“Can Climate Mitigation and Sustainable Food Systems Enhance Global cropland Soil Organic Carbon Sequestration ?”

Dianti Farhana KAMASELA[1], Shinichiro FUJIMORI[1], Tomoko HASEGAWA[1,2] and Saritha Sudharmma VISHWANATHAN[1]
[1]Department of Environmental Engineering, Graduate School of Engineering, Kyoto University, Japan (C-cluster, 1-3-367, Kyoto daigaku-katsura, Nishikyo-ku, Kyoto 615-8540 JAPAN)
[2]Department of Civil and Environmental Engineering, College of Science and Engineering, Ritsumeikan University, Kyoto, Japan

1 Introduction

Soil Organic Carbon (SOC) sequestration is increasingly recognized as a nature-based solution to mitigate climate change. Studies have shown that improved land management practices, can effectively enhance SOC stocks. However, the availability and selection of land for SOC sequestration varies depending on the pathways chosen and the specific land-based mitigation strategies implemented. This study filled that gap by evaluating the Global SOC sequestration potential in crop and bioenergy lands under three major land-use pathways: business-as-usual, sustainable food system, and a 2°C climate target, and a 2°C climate target.

(Lal, 2004; Smith et al., 2008; Zomer et al., 2017; Roe et al., 2021, Minasny et al., 2017, Smith et al., 2013; Havlík et al., 2014; Hertel, 2015; Searchinger et al., 2015; Kreidenweis et al., 2016; Popp et al., 2017; Frank et al., 2017, Hasegawa et al., 2017; Roe et al., 2021, Leclère et al., 2020; Jansakoo et al., 2024)

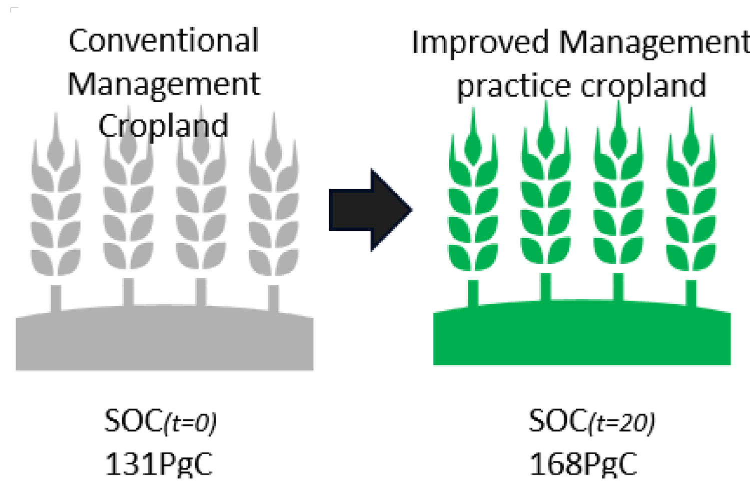

Fig 1. Principle of SOC sequestration by Improved Management Practice

2 Model and Methods

The study framework begins with the assessment land areas for the demand of crops, grasslands, bioenergy, and forests by AIM-Hub model, tailored for each land use scenario. The regional land demand is subsequently integrated into AIM-PLUM model, the land allocation is done by profit-maximization. Carbon sequestration is calculated by multiplying $\Delta SOCV_n$ by the allocated area and management practice implement. Scenario setting consist of : Business-as-Usual (BAU) as continuation of current land-use trends with no major interventions; serves as the baseline, Climate Mitigation (2°C Scenario) where Land allocation limits cumulative CO_2 emissions to 500 $GtCO_2$ post-2020, aiming for a 50% chance to stay below 1.5°C warming (Fujimori et al., 2016) and Sustainable Food System, which Integrates dietary shifts, food waste reduction, and trade openness to balance food, health, and climate goals

$$GHG_n = \Delta SOCV_n \times r \times Ar \times \frac{44}{12} \times LA_{(l,n)}$$

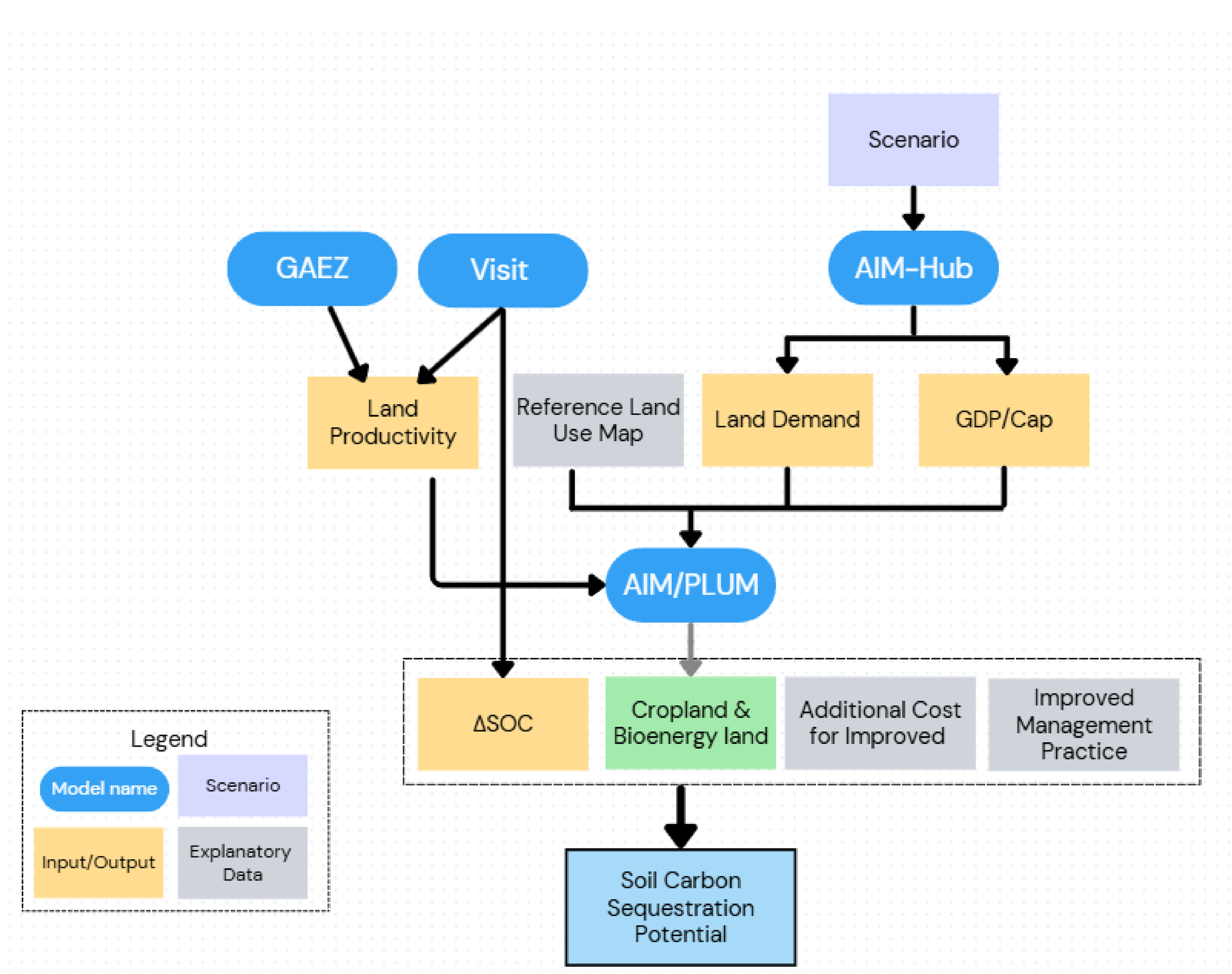

Fig 2. Overall Research Framework

3 Results

Key findings : Our results show that Food and climate policies play crucial roles in shaping land-use transitions, which in turn drive overall small increased in SOC sequestration potential.

The 2Degree scenario resulted in a reduced cropland area compared to the BAU case. However, this decrease was accompanied by substantial expansion of land for bioenergy production to up to 500 Mha of the total land allocated for SOC sequestration. The FOOD scenario featured a low proportion of cropland, resulting in a small increase in overall carbon sequestration potential compared to BAU

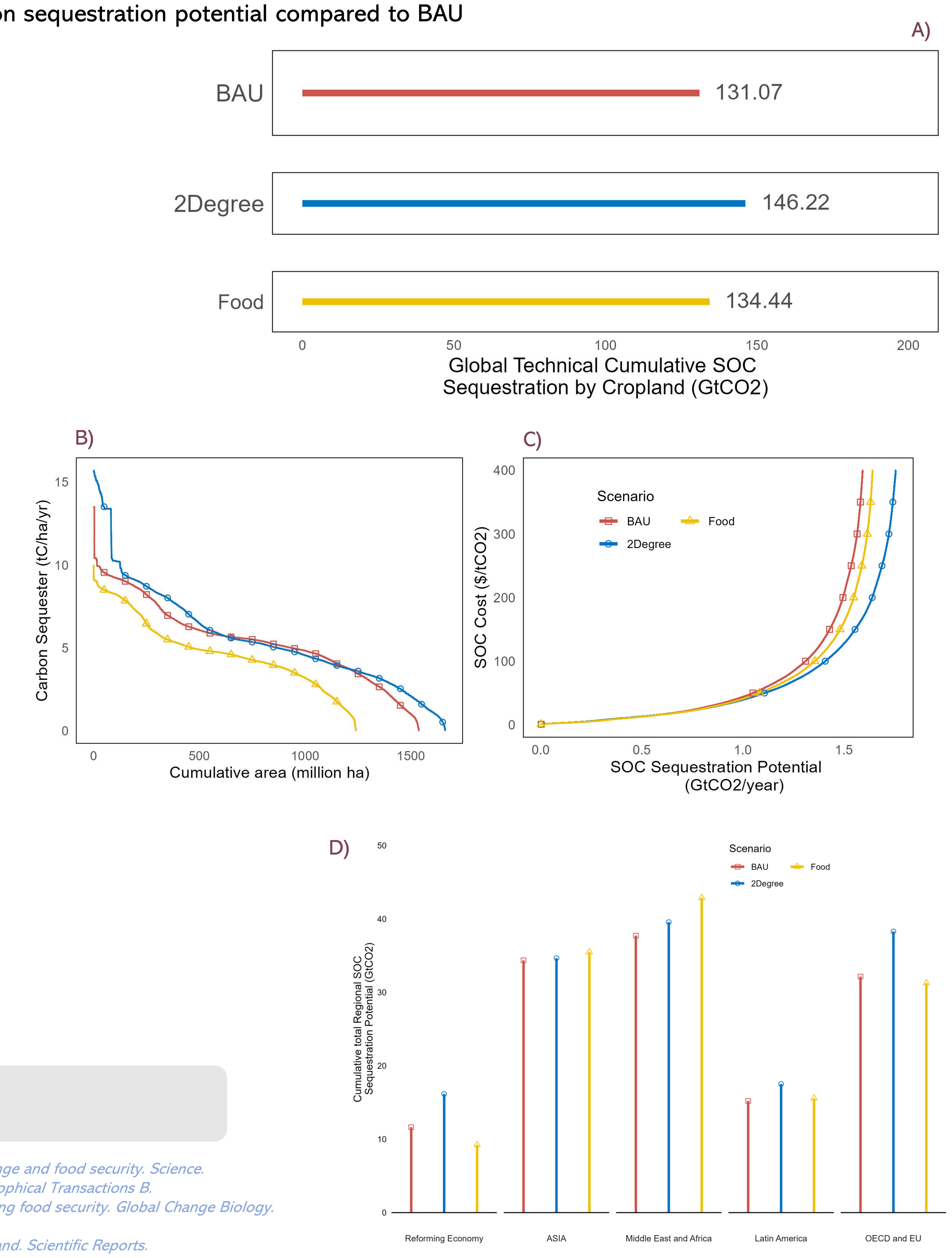

Fig 3. A) Global SOC sequestration potential, B). Yield productivity curve, C). Carbon supply curve, D). Regional Potential

4 Discussion

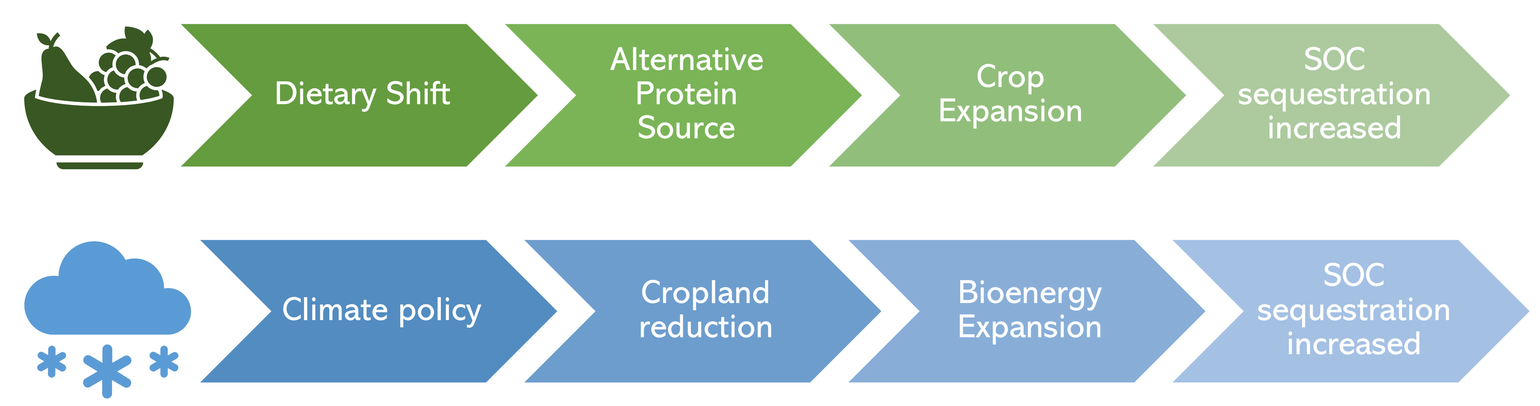

Fig 4. The effect of Climate and Food policy to Global SOC sequestration

Under the 2°C scenario, cropland area declines, but bioenergy land expands up to 500 Mha, contributing substantially to SOC sequestration. The FOOD scenario leads to only a slight SOC increase due to reduced cropland availability. Regions like Reforming Economies, Middle East & Africa, Latin America, and OECD/EU see SOC gains from bioenergy expansion. In contrast, dietary shifts reduce cropland in Reforming Economies, Latin America, and OECD/EU, causing a decline in SOC potential. OECD countries, especially the USA, show the highest cost-efficiency in SOC sequestration, supported by advanced infrastructure and funding. ~90% of global SOC potential can be achieved at costs below \$100/tCO_2, confirming its economic feasibility as a climate strategy. **70%** of the global potential contributed from Middle East, Africa, and Asia due to its high cropland area.

5 Acknowledgement

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