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Global analyses of climate mitigation for achieving net-zero emissions and sustainable development

世界を対象としたネットゼロ排出達成のための気候緩和策及び持続可能な開発

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Background of the research project

- The Paris Agreement / 2℃・1.5℃ Target → Net-Zero emission
  - In the Paris Agreement, countries around the world agreed to the so-called 2° C target as their long-term climate goal. Following the IPCC 1.5° C Special Report, voices in favor of the 1.5° C target are growing.
  - To achieve either goal, it is essential to achieve net-zero greenhouse gas emissions in the second half of the 21st century, or, depending on emissions in the first half of the century, negative emissions (absorption and sequestration) using large-scale bioenergy crops and afforestation.
- The feasibility and difficulty of achieving net-zero emissions must be examined
  - What measures and policies are necessary to achieve net-zero emissions? What are the paths of social development and change that are the premise for the implementation of these measures and policies?
  - Are there any serious ripple effects that the implementation of measures and policies will have on the sustainability of human society and ecosystems in ways other than climate impacts?
  - What are the changes in the carbon cycle and climate system, and the climate impacts of each sector under a net-zero emission situation?

Research objective and goals

Research objective : By presenting the emission pathways necessary to achieve climate goals, evaluating the climate impacts that would result from those emission pathways, and examining strategies for climate mitigation that take sustainability into account, we aim to provide an answer to the question, "What kind of society will we create and accept in order to achieve net-zero emissions without compromising the sustainability of human society and ecosystems?" in a form that can be understood by citizens and policymakers

- Analysis of emission pathways corresponding to climate goals and socio-economic development paths
- Integrated assessment of climate impacts that quantitatively considers the uncertainties of social and climate change
- Strategic consideration of climate mitigation measures that take sustainability into account

Summary of the research outputs

・Mitigation for the 1.5/2° C target may have negative spillover effects on other SDGs, and additional policies are needed to mitigate them.

・Mitigation measures involving land use changes have a negative impact on biodiversity.
・Comprehensive land management from both the perspectives of climate management and biodiversity protection is necessary.
・Food system transformation is key.

- Climate mitigation measure… …ustainabl… emissions
  - Integrated assessment of climate mitigatio… marginal SDG emission reduction indicato…
  - Impact of climate mitigation measures o… biodiv…
  - Conserving biodiversity through nature conservation and restoration and food system …

・Emphasis on the need for additional adaptation measures in addition to adhering to the 1.5/2° C target

…om land-related GHG emission reduction …

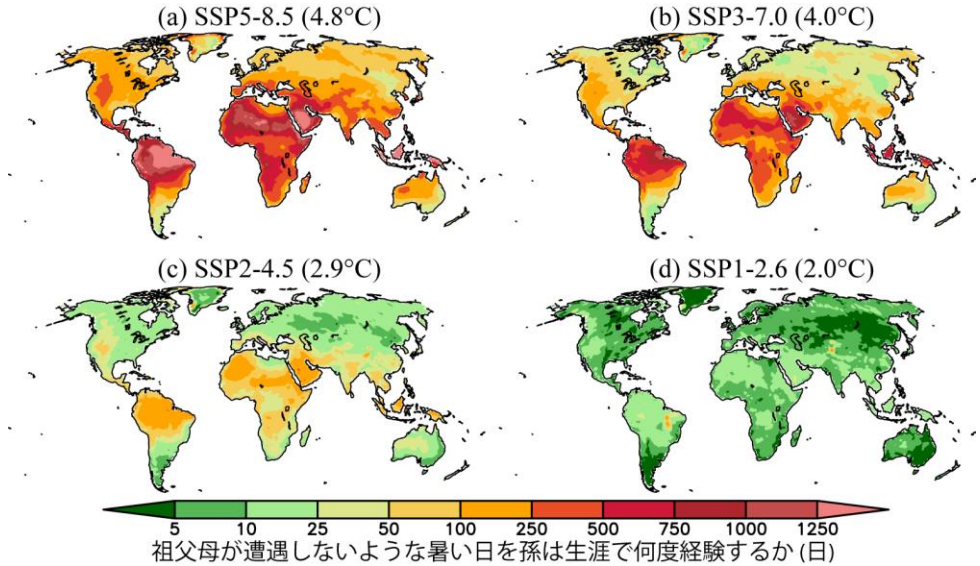
…d land use strategies under climate change …

  - Poverty alleviation policy … …on tax revenue
  - Assessment of environmental … …alth impacts … replacing red meat with small pelagic fish
- Climate mitigation measures and cli… …ate impacts
  - Calculation of hunger risk and countermeasures taki… …count future uncertainties
  - Assessment of health impacts caused by clim… changes in PM2.5 concentration in wildfires

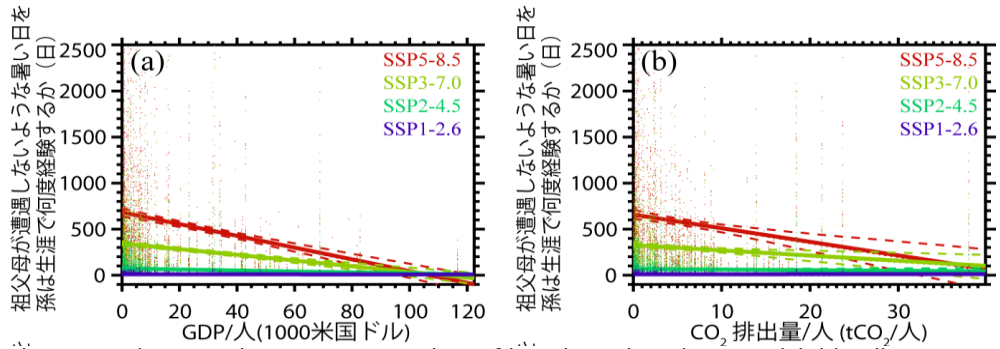
・Importance of international cooperation in simultaneously achieving SDGs and climate goals

Intergenerational inequality and regional inequality in changes in extreme weather events

- Proposal and estimation of indicators for **"how many times will grandchildren experience hot days and heavy rains that their grandparents never encountered in their lifetimes"**
  - In a scenario where climate change mitigation does not progress well (SSP5-8.5), grandchildren will experience more than 1,000 hot days (about 400 in Japan) and more than 5 heavy rain days (about 3 in Japan) in parts of the tropics.
- Comparing current per capita GDP and CO2 emissions with the number of extreme weather events
  - The poorer a country is and the lower its CO2 emissions, the greater the intergenerational inequality in the frequency of unprecedented hot days.
  - Mitigation measures to meet the 2° C target (SSP1-2.6) will also be effective in narrowing regional disparities in intergenerational inequality.



If a grandparent who was 60 years old in 2020 has a grandchild, and the grandchild lives to age 80, how many hot days will the grandchild experience in his or her lifetime that the grandparents never experienced? The median value of the model group is shown. The number in parentheses is the model-averaged global mean temperature rise from 1851-1900 to 2080-2100.



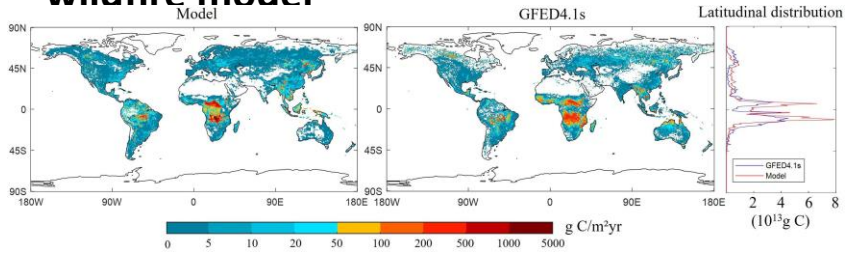
The vertical axis is the average number of hot days that the grandchild will experience in his or her lifetime that the grandparents never experienced, averaged across countries. The horizontal axis of the left figure is GDP per capita (2010-2018; World Bank estimate), and the horizontal axis of the right figure is CO2 emissions per capita (2018; Global Carbon Project). The dots are the average values for each country, the solid line is the regression line, and the dashed line is the 95% confidence interval of the regression line.

Shiogama et al. (2021) How many hot days and heavy precipitation days will grandchildren experience that break the records set in their grandparents' lives? *Environmental Research Communications*, **3**, 061002.

Wildfire, air pollution and human health impacts

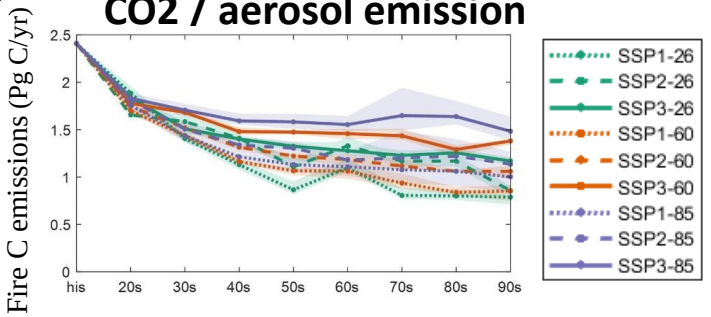
・In present (2006-2015), about 10% of the total PM2.5 in the atmosphere is attributed to wildfire and about 90,000 PM2.5-related deaths are attributed to wildfires.
・In the mid of the century, wildfire's PM2.5 mortality is projected to decrease in most scenarios and regions.
・Toward the end of the century, increase in wildfire's PM2.5 mortality is projected.

Development and validation of wildfire model



- Consideration of socio-economic factors
- Validation of the model (comparison with the obs.)

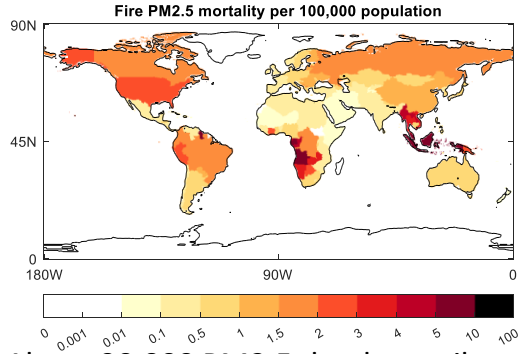
Projection of wildfire and CO2 / aerosol emission



- Larger carbon release under RCP8.5
- General decreasing trend by economic growth

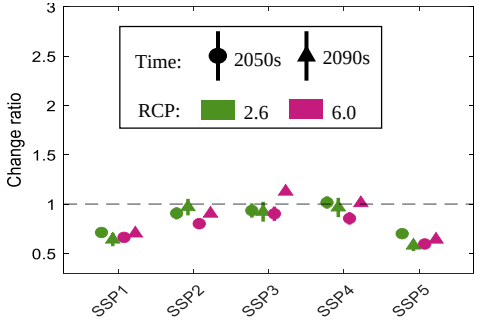
Park et al. (2023) Impact of climate and socioeconomic changes on fire carbon emissions in the future: Sustainable economic development might decrease future emissions. Global Environmental Change, 80, 102667.

Mortality caused by wildfire PM2.5 emission



- About 90,000 PM2.5 deaths attributed to wildfires
- Relatively high mortality in tropical

Future projection of health impact

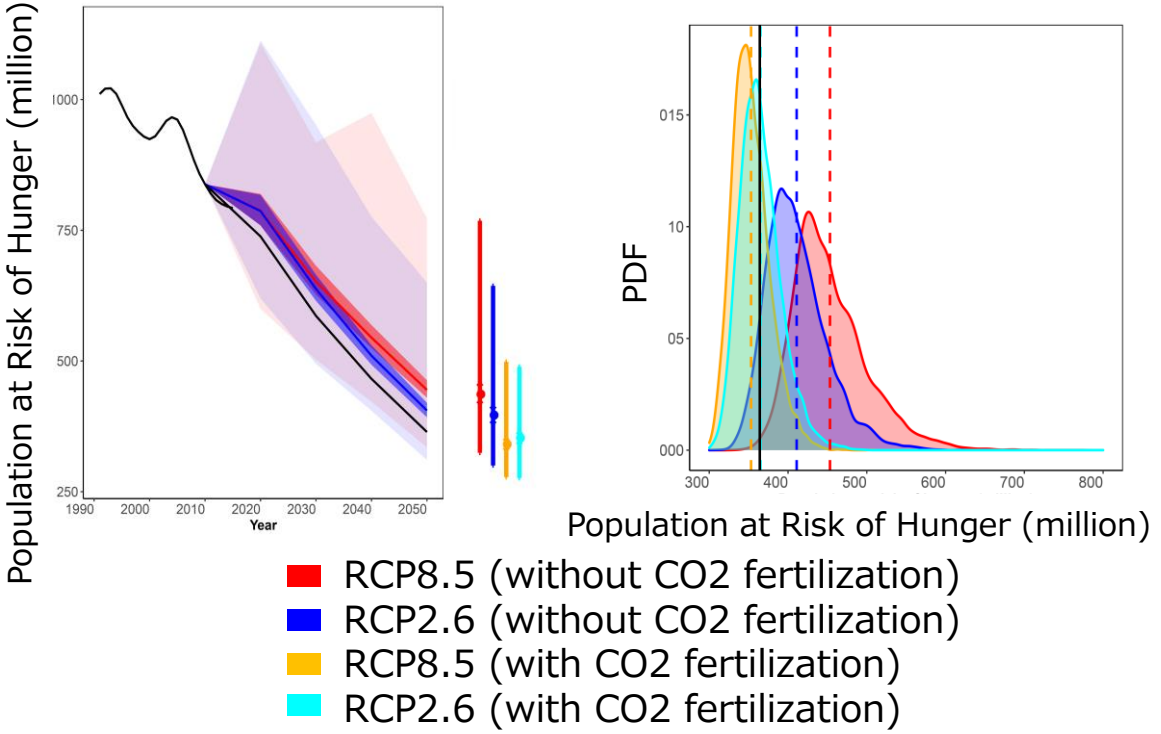


- Mortality increase in 2090s under SSP3-6.0 and SSP4-6.0
- Increase in low-income countries in SSP4 (inequal world).

Park et al. (2024Future fire PM 2.5 mortality varies depending on climate and socioeconomic changes. Environmental Research Letters, 19(2), 024003.

Extreme climate events increase risk of global food insecurity and adaptation needs

- Considering uncertainties in crop model and climate, impact of extreme weathers on food security is projected.
- Relative to median-level climate change, we find that an additional 20–36% and 11–33% population may face hunger by 2050 under a once-per-100-yr extreme climate event under high and low emission scenarios, respectively.
- In some affected regions, such as South Asia, the amount of food required to offset such an effect is triple the region's current food reserves.



Probability distributions of risk of hunger

Left: risk of hunger with climate variability under the two climate pathways up to 2050 with and without CO2 fertilization effects. Areas show the ranges from the highest to the lowest (lighter shading) and the 65th percentile to the median (darker shading) values. The red and blue lines show the median levels. **Right: Probability density functions for 2050 under two climate pathways for risk of hunger.** The red and blue dashed vertical lines show the median levels. The black lines in all panels show the baseline levels with no climate change. The ranges in the panels represent the uncertainty of interannual climate variability, multiple GCMs and crop model parameters.

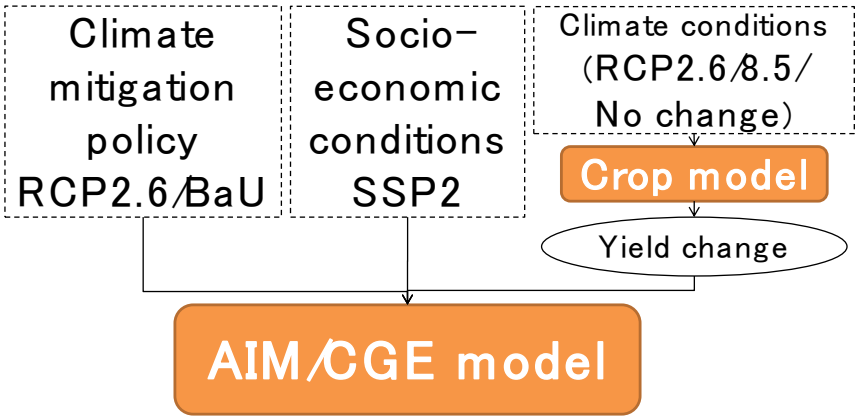
Hasegawa et al. (2021) Extreme climate events increase risk of global food insecurity and adaptation needs. *Nature Food*, **2**, 587-595.

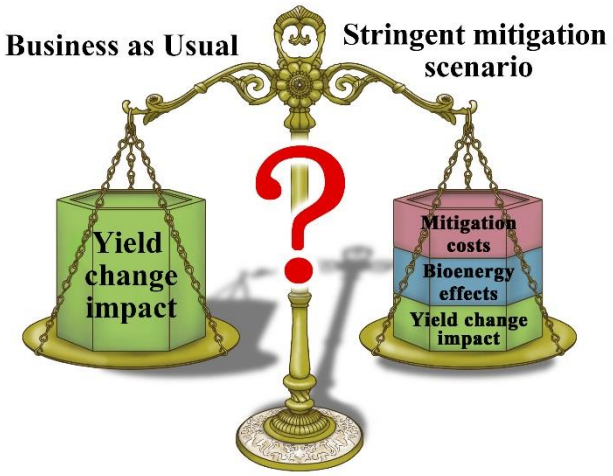
Sustainable Development Goals and climate policy

Trade-off ? Co-benefit ?

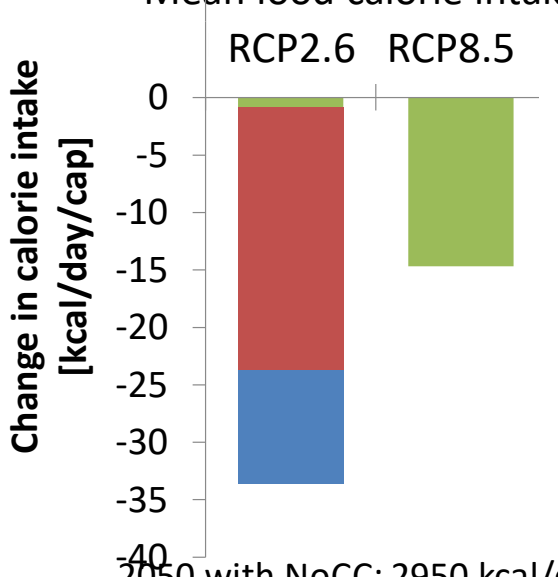
Consequence of climate mitigation on the risk of hunger

Methods



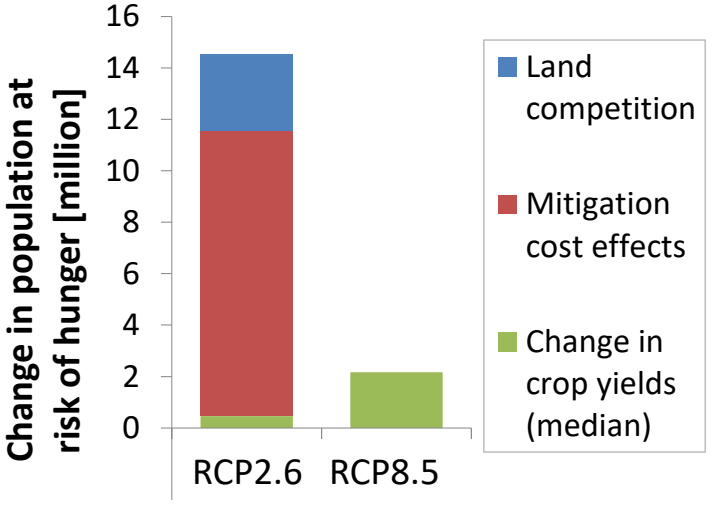


Mean food calorie intake



2050 with NoCC: 2950 kcal/cap/day
2005: 2680 kcal/cap/day

Global population at risk of hunger



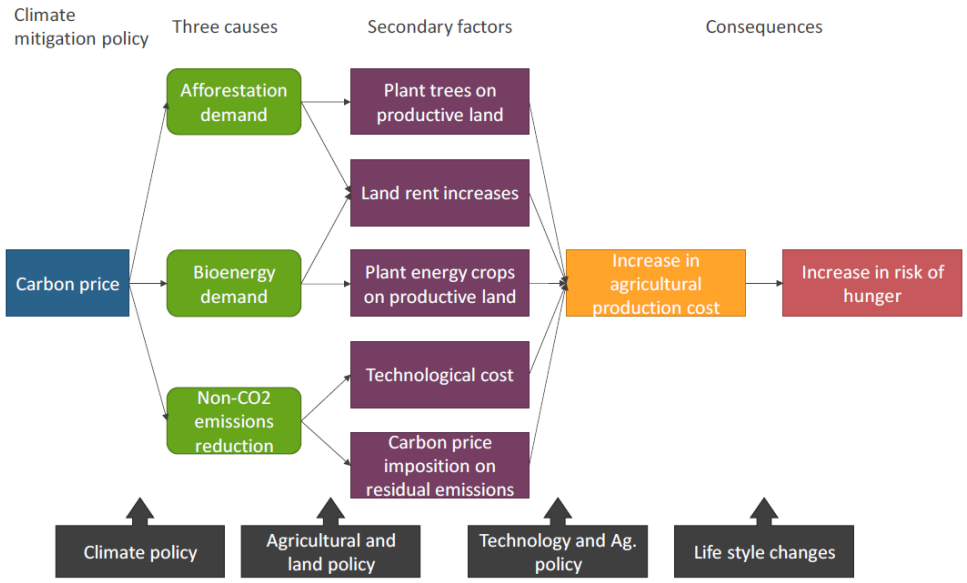
2050 with NoCC: 90 mil.
2005: 830 mil.

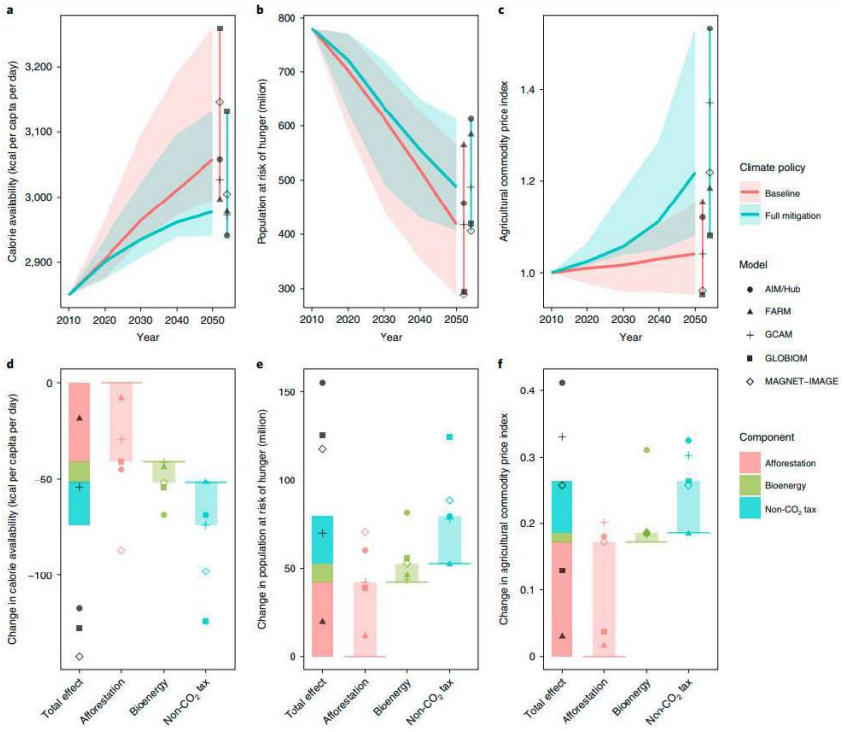
Hasegawa et al. (2015) Consequence of Climate Mitigation on the Risk of Hunger. Environmental Science & Technology, 49 (12)

Decomposition analyses of impacts of climate policies on food security

Using six global agroeconomic models, we showed the extent to which three factors—non-CO_2 emissions reduction, bioenergy production and afforestation—may change food security and agricultural market conditions under 2 ° C climate-stabilization scenarios.

Results showed that afforestation (often simulated in the models by imposing carbon prices on land carbon stocks) could have a large impact on food security relative to non-CO_2 emissions policies (generally implemented as emissions taxes).





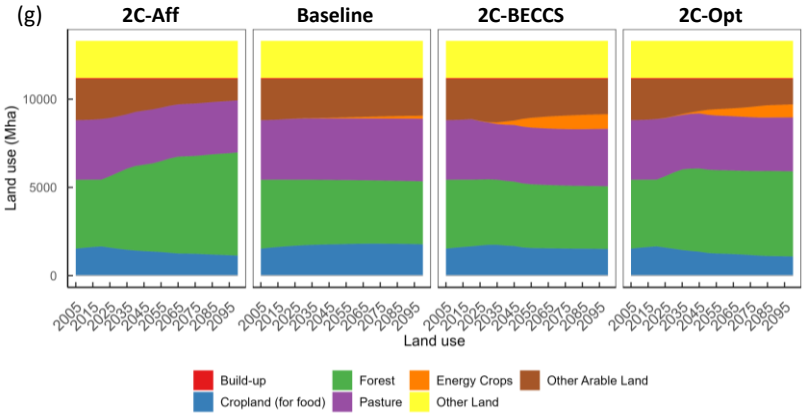
Fujimori, Wu and et al. (2022) Land-based climate change mitigation measures can affect agricultural markets and food security. Nature Food

Impact of achieving the 2°C target through the introduction of CDR (BECCS and afforestation) on biodiversity

Scenarios

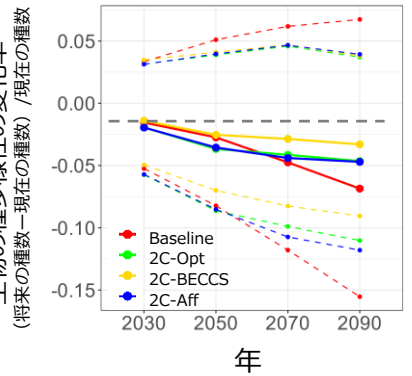
シナリオ名	気候シナリオ	概要
Baseline	SSP3-7.0	No special mitigation measures will be implemented
2C-Aff	SSP1-2.6	The demand for biofuels will be almost eliminated and CDR will be achieved through the introduction of afforestation.
2C-BECCS	SSP1-2.6	The introduction of BECCS will achieve CDR, and forest area will not fall below the Baseline scenario.
2C-Opt	SSP1-2.6	Optimal adoption of BECCS and afforestation

Land use change in each scenario

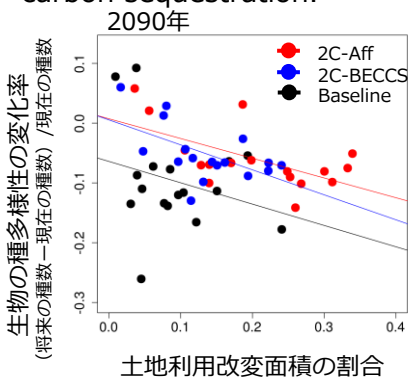


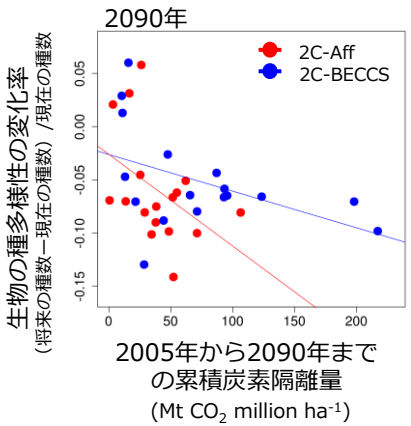
Result

Biodiversity is on a downward trend in all scenarios. Implementing mitigation measures will help to slow this downward trend.



The tendency for biodiversity to decline is greater in areas with greater land use change and areas that contribute to carbon sequestration.

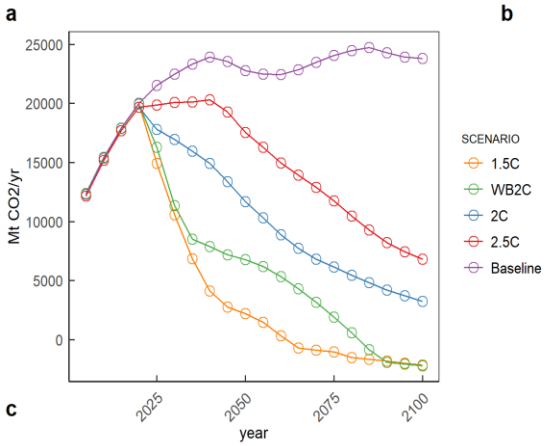




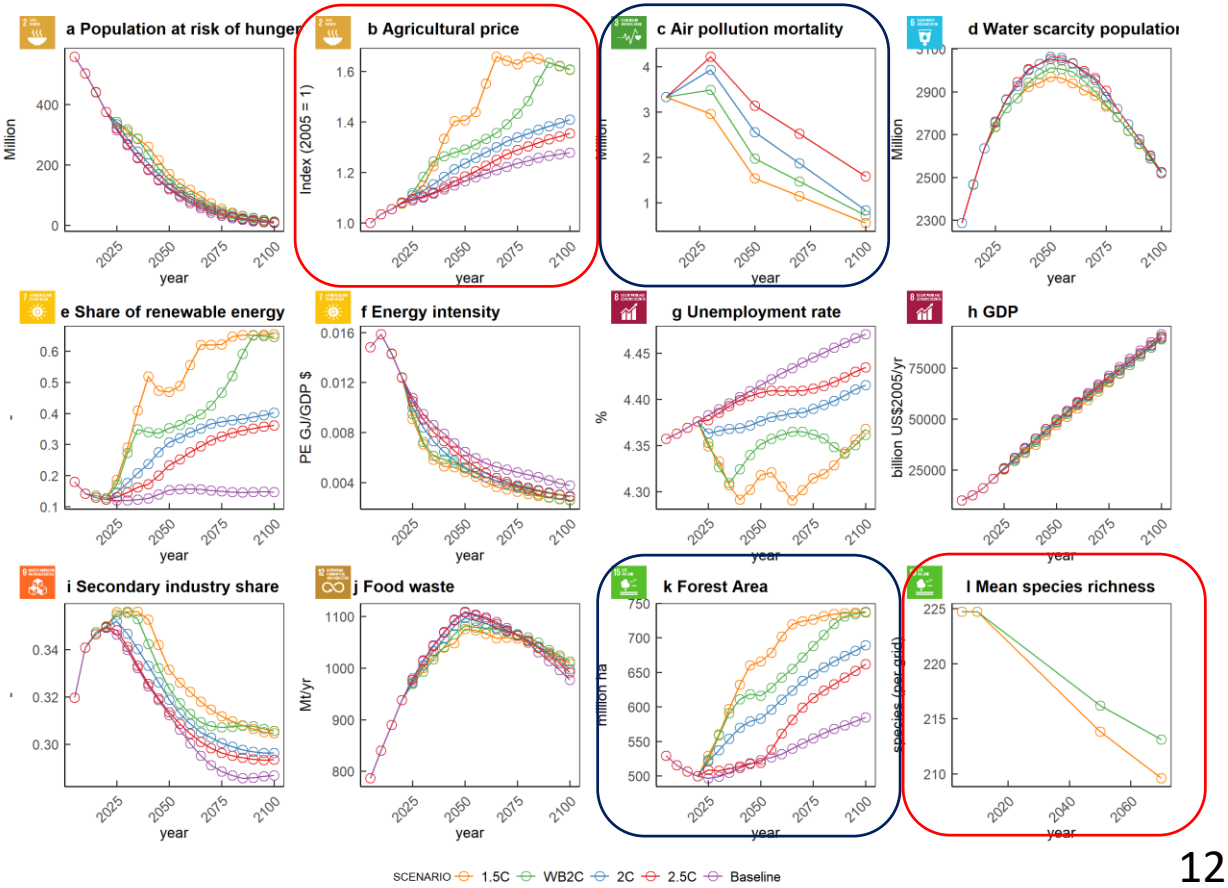
- We conducted an impact assessment of BECCS and afforestation on biodiversity to clarify the differences in the impact on ecosystems due to climate mitigation strategies.
- Even taking into account the impacts of land use change associated with the introduction of BECCS and afforestation, we showed that mitigating climate change through land-use-based mitigation measures has the potential to reduce biodiversity loss.
- However, it was also shown that the impacts of mitigation measures may differ by region. There was a tendency for biodiversity loss to be greater in areas where land use change and carbon sequestration contributed to mitigation.

Hirata et al. (2024) The choice of land-based climate change mitigation measures influences future global biodiversity loss. *Commun. Earth Environ.*

Climate mitigation policy and SDGs



Scenario	Climate target
1.5C	Below 1.5c with probability larger than 50%
WB2C	Below 2.0c with probability larger than 66%
2C	Below 2.0c with probability larger than 50%
2.5C	Below 2.5c with probability larger than 66%
Baseline	Realization of NDC



- Interpretation of the side effects (synergy and tradeoff) of climate policies in the context of SDGs achievement.

Fujimori et al (2020) *ERL*, **10**, *DOI: 10.1088/1748-9326/ab9966*

Health impact assessment of replacing red meat with small pelagic fish

- Red meat, especially processed red meat, is associated with an increased risk of non-communicable diseases.
- It has been pointed out that small pelagic fish contain more nutrients required by the human body than red meat and reduce the risk of non-communicable diseases.

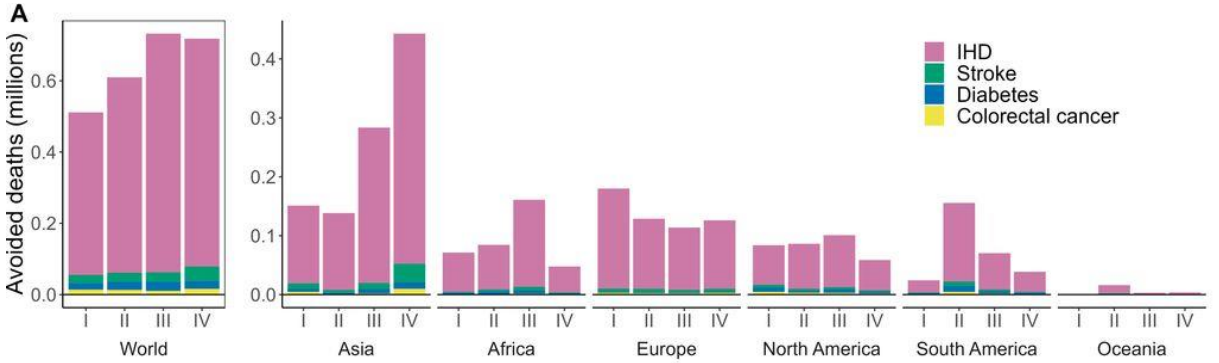
BAU: Consumer preference for red meat remains unchanged by 2050

I: Small pelagic fish caught are consumed domestically, and red meat replacement occurs only in coastal countries

II: Replacement is prioritized in countries with high per capita intake of ruminant meat

III: Replacement is prioritized in countries where per capita fish intake does not meet the recommended intake of 40 kcal/day

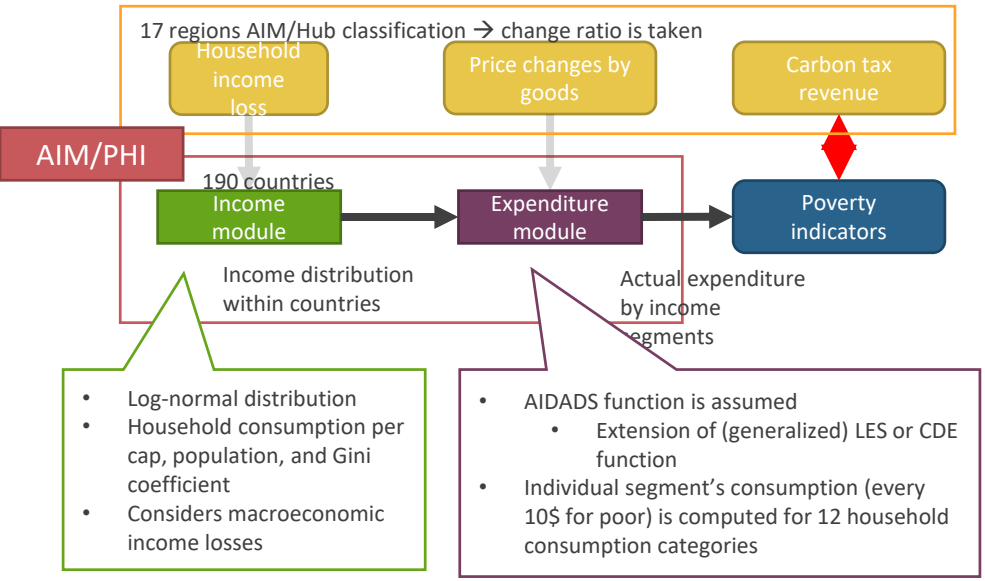
IV: The proportion of red meat replaced by small pelagic fish is uniform in all countries

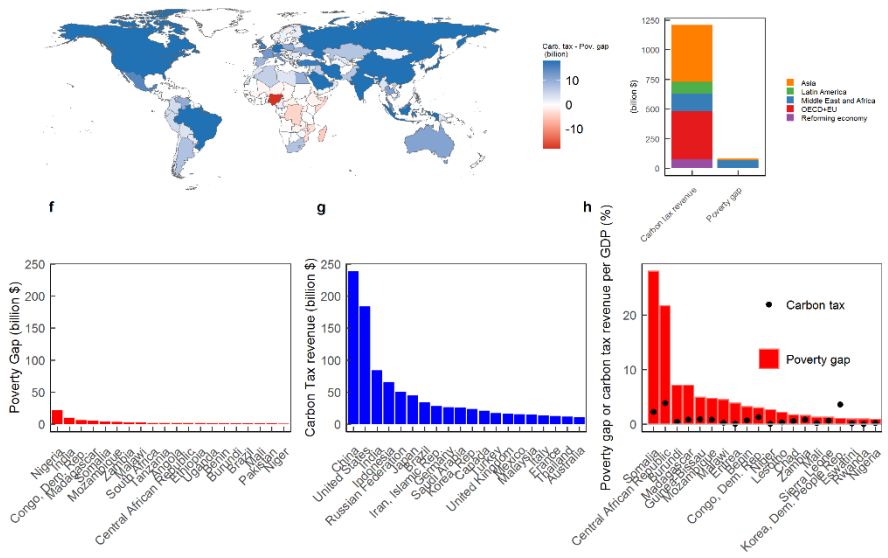


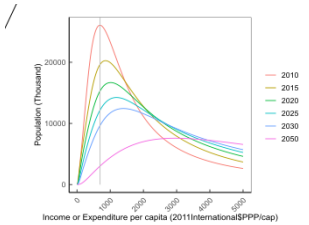
Replacing red meat with small pelagic fish could reduce non-communicable disease deaths by 500,000 to 750,000, potentially avoiding more than double the number of deaths than simply reducing red meat

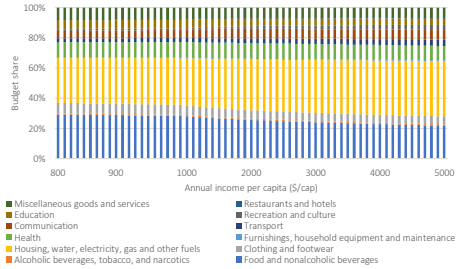
Xia et al., (2024) Unlocking the potential of forage fish to reduce the global burden of disease BMJ Global Health

Country-wise poverty gap and carbon tax comparison









- Carbon tax is much larger than poverty gap.
- Small potion of carbon tax via International transfer might help poverty eradication.

Fujimori et al. (2020) An assessment of the potential of using carbon tax revenue to tackle poverty. *Environ. Resear. Lett.*

Public dialogue / Policy contributions

Co-hosted a webinar (Climate Crisis Initiative Promotion Fund 2-2101)
"What is being discussed around the world about climate change scenarios right now? – Report from Scenarios Forum 2022" (September 2022)

Co-hosted a webinar series with FFFJ (Fridays for Future Japan)
"Young People Ask Series: How bad is climate change?"
(Biodiversity 2021.1 / Food and Agriculture 2021.3)

Report on hunger-related findings at the UN SD High-Level Policy Forum Hasegawa (July 2022/UN Headquarters)

Co-hosted a symposium (S-18/2-2005)
"What will be the effects of climate change? How should we respond? IPCC Sixth Assessment Report and Japanese Research Report" (April 2022)

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