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研究課題名（和文）Measuring the global health burden and economic consequence of micronutrient deficiency under climate change impact and mitigation policy

研究課題名（英文）Measuring the global health burden and economic consequence of micronutrient deficiency under climate change impact and mitigation policy

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研究成果の概要（和文）：本研究により、二酸化炭素濃度の上昇は、栄養欠乏症、特にタンパク質、鉄、亜鉛を含む微量栄養素に大きなリスクをもたらす可能性があることが明らかにした。高二酸化炭素濃度シナリオでは、タンパク質、鉄、亜鉛の欠乏状態にある人口の割合が増加すると分かった。さらに、この影響は分配的な効果もある。低所得者層の人口は、高所得者層と比較して、より高い栄養損失を被る傾向がある。一方、厳しい気候緩和政策は、食料価格の上昇と所得の低下により、栄養不足のリスクを高める可能性もある。シミュレーションの結果、食生活の変化は、栄養不足を緩和し、緩和にも貢献できることが示された。

研究成果の学術的意義や社会的意義
本研究は、大気中の二酸化炭素の上昇と気候変動が、人間の栄養状態、特に微量栄養素の欠乏に広く影響を与えていることを明らかにした。また、二酸化炭素の排出が栄養に及ぼす不平等な問題も示した。したがって、SDGsの飢餓ゼロの目標を達成するために、対策を実施する必要がある。

研究成果の概要（英文）：This study revealed that elevated carbon dioxide level under future emission could impose substantial risk to nutrient deficiency, particularly for micronutrients, including protein, iron, and zinc. In the high CO2 concentration scenario, the percentage of population under protein, iron, and zinc deficiency will increase. In addition, the impact has distributional effect. Population in the low income class tend to suffer higher nutritional loss compared to the high income class. Meanwhile, stringent climate mitigation policy could also increase the risk of nutrient deficiency due to higher food prices and lower income. Simulation anslysis shows that dietary change (i.e., replacing certain of ruminant meat with fish) could alleviate nutrient deficiency and contribute to climate mitigation.

研究分野：食料安全保障、気候変動、緩和策

キーワード：climate change　hidden hunger　nutrient deficiency　climate mitigation

様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９（共通）

１．研究開始当初の背景

Food and nutrition security is fundamental to human development. Globally, about 820 million population are in chronic hunger. In addition, a larger population (2 billion) is under the threats to health and wellbeing of micronutrients deficiency (i.e. hidden hunger), which causes one million death annually on a global scale. Along with calories, supply of micronutrients is projected to face a pronounced challenge in 2050 under climate change.

The annual globally averaged CO2 concentration continues to rise yearly, with a value of 407 ppm at a historical high reported for 2018. If anthropological CO2 emissions are allowed to continue unabated, the annual globally averaged CO2 concentration is predicted to reach 550 ppm by 2050.

Raising CO2 and the subsequent climate change jeopardizes micronutrition security by reducing crop yield and micronutrient density for food. Modeling studies have found that changes in the 21st century, such as temperature and precipitation, are likely to reduce crop yield. For example, the yield of wheat will decrease by 16% in tropical regions under 2℃ of warming. Besides, field experimental studies conducted under free-air carbon enrichment conditions have suggested that elevated atmospheric CO2 substantially decreases the protein and micronutrient content of crops, which are the primary source of micronutrients for the poor. For example, C3 crops, such as wheat and rice, produce up to 15% less protein under 550 ppm CO2; the iron content of the edible portion of food crops is decreased by 4–10%; and the zinc content in C3 grasses is also drastically reduced.

Stringent climate mitigation policy to achieve the Paris Agreement goal could avoid the negative effect on yield and nutrition density. However, the subsequent expansion in bioenergy (by leading to competition in land and water with food production), mitigation costs, and reduction in income in developing countries accompanying the mitigation policy might also reduce food availability and consequently hamper micronutrient security. Failure to obtain adequate micronutrients can result in sickness and death. For example, iron deficiency lowers cognitive ability and increases maternal mortality. Zinc deficiency causes diarrhea and delayed sexual maturation.

With an expected world population of 10 billion by 2050, food and nutrition security will face enormous challenges and humanity will be exposed to considerable health risks under climate change impact and mitigation policy. Therefore, it is imperative to assess the effects of climate change impact and mitigation on global micronutrition security for the 21st century and propose the countermeasures to alleviate the side-effect of mitigation policy.

２．研究の目的

This study aims to investigate the potential impact of climate change (elevated atmospheric CO2) and climate mitigation on human nutrient deficiency and explore the countermeasures. In specific, it aims to answer the following research questions: (1) What are the effects of elevated CO2 and climate change nutrient deficiency (iron, zinc, and vitamins) in 2050 ? (2) What are the effects of climate mitigation policy on nutrient deficiency in 2050? (3) What countermeasures could offset the negative effect of mitigation (such as trade, redistribution, and bioenergy tax)?

３．研究の方法

This study adopted an integrated assessment modeling framework, with the combination of various approaches. The impact of elevated CO_2 on nutrient deficiency was simulated by combining future dietary scenario, nutrient density data under high CO_2 concentrations, and regression analysis. The impact of climate mitigation policy on nutrient deficiency was investigated with a series of integrated assessment models, which allow the incorporation of biophysical condition, socioeconomic change in future, and policy intervention simultaneously. The exploration of countermeasures was implemented through dietary change scenario analysis.

４．研究成果

(1) The impact of elevated CO_2 on nutrient deficiency

Using the Chinese adult population as the study population, results (Table 1) suggest that for protein, mean daily intake was predicted to decrease by 4.6% (4.75%) for males (females); as a result, the prevalence of protein deficiency will increase by 4.42% (3.90%), which is an additional 27.14 million adults (males, 15.20 million; female, 11.94 million) with protein deficiency. For iron, mean daily intake was predicted to decrease by 2.23% (2.17%), although the absolute reduction is small (males, 0.48 mg; females, 0.39 mg). As a result, the prevalence of iron deficiency will increase by 1.35% (1.77%), or an additional 10.06 million adults (males, 4.64 million; females, 5.42 million). For zinc, mean daily intake was predicted to decrease by 3.29% (3.44%) for male (female); as a result, the prevalence of zinc deficiency will increase by 3.29% (3.40%), which is an additional 21.73 million adults (males, 11.32 million; females, 10.41 million) with zinc deficiency.

Table 1. Changes in nutrient daily intake and deficiency prevalence under the 550-ppm CO_2 scenario.

(a) Male	Protein		Iron		Zinc	
	Percentage	Absolute	Percentage	Absolute	Percentage	Absolute
Mean daily intake	−4.60%	−3.75 g	−2.23%	−0.48 mg	−3.29%	−0.37 mg
Deficiency prevalence	+4.42%	15.20 m.	+1.35%	4.64 m.	+3.29%	11.32 m.
(b) Female	**Protein**		**Iron**		**Zinc**	
	Percentage	Absolute	Percentage	Absolute	Percentage	Absolute
Mean daily intake	−4.75%	−3.27 g	−2.17%	−0.39 mg	−3.44%	−0.32 mg
Deficiency prevalence	+3.90%	11.94 m.	+1.77%	5.42 m.	+3.40%	10.41 m.

Note: m. (million)

Nutrient loss rates would be greater for lower-income groups than for higher-income groups (Figure 1). The average nutrient loss rate of the lowest income group (D1) was 1.54 (protein), 1.44 (iron), and 1.37 (zinc) times that of the highest income group (D10). The difference of percentage changes for the lowest income group and the highest income group was 1.81%, 0.84%, and 1.12% for protein, iron, and zinc, respectively.

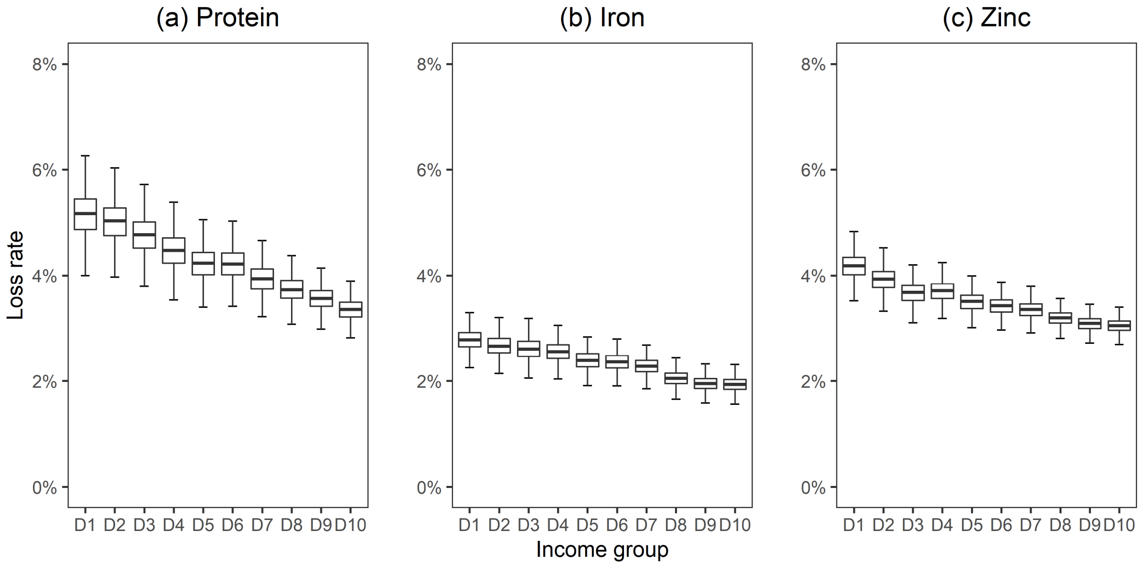

Figure 1. Nutrient loss under the 550-ppm CO2 scenario stratified by income class. (D1 denotes the lowest income group and D10 denotes the highest income group)

Nutrient losses for the pairs of nutrients were highly positively correlated, implying that individuals who experience a large reduction in intake for one nutrient also experience a large reduction in intake for the other two nutrients. In addition, the lower-income groups are concentrated toward the upper-right corner in all three plots, suggesting that the lower-income populations will experience pronounced losses of all three nutrients simultaneously.

(2) The impact of climate mitigation policy on nutrient deficiency

Simulation of various agroeconomic models revealed that the extent to which three factors—non-CO2 emissions reduction, bioenergy production and afforestation—may change food security and agricultural market conditions under 2°C climate-stabilization scenarios. Under climate mitigation policy for such a target, global average calorie availability decreases by 117 (19–142) kcal per capita per day, and the population at risk of hunger increases by 117.7 (19.5–155.4) million in 2050, and that increases over the period (Figure 2).

Decomposition of individual factor shows that afforestation could have a large impact on food security relative to non-CO2 emissions policies (generally implemented as emissions taxes). Respectively, these measures put an additional 41.9 million and 26.7 million people at risk of hunger in 2050 compared with the current trend scenario baseline. This highlights the need for better coordination in emissions reduction and agricultural market management policies as well as better representation of land use and associated greenhouse gas emissions in modelling.

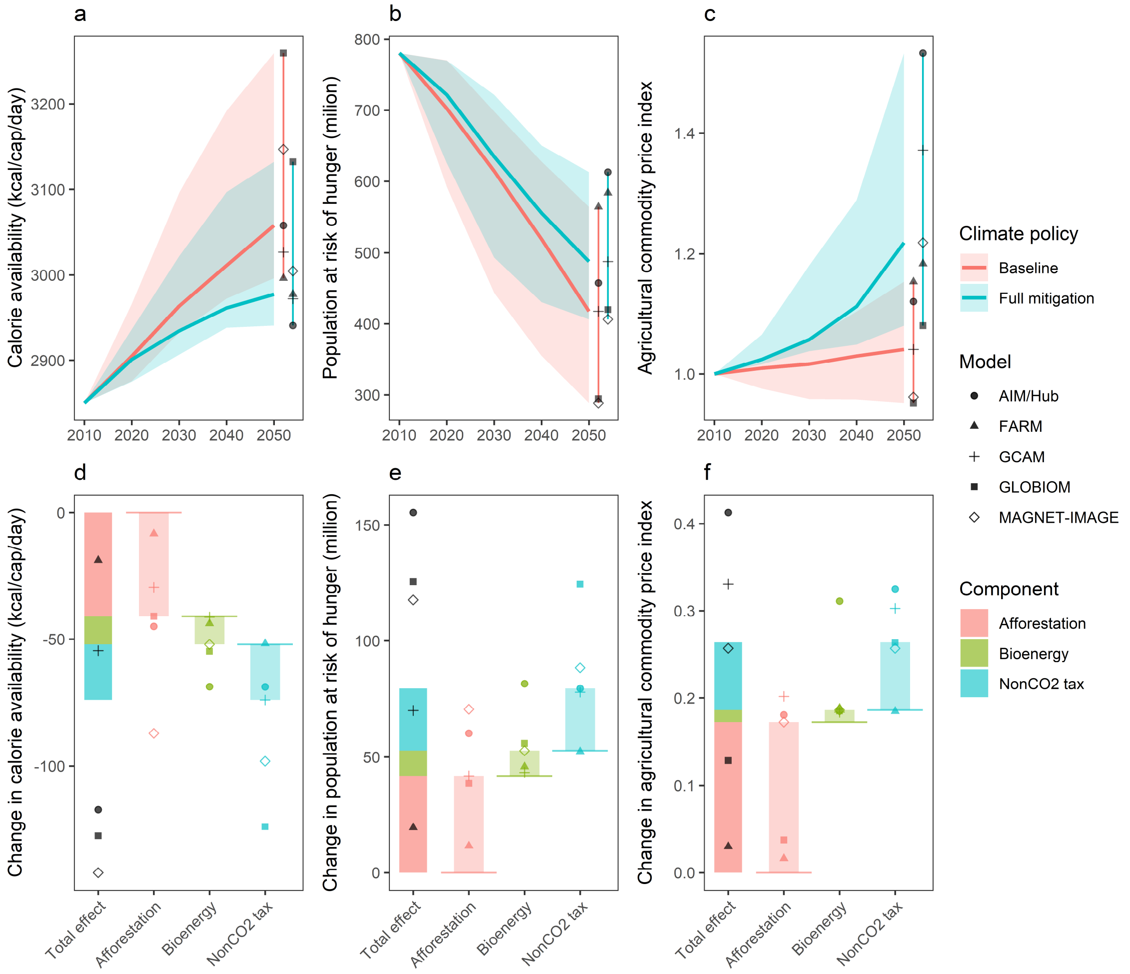

Figure 2. The aggregate and individual effect of mitigation option on hunger

(3) The contribution of dietary change to nutrition and climate mitigation

Dietary change scenarios in 2050 were constructed to realize both nutrition and mitigation targets. Simulation results suggest that the potential forage fish supply could replace 10% of global ruminant meat consumption, which could reduce global ruminant related GHG emissions and land use by up to 15% and 10%, respectively. In addition, such a dietary change could also increase the intake of several essential nutrients, such as omega-3 fatty acids (DHA and EPA), vitamin B12, and calcium.

5．主な発表論文等

〔雑誌論文〕　計3件（うち査読付論文　3件／うち国際共著　3件／うちオープンアクセス　3件）

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掲載論文のDOI（デジタルオブジェクト識別子） 10.1038/s43016-022-00464-4	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

1．著者名 Wu Wenchao、Takahashi Kiyoshi、Zhou Lin、Jin Shaosheng	4．巻 265
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オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

1．著者名 Leclere David、et al. including Wu Wenchao	4．巻 585
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オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

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〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関