Emulating process-based simulation of economic impacts of climate change

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AIM international workshop

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ASIA-PACIFIC INTEGRATED MODEL

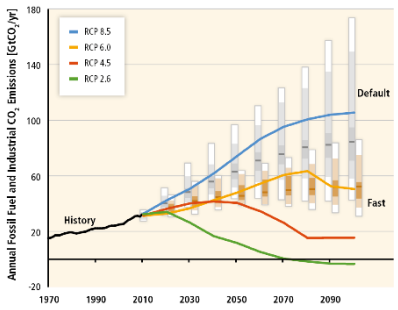
NIES JAPAN

Framework of economic impact "simulation"

Emission scenario

Socioeconomic scenario

RCP

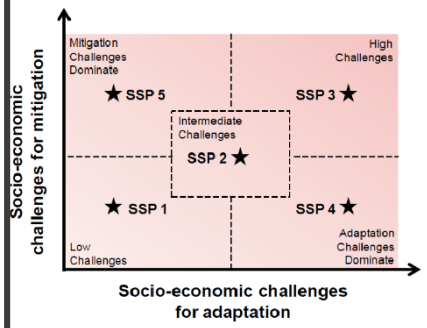


Climate change

RCP8.5
RCP6.0
RCP4.5
RCP2.6

2℃

SSP



SSP1: Suntainability
SSP2: Middle of the Road
SSP3: Reginal Rivalry
SSP4: Inequality
SSP5: Fossil-fueled Development

GHG emissions constraint

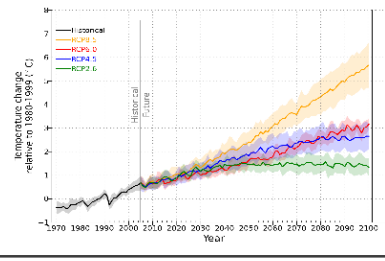
GHG concentration

Socioeconomic assumptions

Gridded population and so on

Climate model

Climate



Crop model

Crop yield

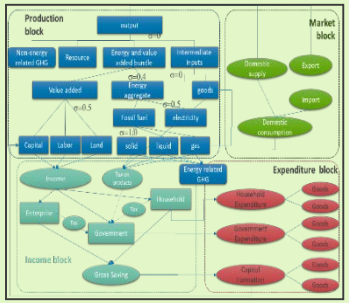
Water model

Water resource

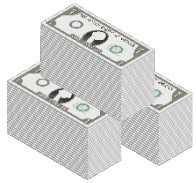
Health model

Number of Death

IAM (AIM/CGE)



GDP



Bio/physical impacts

Economic impacts

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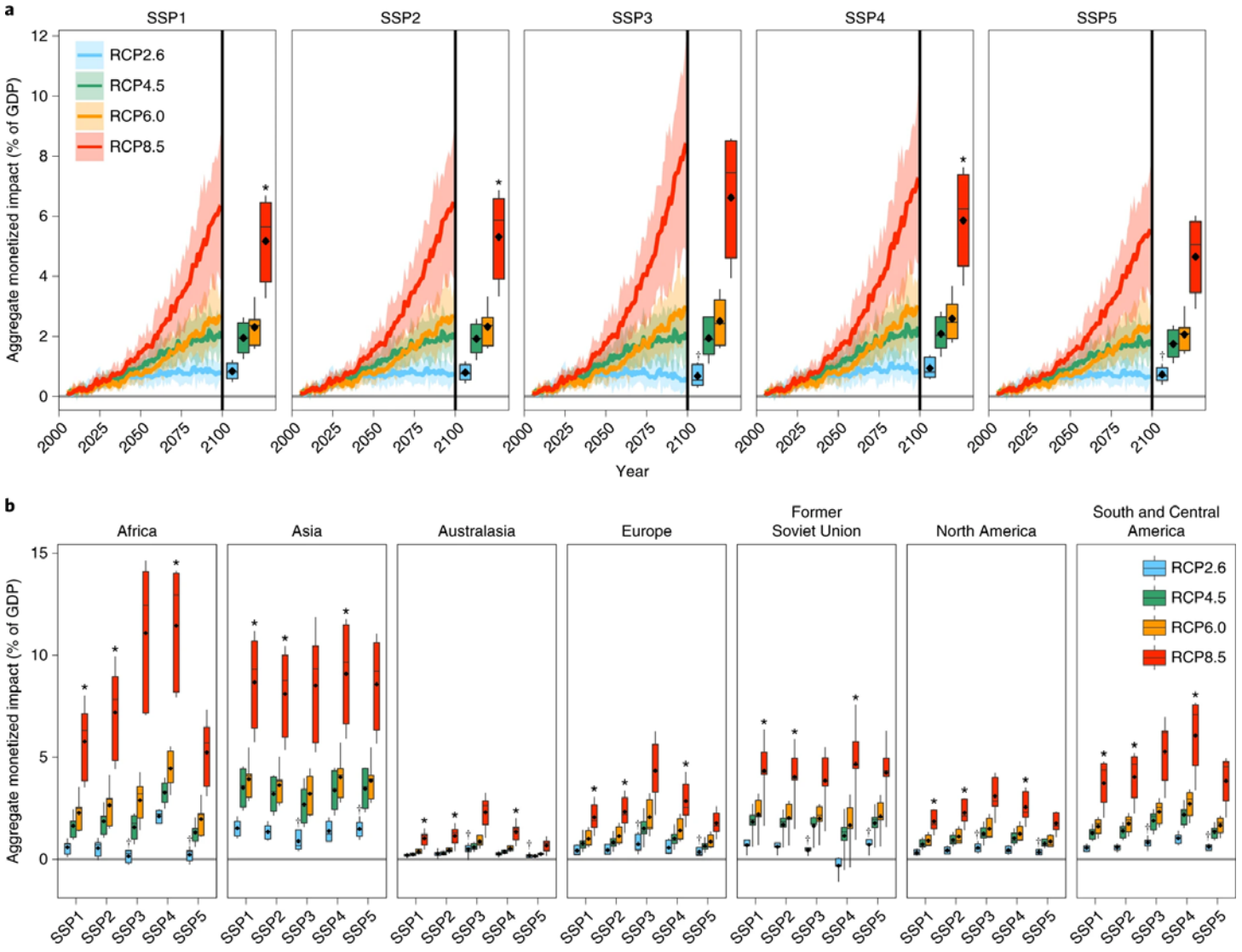
Included Sectors

Sector	Institute	Way of valuation	Paper
Agricultural productivity	NIAES NIES	CGE	Fujimori et al. (2018)
Undernourishment	Univ. Tsukuba NIES	CGE+VSL	Hasegawa et al. (2016)
Heat-related excess mortality	Univ. Tsukuba NIES	VSL	Takahashi et al. (2018)
Occupational-health cost	Univ. Tsukuba NIES	CGE	Takakura et al. (2017)
Cooling/heating demand	NIES	CGE	Park et al. (2018)
Hydropower generation capacity	NIES	CGE	Zhou et al. (2018)
Thermal power generation capacity	NIES	CGE	Zhou et al. (2018)
River flooding	Univ. Tokyo	Econometric	Kinoshita et al. (2018)
Coastal inundation	Ibaraki Univ.	Econometric	Tamura et al. (2019)

Results of Economic Impact Simulation



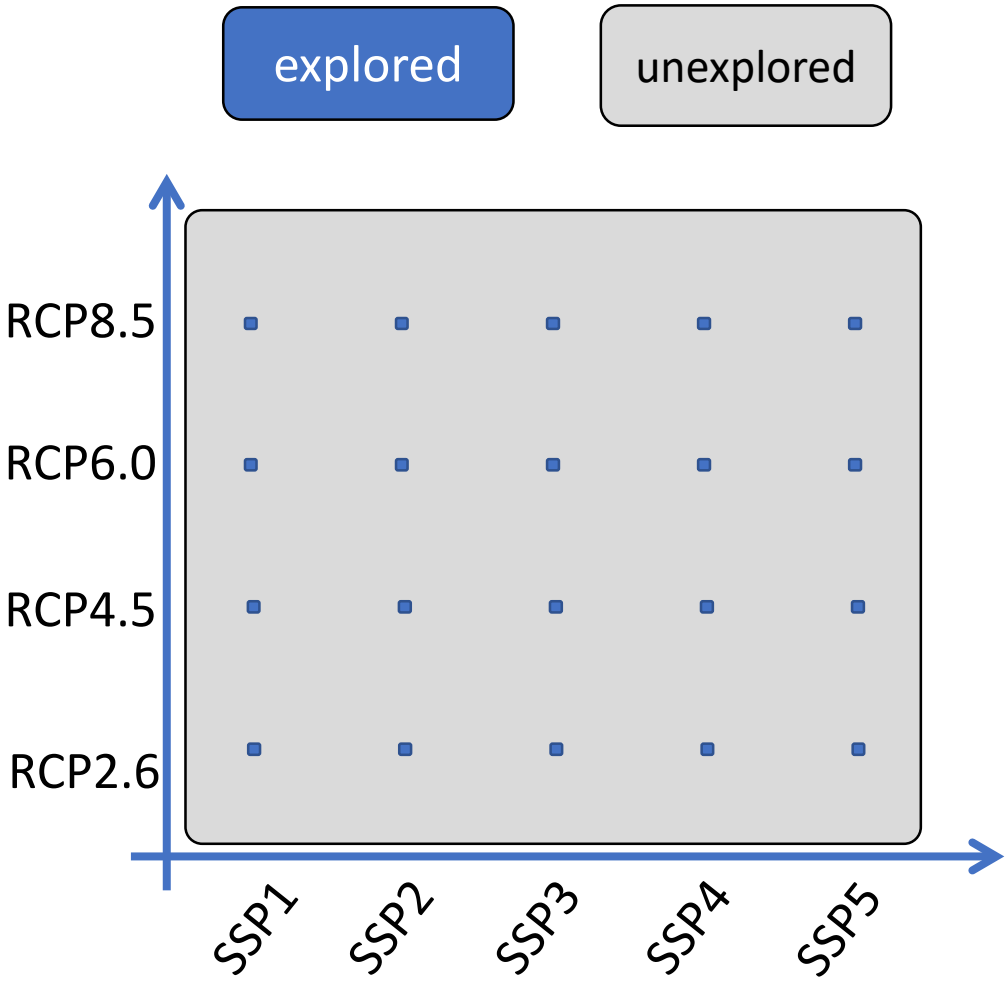
Takakura et al. (2019) *Nature Climate Change*

Expanding scenarios

We have explored the impact under substantial number of scenario-combinations.

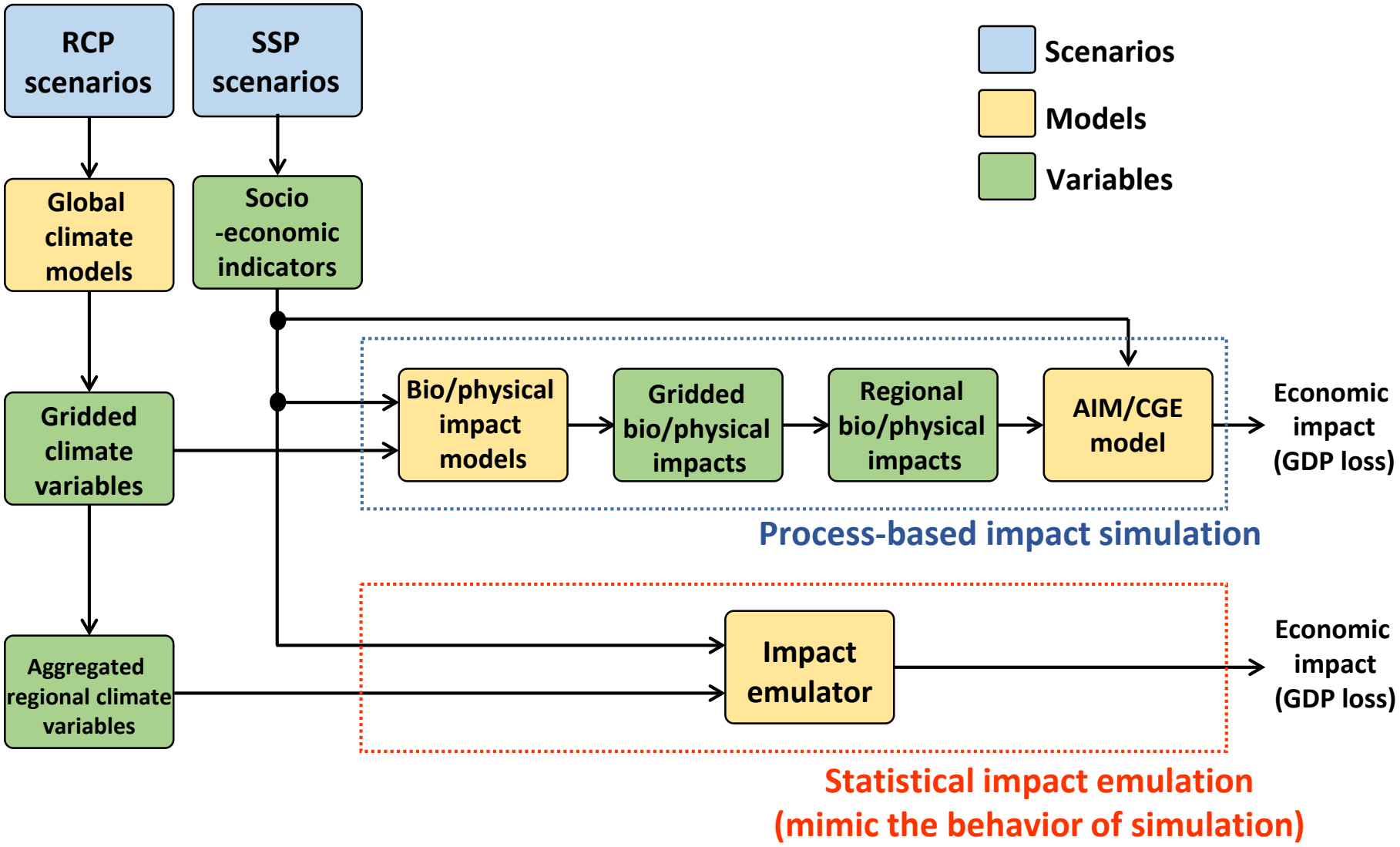
However, massive space still remains unexplored.

Exploring this space in the same way is not computationally practical.



Emulation may be an effective way to expand the scenario analysis.

Simulation and Emulation



Selection of input variables

What kind of input variables should we use?

- **Global mean temperature**
  - the simplest, but widely used way particularly in global-scale assessments

- **Regional mean temperature/precipitation**
  - heterogeneous reginal climate conditions can be considered

- **Regional population, GDP, GDP/capita**
  - exposure and vulnerability, not only hazards can be considered

- **Regional mean temperature/precipitation including non-target regions**
- **Regional population, GDP, GDP/capita including non-target regions**
  - typically, when we want to emulate the impacts in a certain region, climate and socioeconomic condition of the focused region is used.
  - some economic impacts can be affected by conditions of the other regions through relative advantages (or disadvantages) in international trades

Selection of functional forms

What kind of functional form should we use?

Ordinary-Least-Squares-regression-based techniques.

OLS1: $\hat{y}_t = a_0 + \sum_i a_i x_{t,i}$

OLS2: $\hat{y}_t = a_0 + \sum_i a_{1i} x_{t,i} + \sum_i a_{2i} x_{t,i}^2$

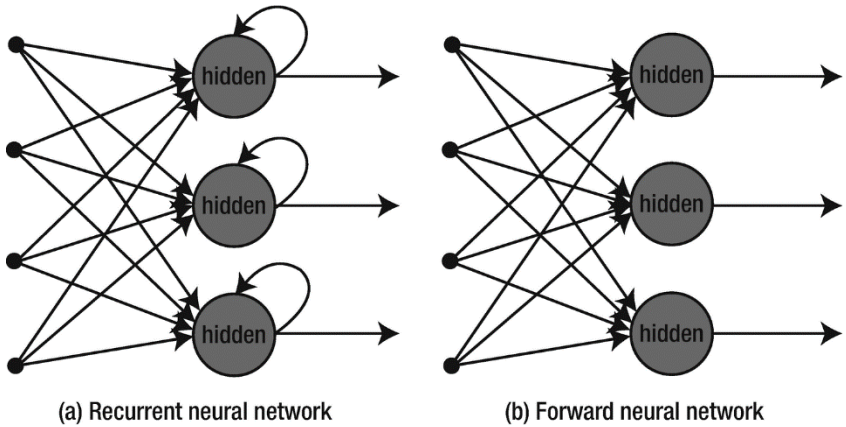
OLS2i: $\hat{y}_t = a_0 + \sum_i a_{1i} x_{t,i} + \sum_i a_{2i} x_{t,i}^2 + \sum_{i \neq j} a_{ij} x_{t,i} x_{t,j}$

Artificial-Neural-Network-based techniques.

MLP: $\hat{y}_t = f(\mathbf{x}_t, \mathbf{W})$

RNN: $\hat{y}_t = f(\mathbf{s}_{t-1}, \mathbf{x}_t, \mathbf{W})$

$\mathbf{s}_t = g(\mathbf{s}_{t-1}, \mathbf{x}_t, \mathbf{W})$

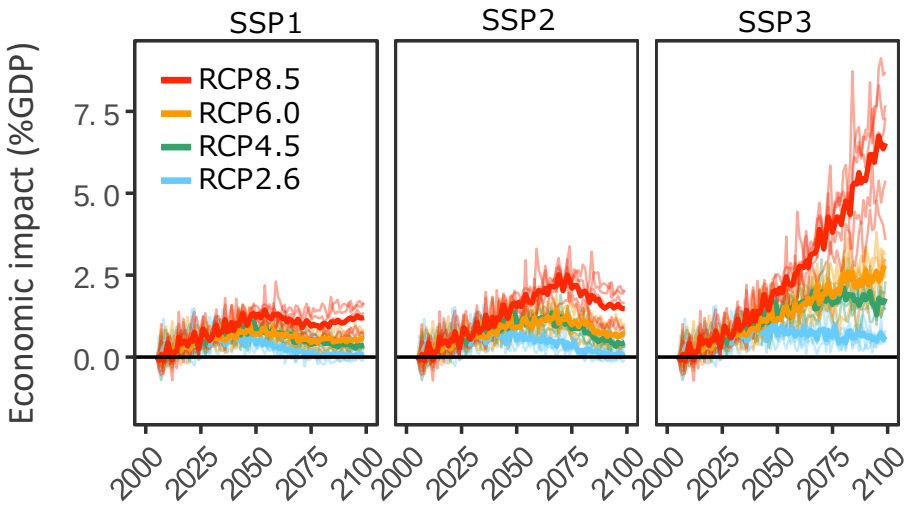


(a) Recurrent neural network (b) Forward neural network

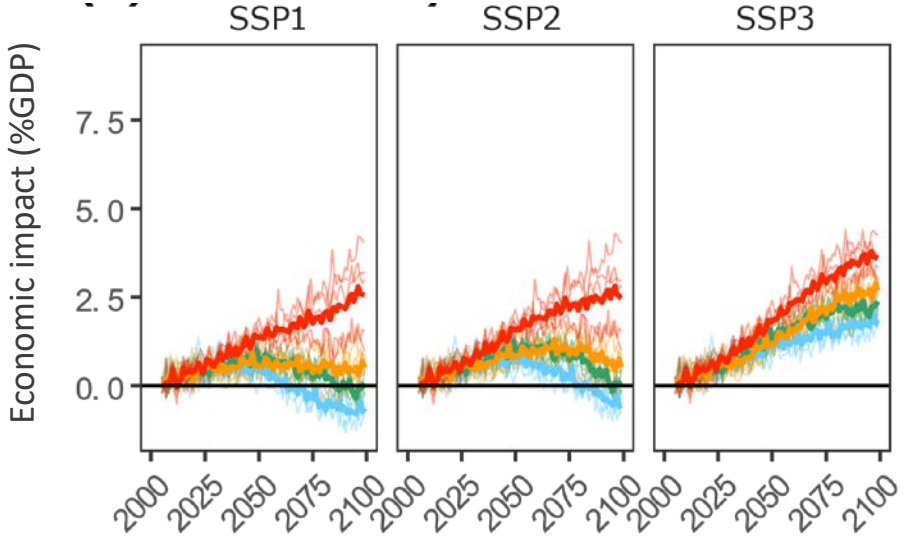
Cited from: https://doi.org/10.1007/978-1-4842-3685-7_3

Sample of emulation and evaluation

Example of simulation result



Example of emulation result



Evaluation procedure

① decide the parameters of an emulator based on the simulation results for each sector and region.

② conduct an emulation based on the parameters calculated in ① by using the cross-validation procedure.

③ Evaluate the similarity between simulation and emulation result.

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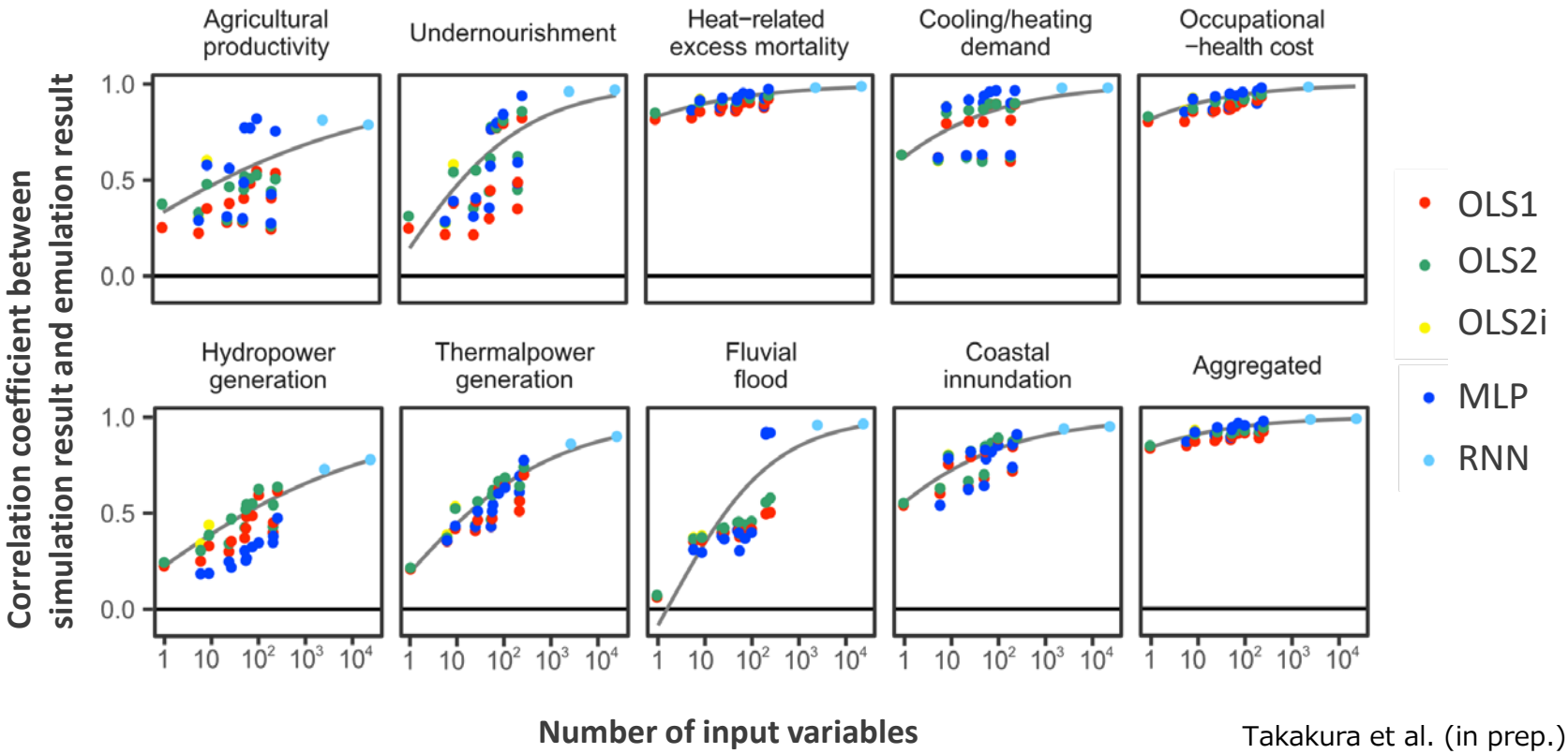
Evaluation results

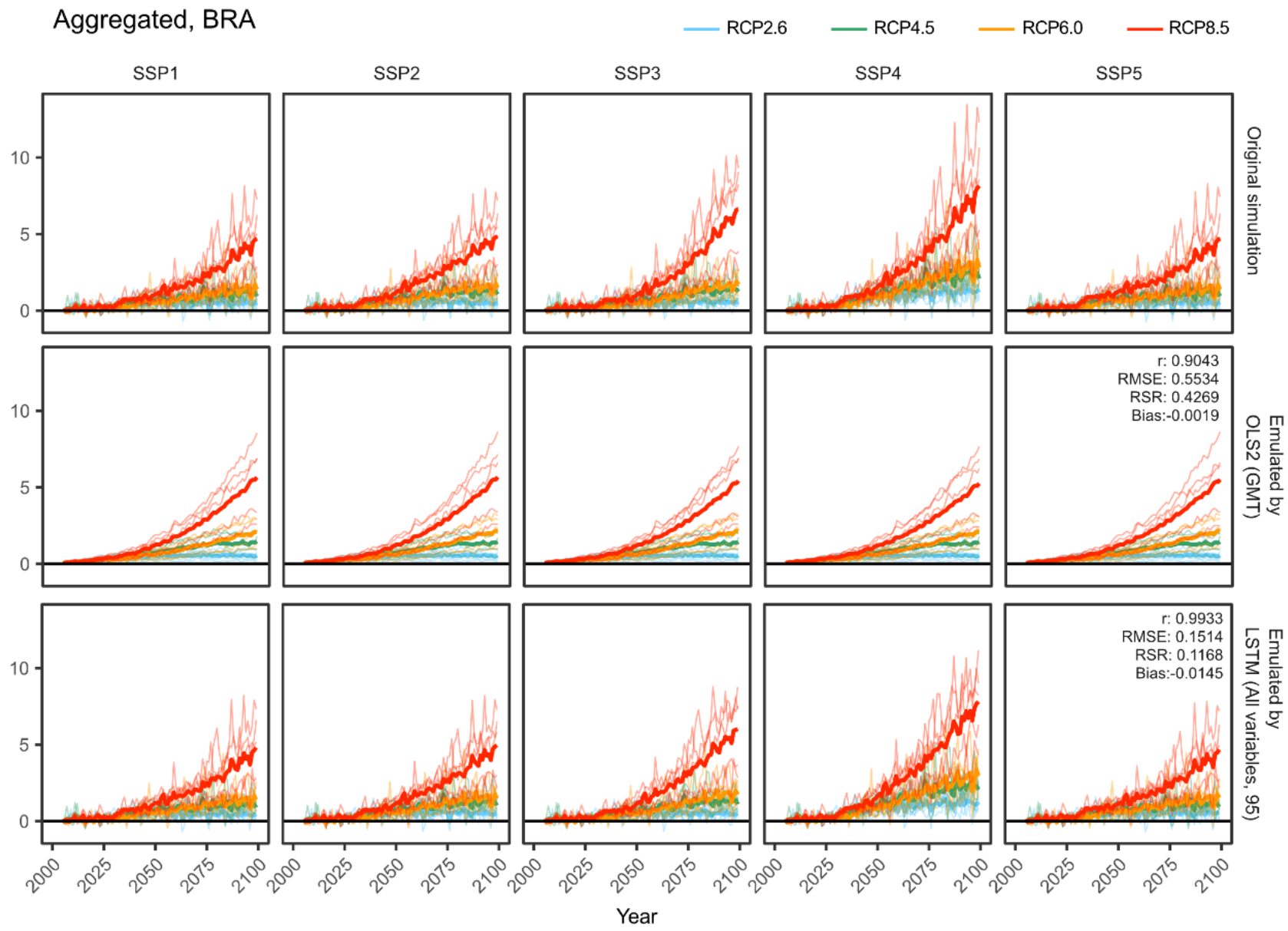


Takakura et al. (in prep.)

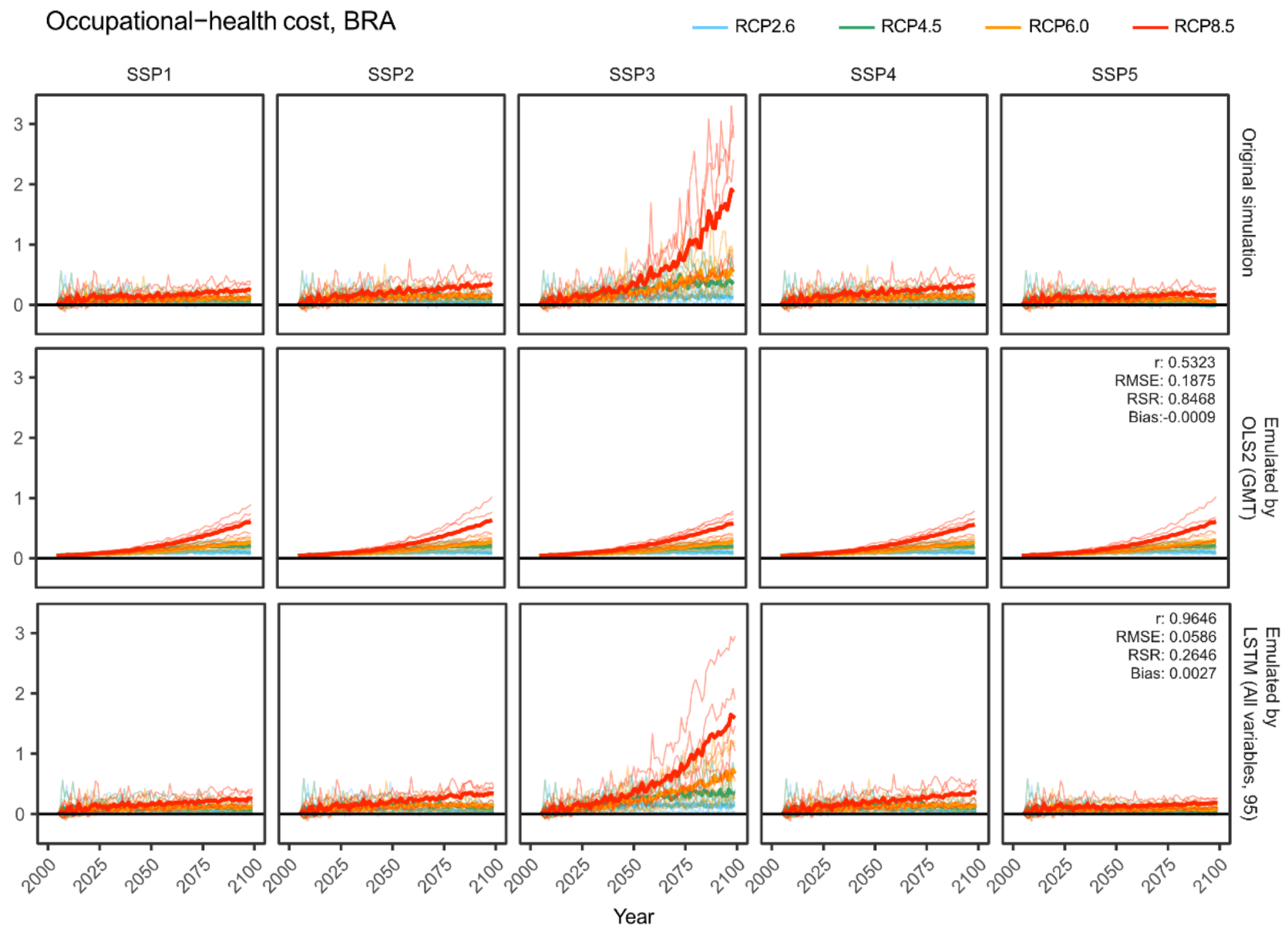
The more input variables and the more complex functional forms we use, the better the emulators reproduce the results of the simulations.

Some sectors' economic impacts are relatively easy to emulate, but other sectors' are difficult even by the complex techniques.

Example (relatively easy to emulate)



Example (relatively hard to emulate)



Summary and future plans

Summary

- We developed various kinds of emulators and evaluated their performances systematically.
- Among the tested emulators, emulators composed of artificial neural networks, which can incorporate nonlinearities and interactions of variables, performed better particularly when finer input variables were available.
- Whereas simple functional forms were also effective to grasp general tendencies, complex models are necessary if the focus is regional or sectoral heterogeneity.

Future plans

- Increasing spatial resolution (AIM's 17 regions -> national or grid level)
- Emulation of bio/physical impacts as well as economic impacts
- Connecting to other tool-chains (e.g., simple climate models)

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Thank you for your attention