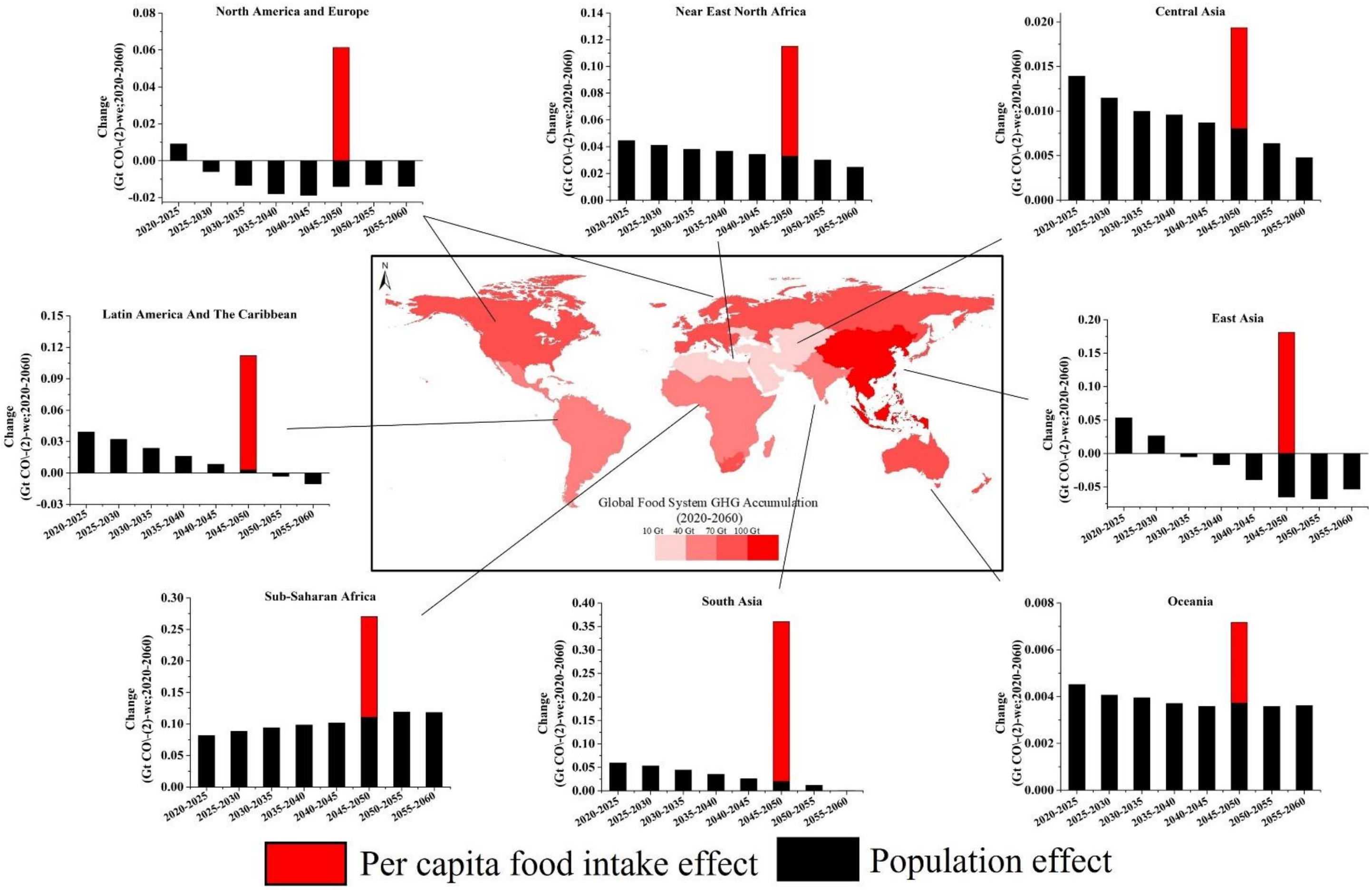


Fig.3. Global Food System GHG Emissions Projections and Regional Drivers for 2020-2060.

Based on the results of the LMDI analysis, we found that the demographic factor among the three drivers and the individual diet structure factor are the dominant drivers of GHG emissions (the decomposition result of the carbon footprint factor is 0 because the carbon footprint data applied in the calculation model do not change over time).

4. CONCLUSIONS

This paper combines population projection data, individual diet structure data, and carbon footprint data of major foods for the cumulative greenhouse gas emissions from the global food system due to food production over the period 2020-2060. Three projection scenarios are presented, a business-as-usual, plant-rich diet, and a mussel replacement scenario for conventional meat. The cumulative GHG emissions due to food production are expected to be 374 Gt CO2-equivalent over the period 2020-2060 under the business-as-usual scenario. The population factor mainly affects GHG emissions, which vary by region due to differences in population and diet, as evidenced by higher emissions in more populated areas and areas with higher meat consumption.

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