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The 28th AIM International Workshop

Development of an earth system model with human water management, crop growth, and land use change: MIROC-INTEG-ES

Earth System Division,

National Institute for Environmental Studies

Tokuta Yokohata

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National Institute for Environmental Studies, Japan

Collaborators

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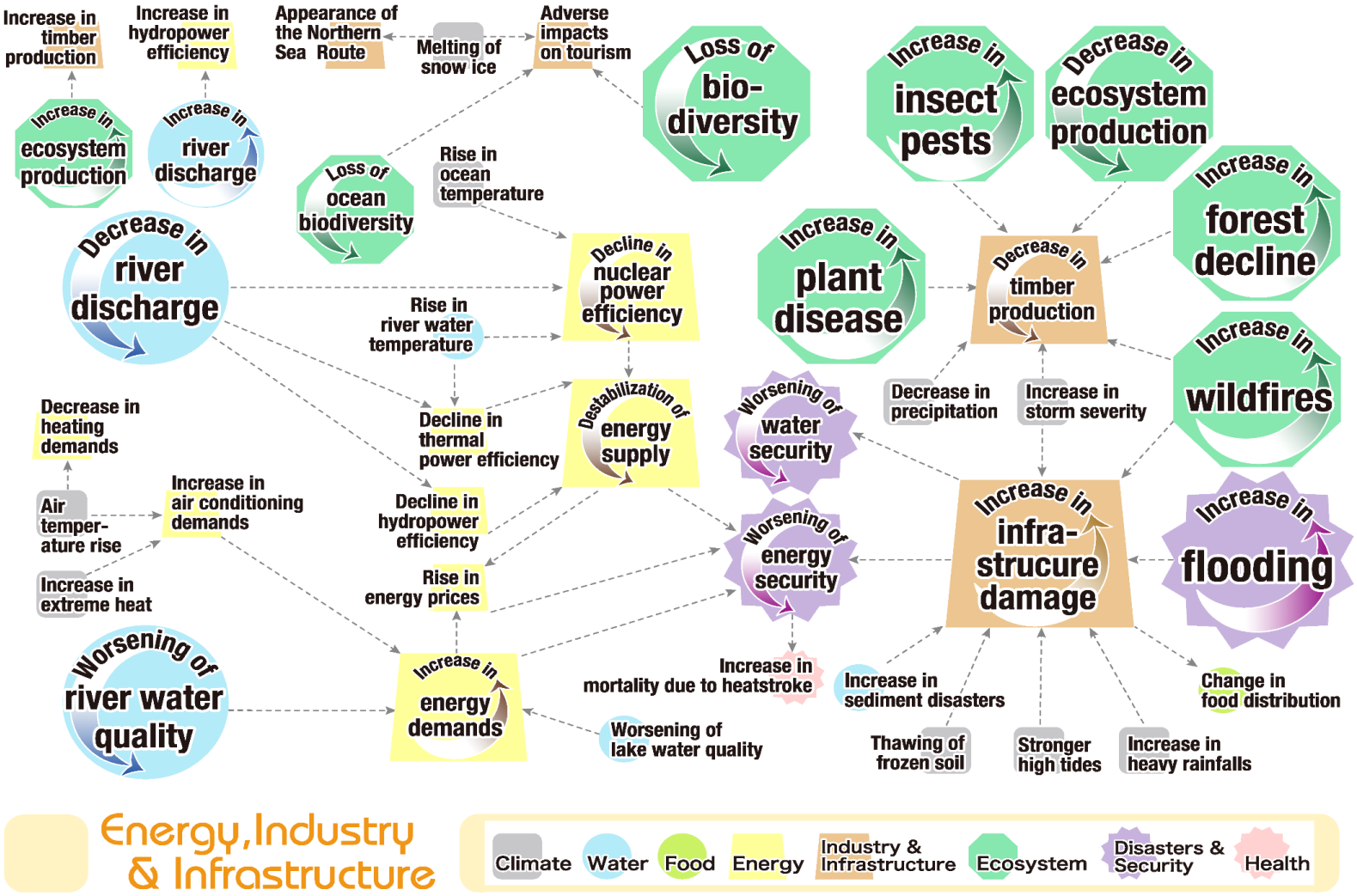
Interaction of Earth-human systems



Visualizing the interconnection of climate risks, Yokohata et al. 2019, Earth's Future

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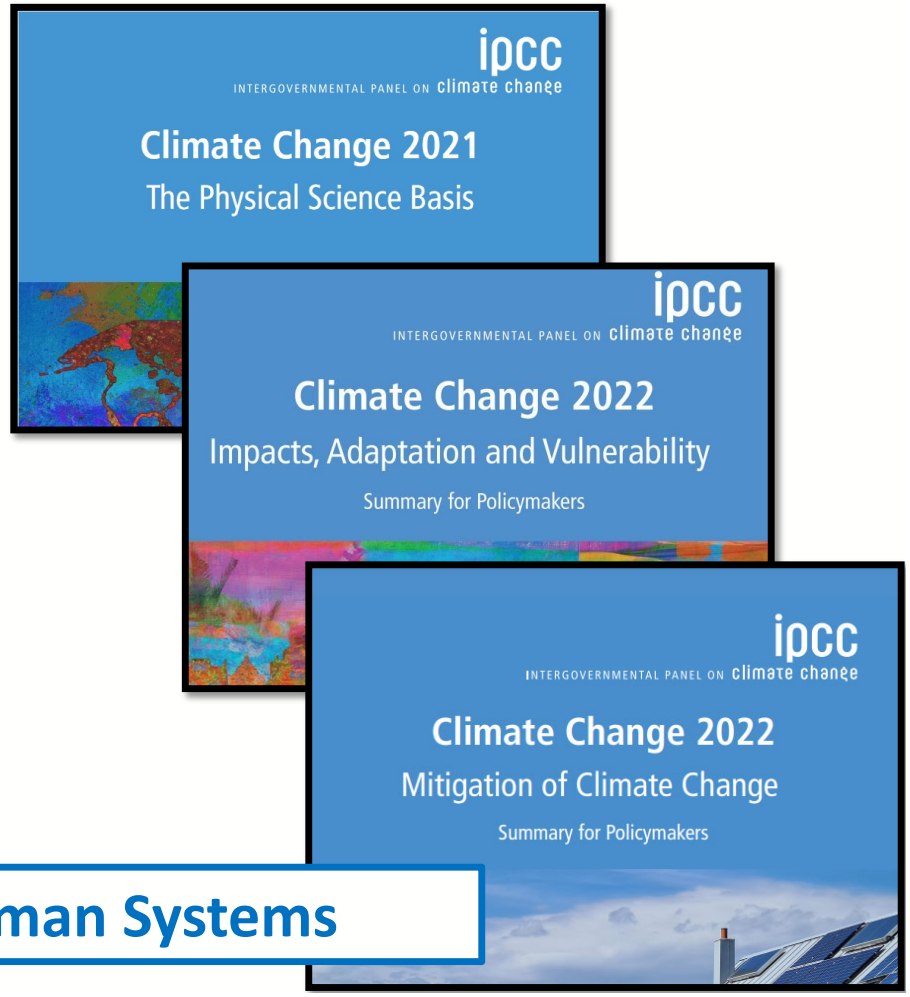
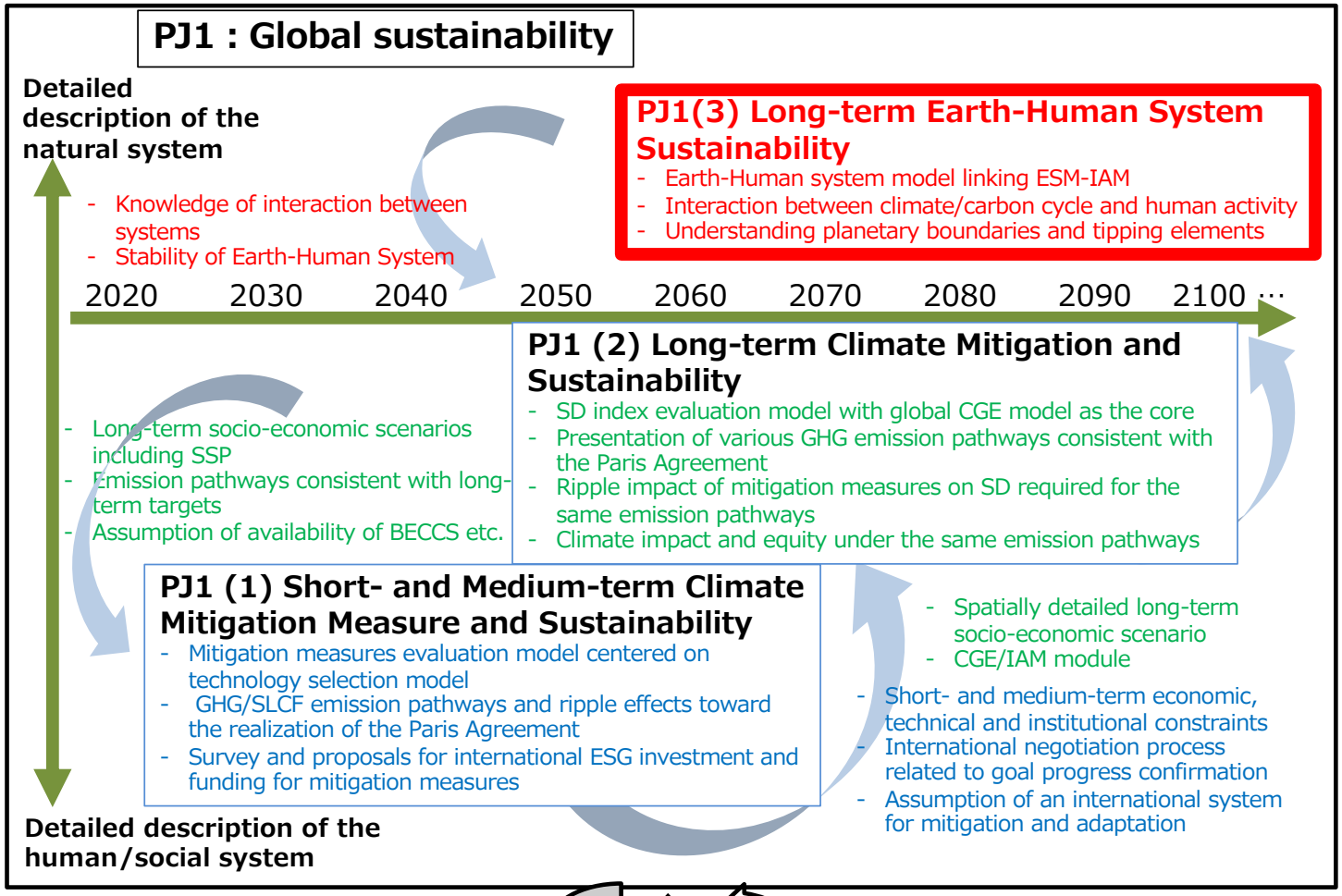
Importance of Earth-Human interaction
(IPCC AR6 WG1, WG2, and WG3)

- Surface air temperature increase
- Decrease/increase in water
  - drought, water stress / flooding
- Desertification / land degradation
- Decline in crop production
- Expansion of cropland area
- Mitigation / adaptation responses
  - Forest management
  - Bioenergy cropland / carbon sequestration



Development of the model with Earth-Human Systems

PJ1:Simultaneous Achievement of Global Decarbonization and Sustainability



PJ3 Equity

Concepts of intergenerational and intragenerational equity and sustainability indicator

Equity within and between generations and Inclusive wealth

PJ2 Asia/ Japan

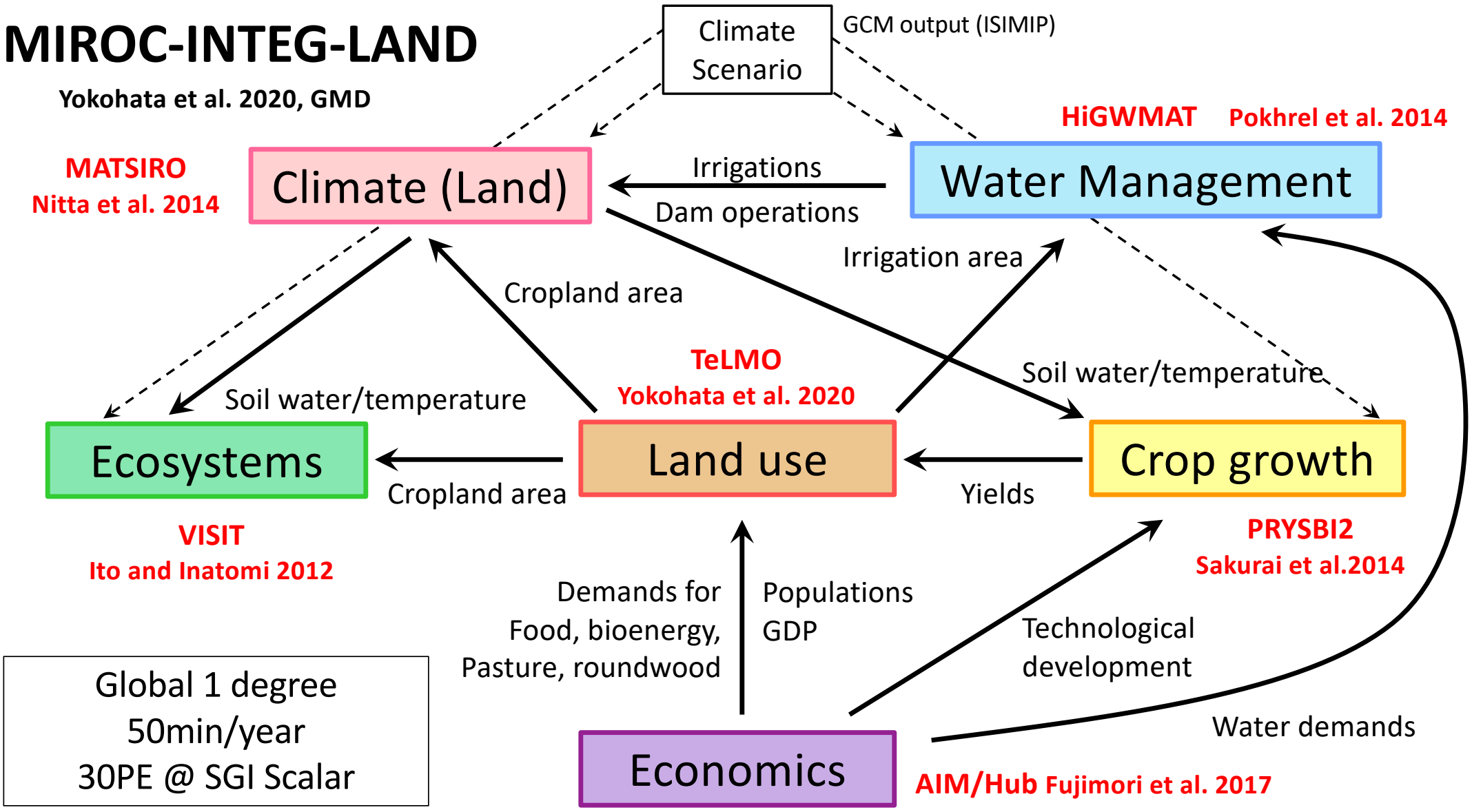
Medium- to short-term GHG emission pathways required for each country

GAP

Medium- to short-term GHG emission pathways that take into account issues for each country

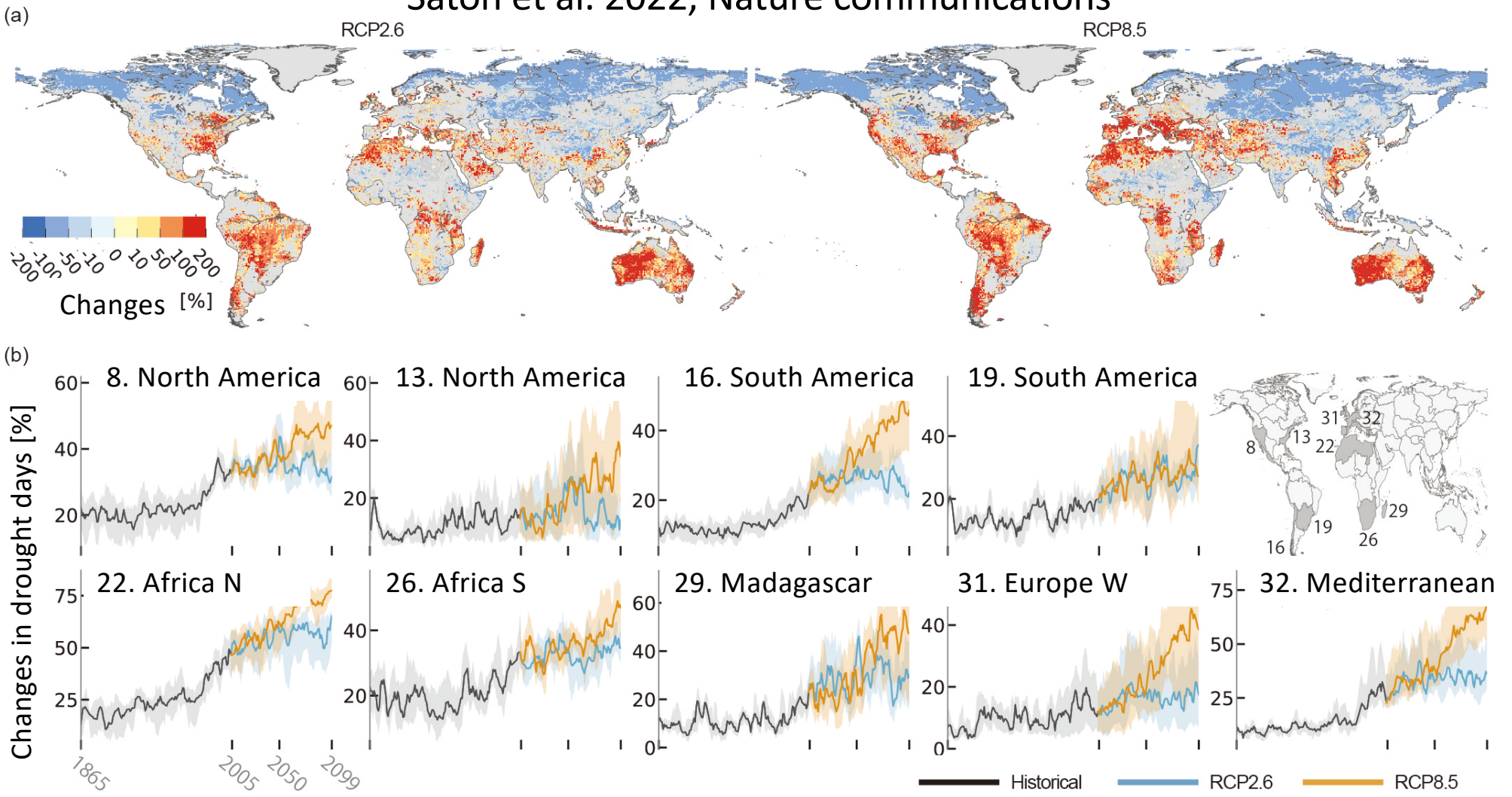
Quantification of National Decarbonization and Sustainable Society Scenarios

Decarbonization and Sustainability Society Research Program


MIROC-INTEG-LAND
Yokohata et al. 2020, GMD
Climate Scenario
GCM output (ISIMIP)
HiGWMAT
Pokhrel et al. 2014
MATSIRO
Nitta et al. 2014
Climate (Land)
Irrigations
Dam operations
Water Management
Irrigation area
Cropland area
Soil water/temperature
TeLMO
Yokohata et al. 2020
Soil water/temperature
Ecosystems
Land use
Crop growth
Cropland area
Yields
VISIT
Ito and Inatomi 2012
PRYSBI2
Sakurai et al.2014
Demands for
Food, bioenergy,
Pasture, roundwood
Populations
GDP
Technological
development
Water demands
Global 1 degree
50min/year
30PE @ SGI Scalar
Economics
AIM/Hub Fujimori et al. 2017

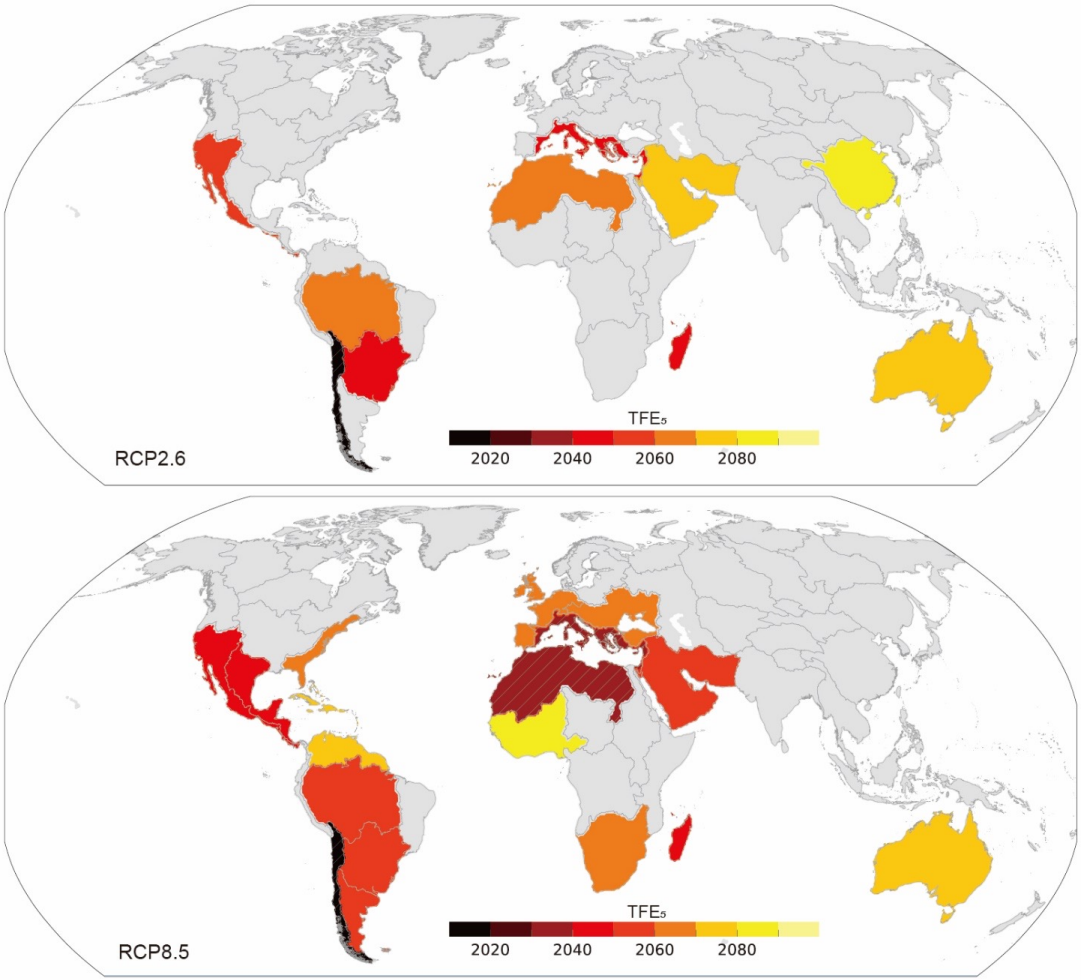
Future projection of drought days (ISIMIP)

Satoh et al. 2022, Nature communications



The timing of unprecedented hydrological drought under climate change

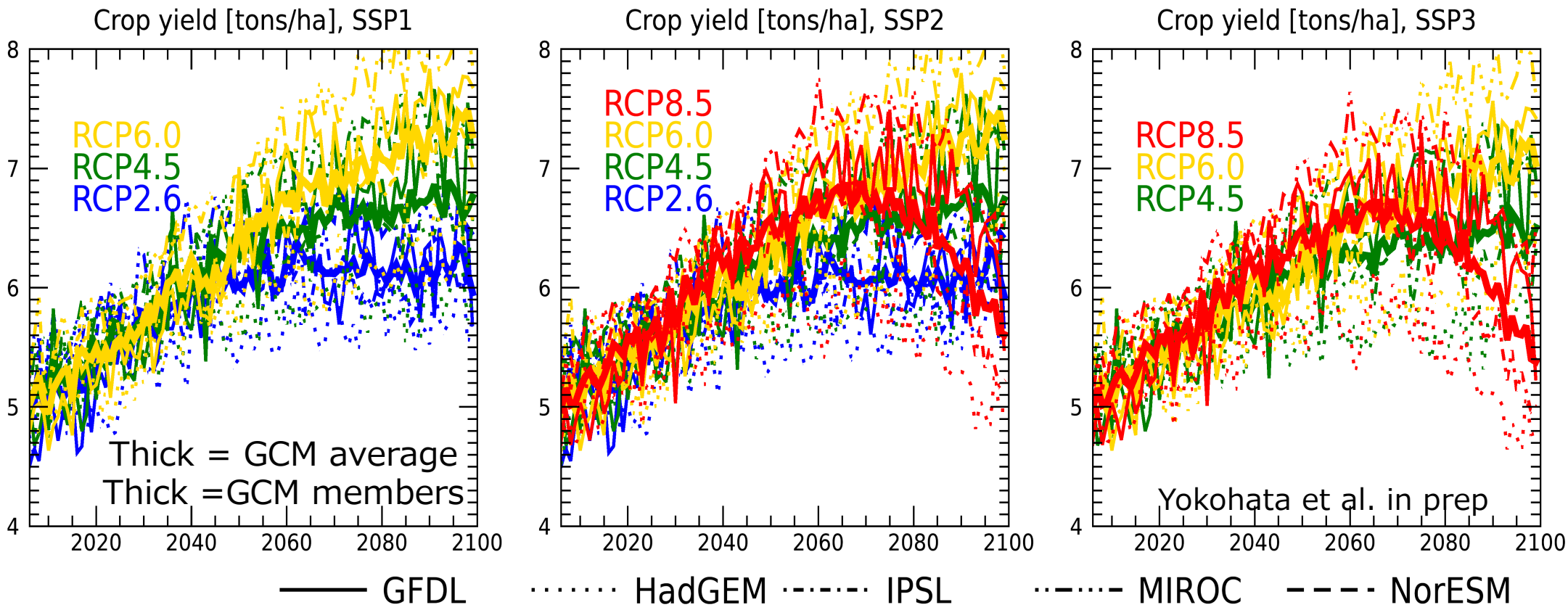
Satoh et al. 2022, Nature communications



- When droughts exceed the historical variation range?
- Exceeding records in the next 20 years regardless of emissions scenarios in multiple regions
- Rapid and serious changes before climate stabilization even under strict mitigation measures of RCP2.6
- We need speed to respond (adaptation) to this change
- Record drought length longer in RCP8.5: benefits of mitigation measures

Future projection of crop yields by MIROC-INTEG-LAND

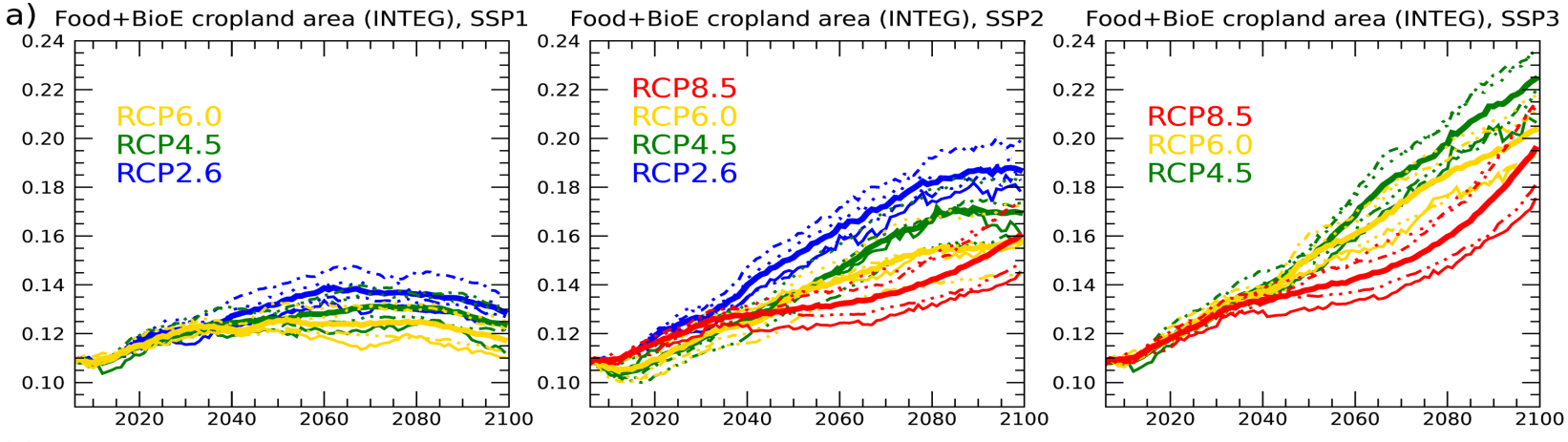
(Grid maximum of wheat, soybeans, maize, rice in t/ha)



Yields increase due to fertilization effect and technological development, decrease due to climate change

Food and Bioenergy cropland area

（Ratio to global land area）



Comparison to IAM calculations

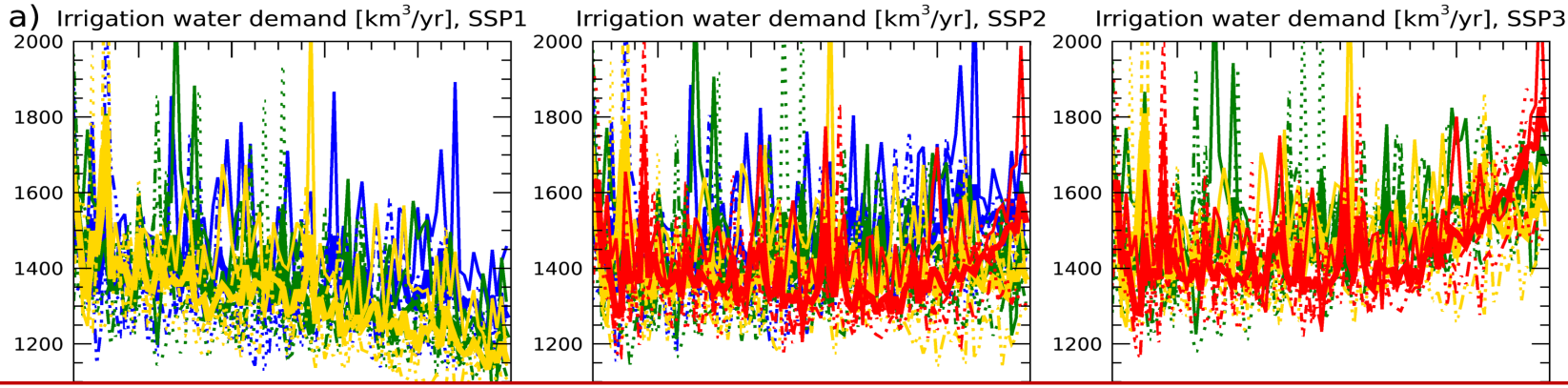
which have the same food and bioenergy demands:

MIROC-INTEG-LAND needs more lands

Larger cropland area for larger demands scenarios (SSP1 < 2< 3)

Yield changes due to fertilizer effect and climate change (RCP2.6 > 4.5 > 8.5)

Earth-Human systems feedback



Irrigation water

Agricultural water demand increases due to crop land area expantion

Feedbacks between climate, water, food and land use!!

Climate change → Decrease in water resources

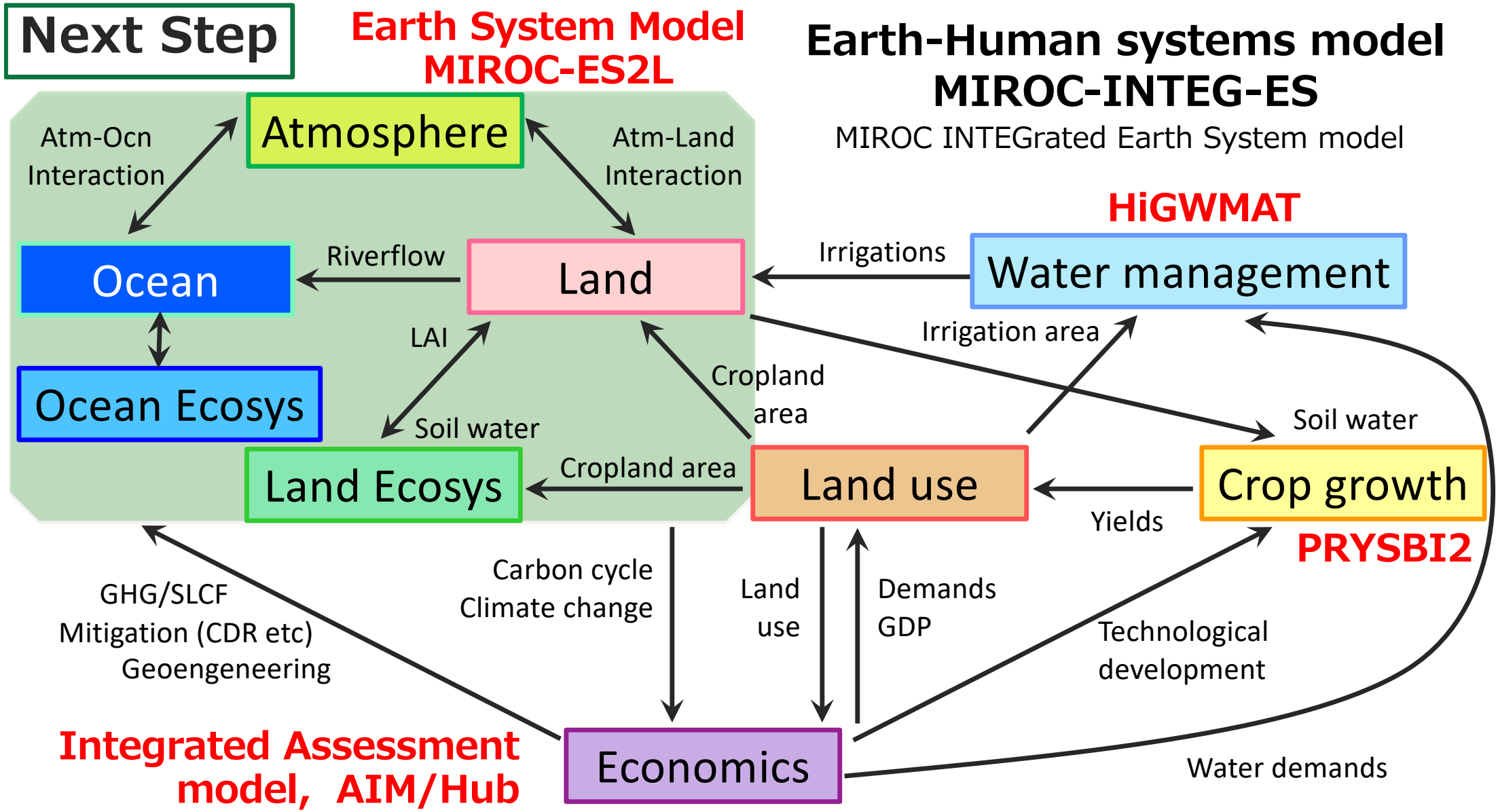
→ Decrease in crop yields

+ Increase in population + Climate mitigation

→ Increase in food and bioenergy demands

→ Increase in cropland area → Increase in CO_2 emission

→ Increase in water demands


Next Step
Earth System Model
MIROC-ES2L
Earth-Human systems model
MIROC-INTEG-ES
MIROC INTEGrated Earth System model
Atmosphere
Atm-Ocn
Interaction
Atm-Land
Interaction
HiGWMAT
Ocean
Riverflow
Land
Irrigations
Water management
Irrigation area
LAI
Cropland
area
Ocean Ecosys
Soil water
Soil water
Land Ecosys
Cropland area
Land use
Crop growth
Yields
PRYSBI2
Carbon cycle
Climate change
Land
use
Demands
GDP
GHG/SLCF
Mitigation (CDR etc)
Geoengeneering
Technological
development
Integrated Assessment
model, AIM/Hub
Economics
Water demands

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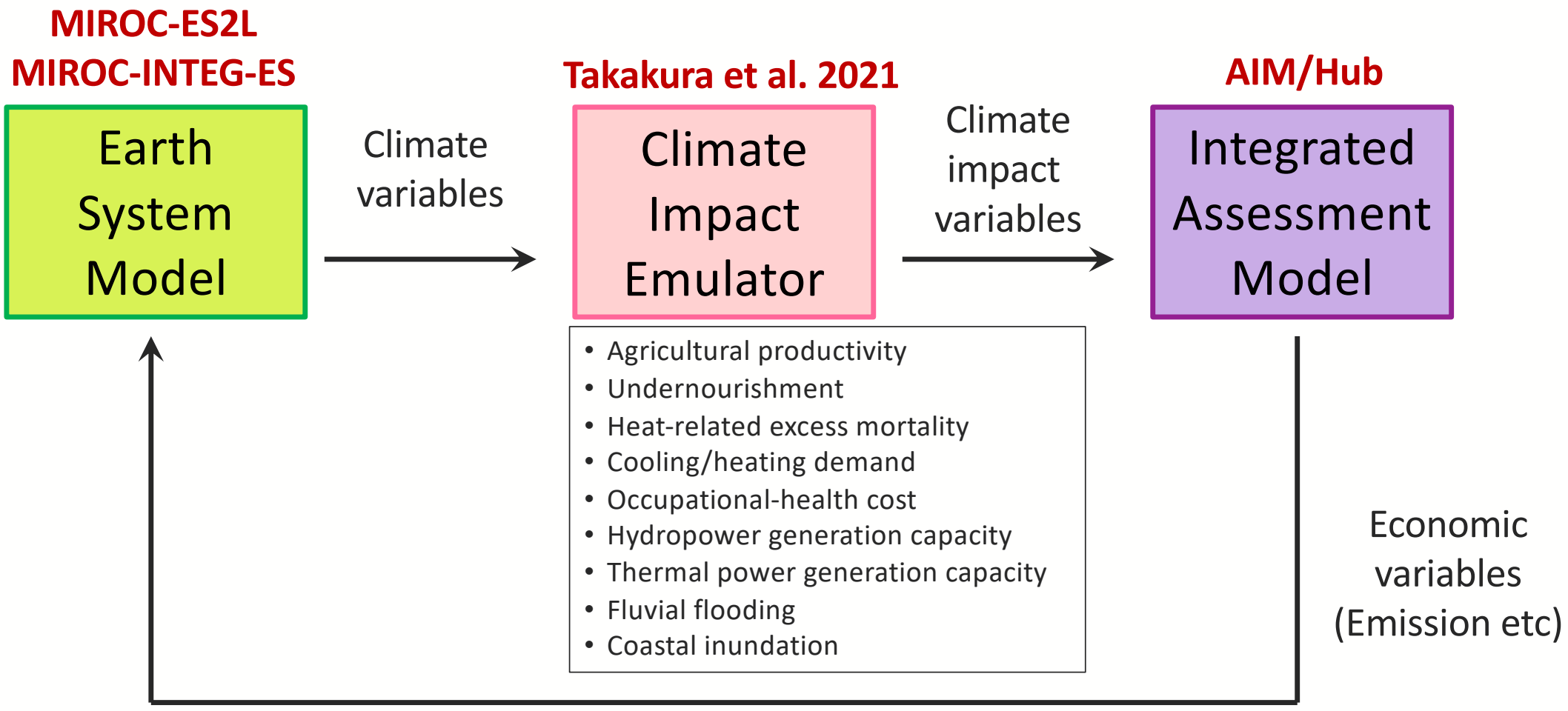
Coupling of ESM-IAM



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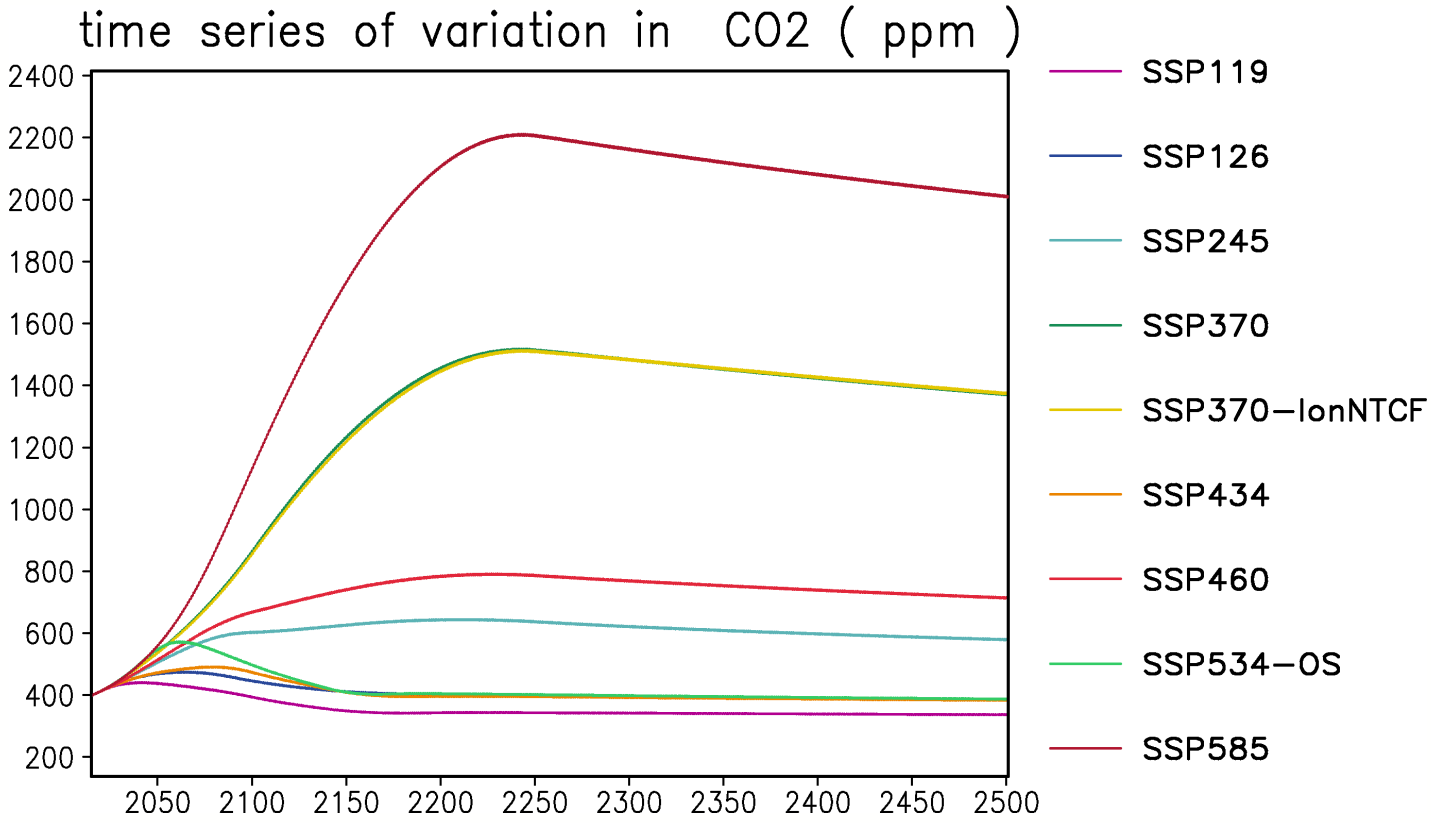
Impacts of climate change on Earth-Human systems in longer time scale (> 2100)



CO2 data obtained from Meinshausen et al. 2020

- Possibility of large climate change in longer time scale
- INTEG-ESM can simulate details in climate, water resources, ecosystems, crop yields
- Climate extreme, tipping elements, planetary boundaries

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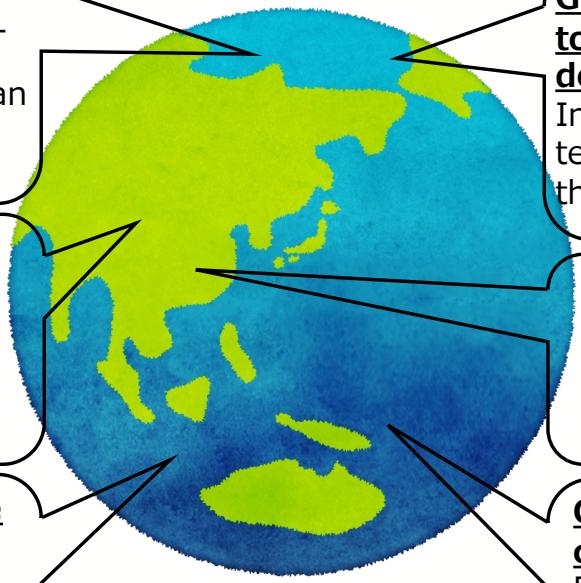
Tipping elements and planetary boundaries collaborations with experts in various fields

Changes in deep ocean circulation :
Ice sheet melting + freshwater supply can weaken the deep ocean circulation

Changes in precipitation and circulation:
Monsoon can be changed due to climate change

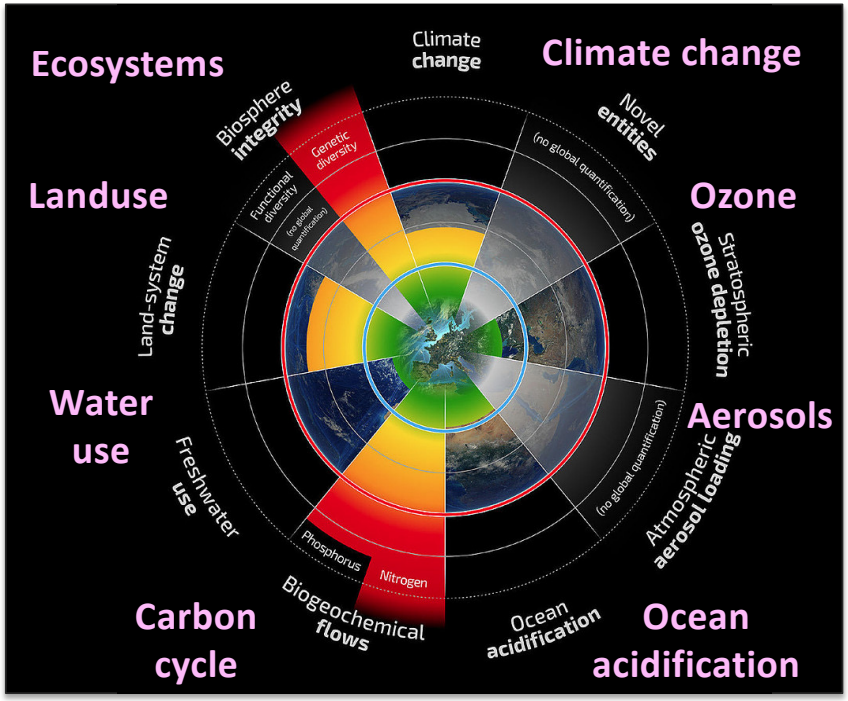
Changes in climate feedback
Cloud, water vapor, ocean heat uptake and ocean thermal expansion



GHG emissions due to permafrost degradation:
Increase in soil temperature cause thawing of permafrost

Changes in land carbon uptake:
Dieback of amazon rainforest or boreal forest

Changes in ocean carbon uptake:
Decrease in net ocean carbon sink due to increase in respiration by ocean plankton



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Summary

- We developed a land surface model with human activity (water management, crop growth, land use), MIROC-INTEG-LAND
  - Future projection of drought, Earth-human systems feedbacks
- An Earth system model with human systems (+ IAM) is under development, MIROC-INTEG-ES
  - Using climate impact emulators
  - Longer time scale, tipping elements, planetary boundaries