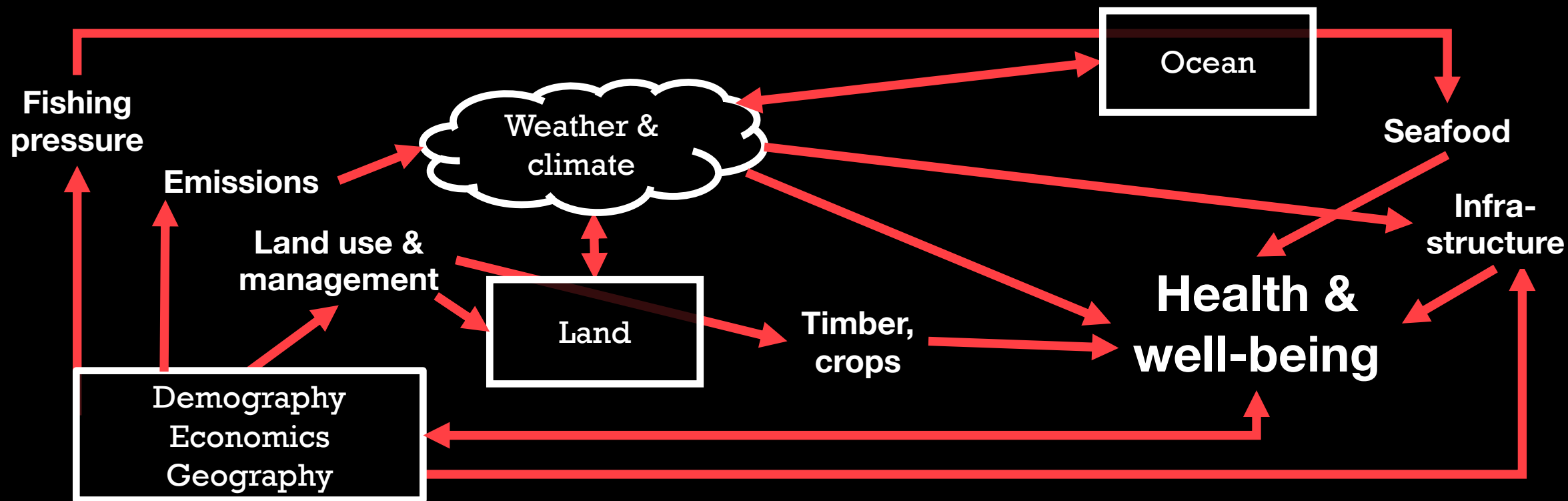


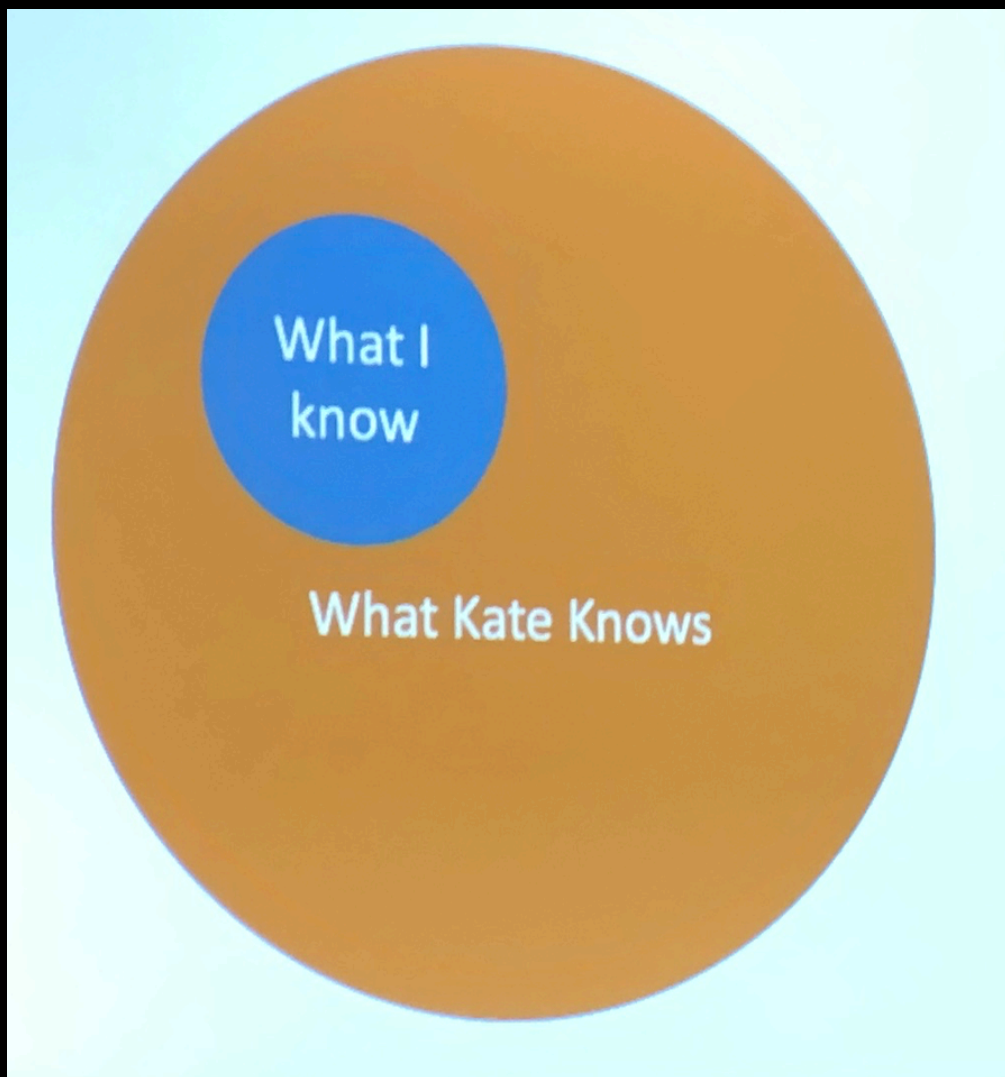
Human-Earth system feedbacks

Sam S. Rabin

Karlsruhe Institute of Technology,
Institute of Meteorology and Climate Research /
Atmospheric Environmental Research

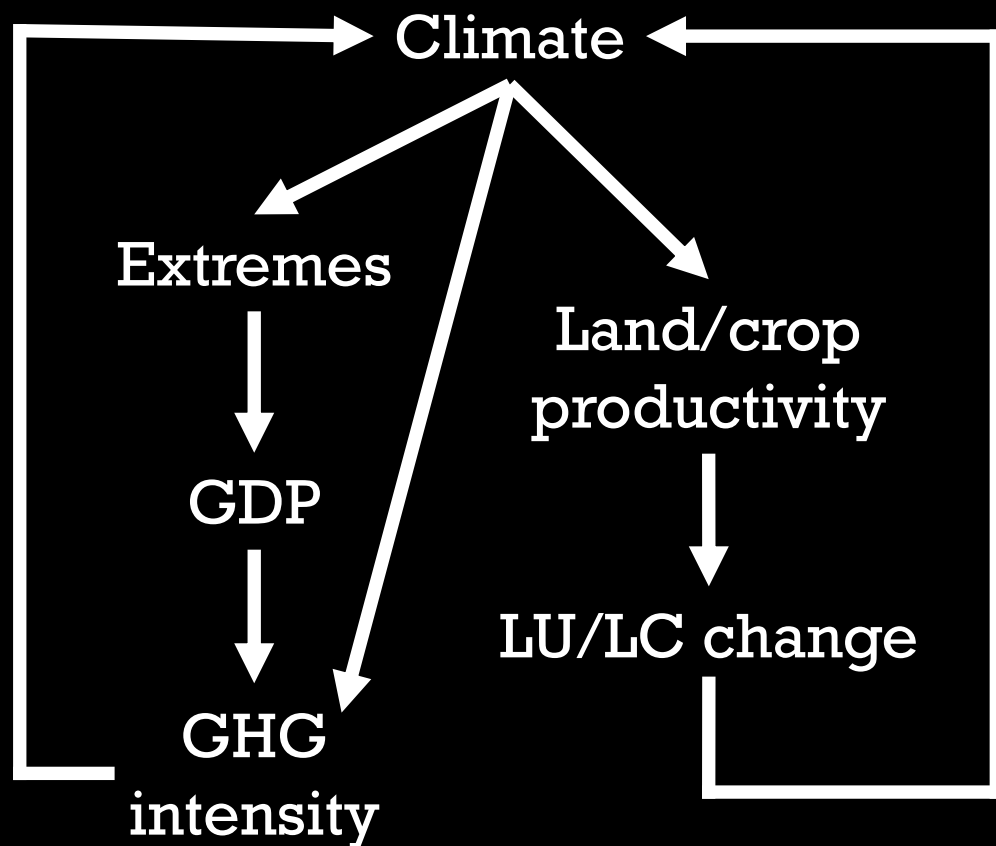
*Impacts of Land Use and Land Management on Earth System Evolution,
Biogeochemical Cycles, Extremes and Inter-Sectoral Dynamics*





Calvin et al. (2018, *ERL*)

- 19 papers (11 models)
- 12 (5) with LU feedbacks

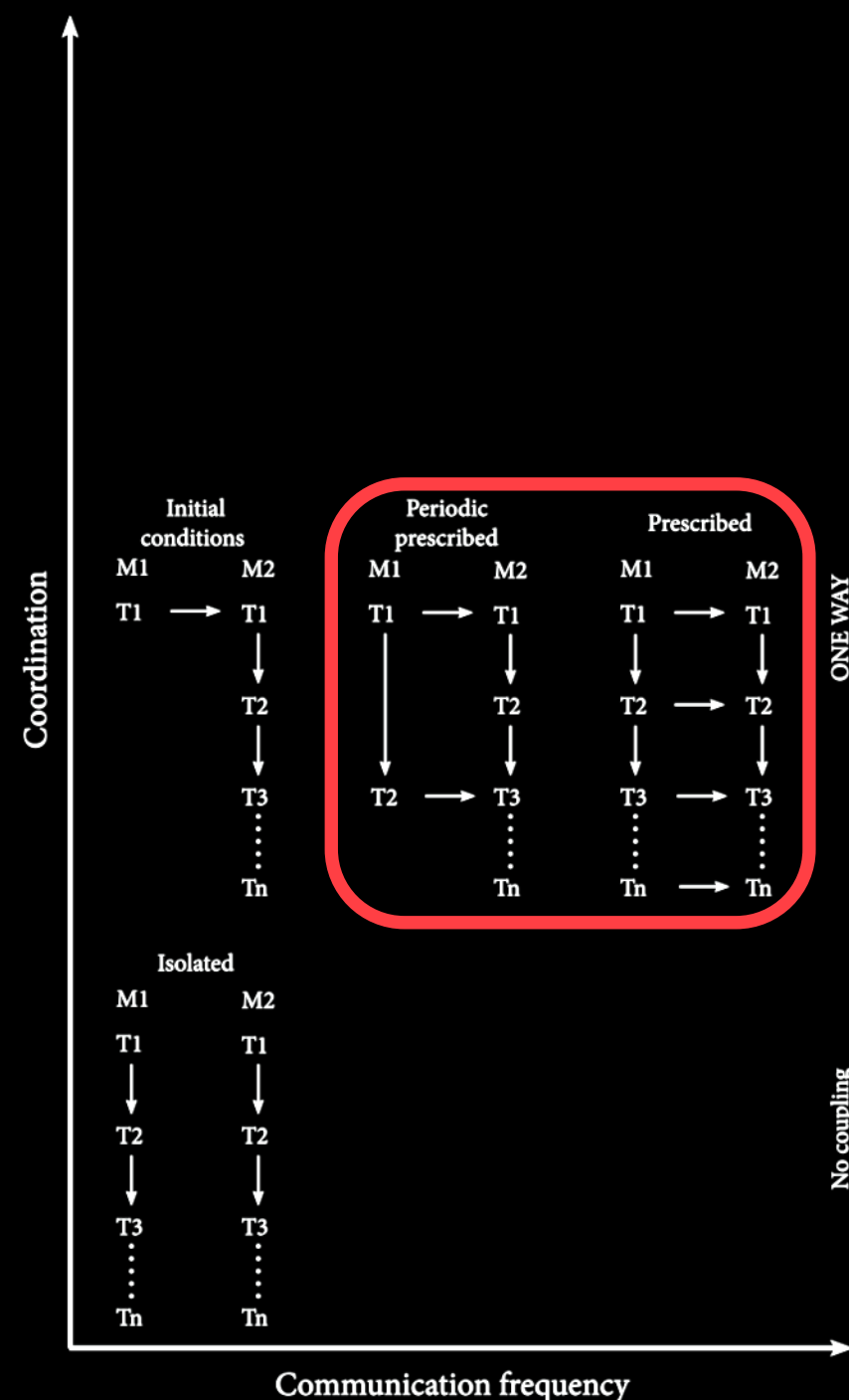


Calvin et al. (2018, *ERL*)

- 19 papers (11 models)
- 12 (5) with LU feedbacks
- Effects of including feedbacks on simulated...
 - Temperature
 - CO₂ emissions & concentration
 - Crop area and production
- Can be substantial!

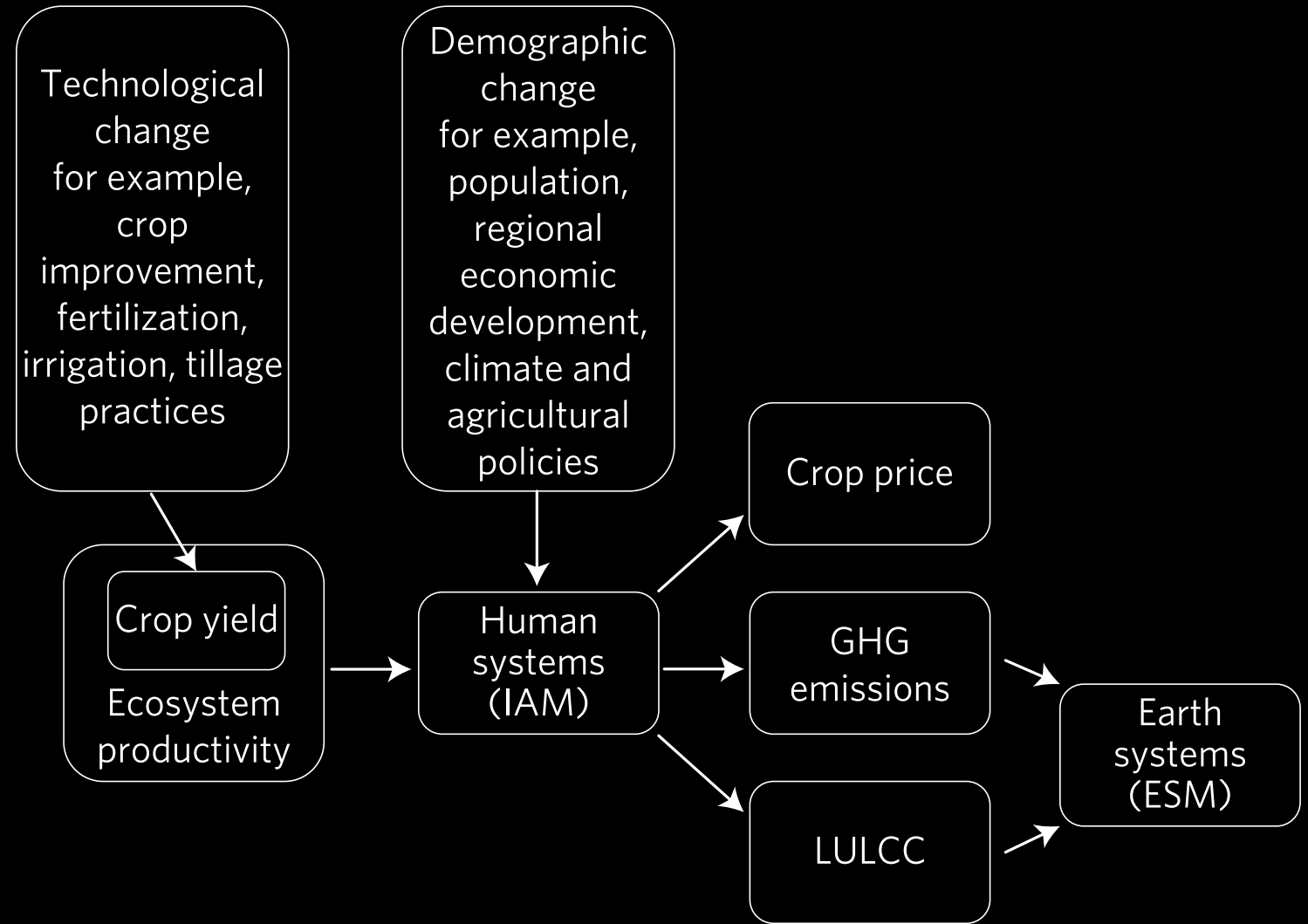
Modeling feedbacks

Analyses have
so often been
one-way...



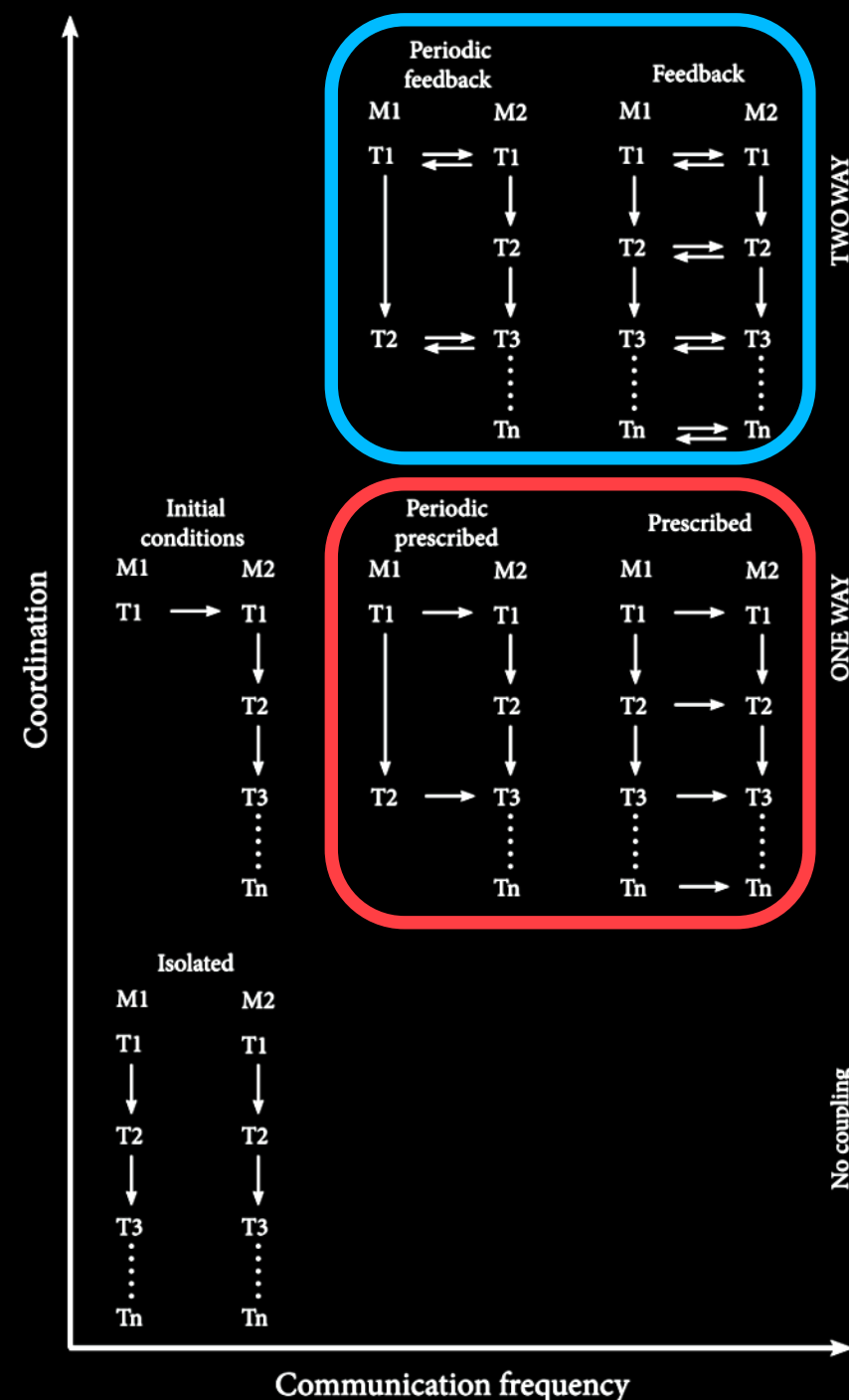
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Modeling feedbacks

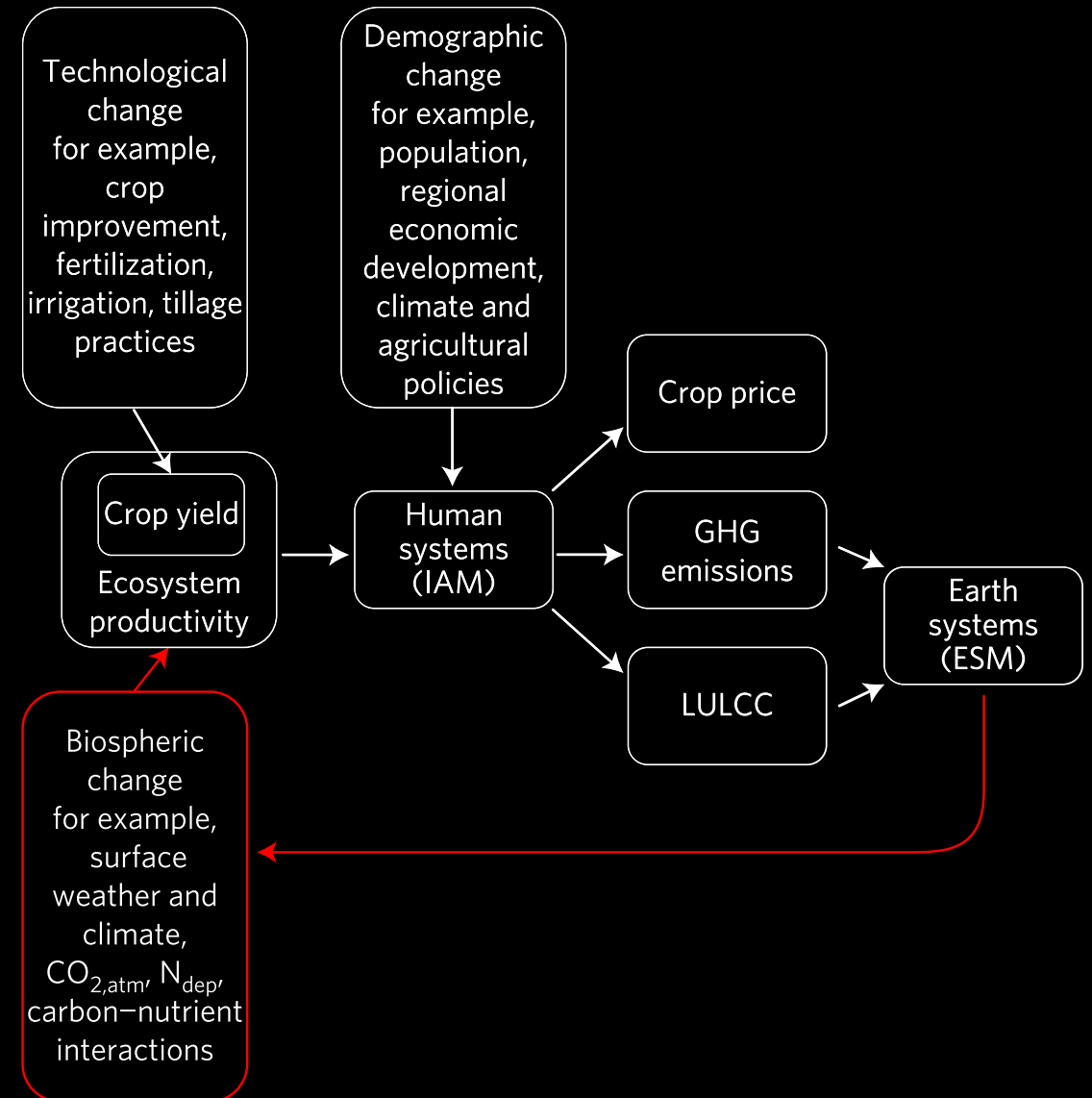
Analyses have
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one-way...



...when we really
need two-way
couplings for
feedbacks.

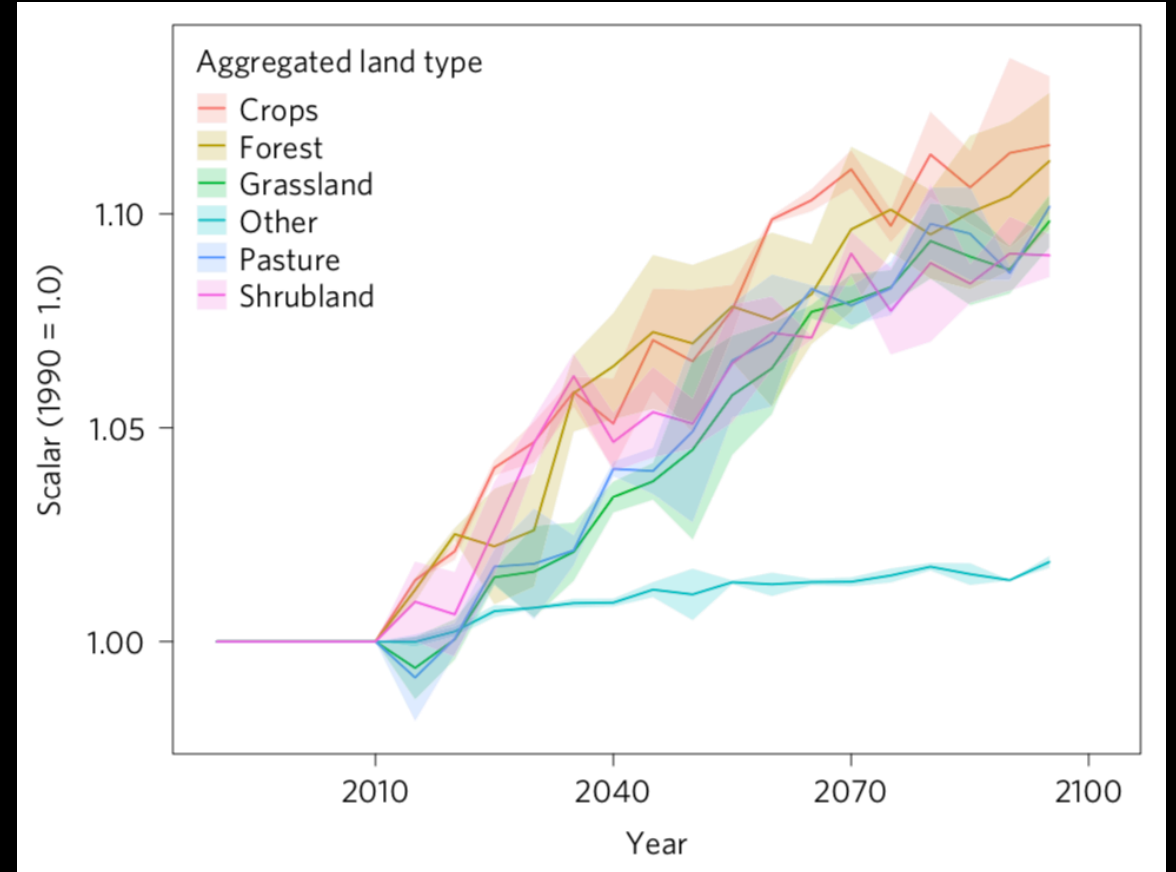
Productivity feedbacks in iESM

- GCAM projects LU and management, typically with fixed historical crop/forest yields
- iESM informs GCAM crop/forest yields with changing NPP & respiration from CESM



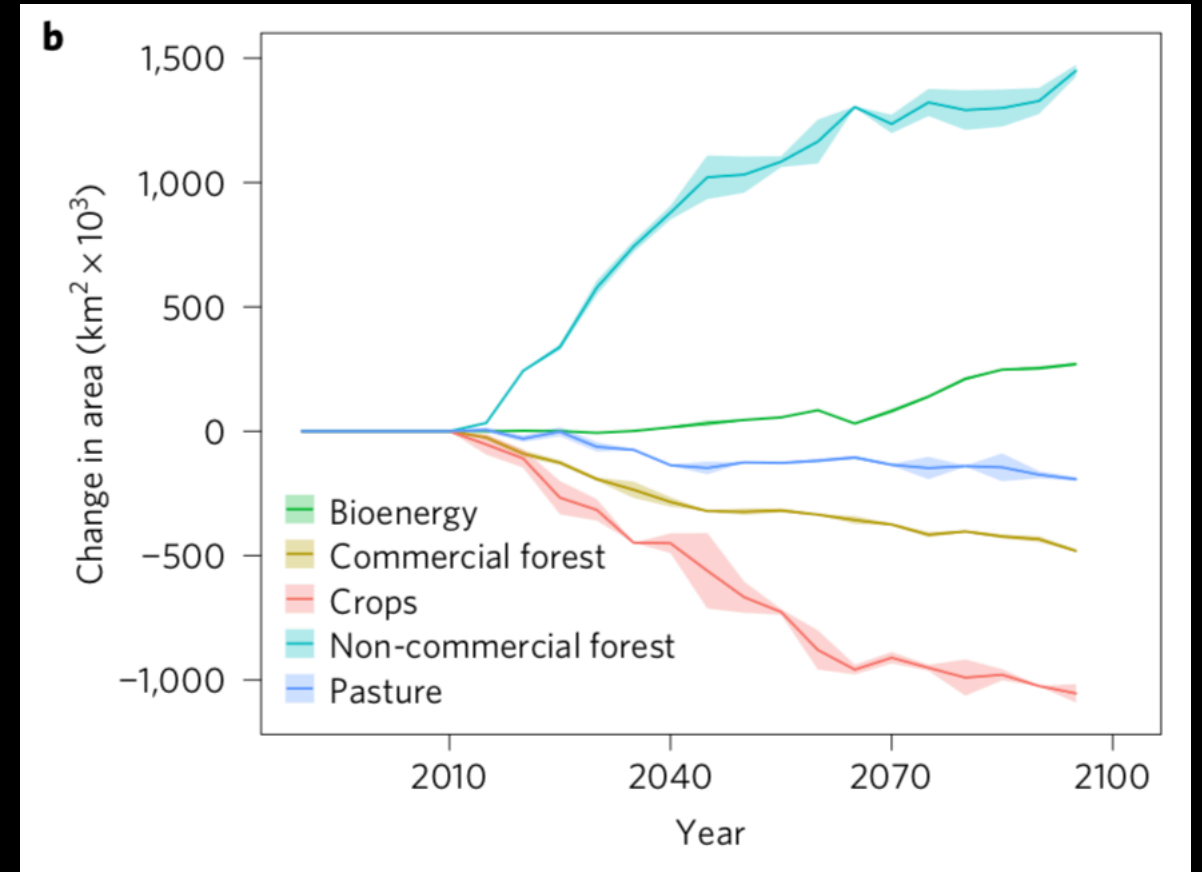
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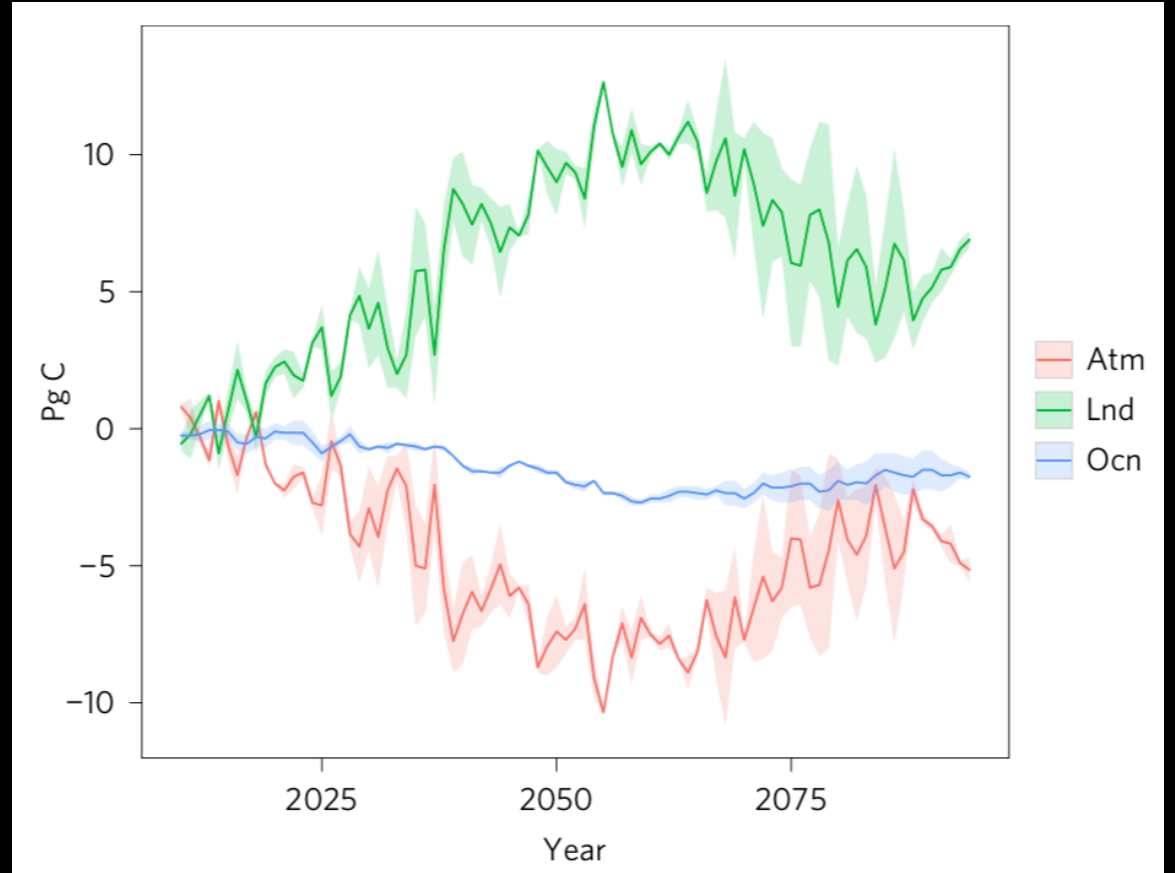
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 - Less cropland, more forest



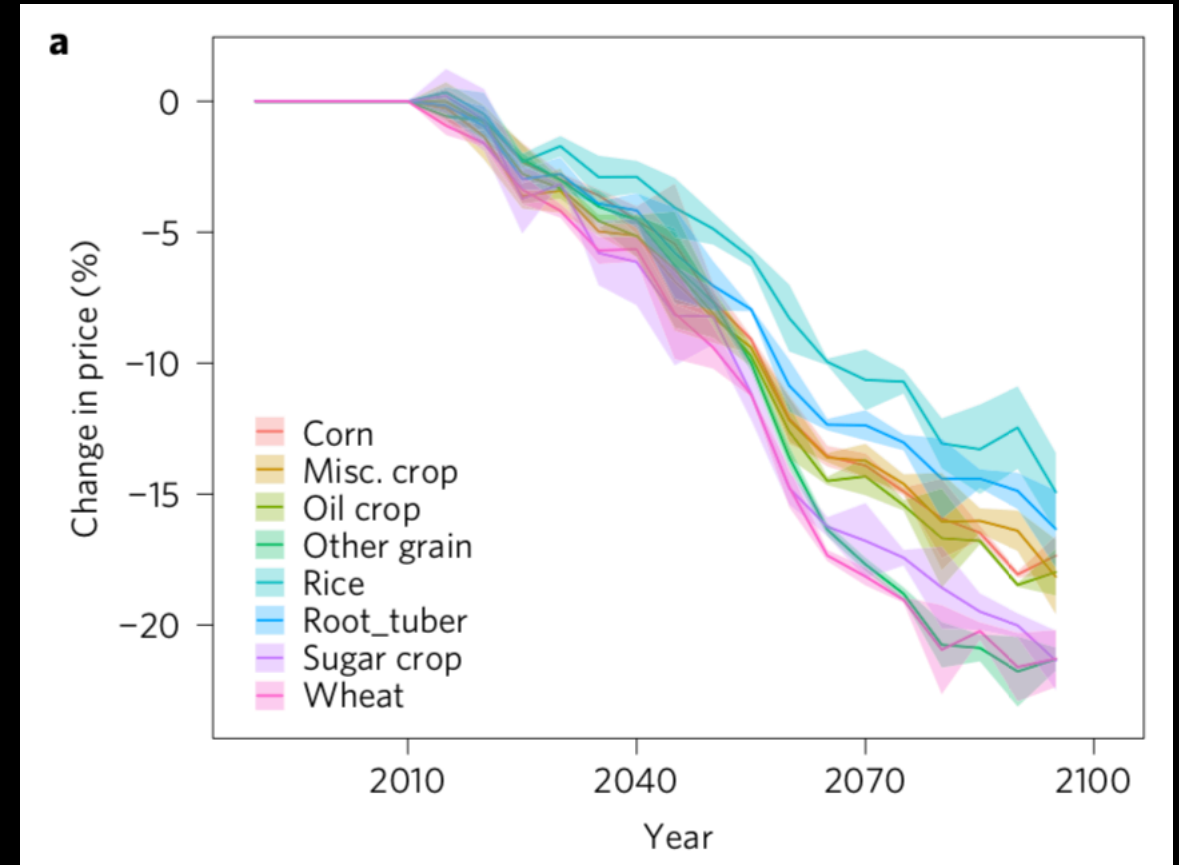
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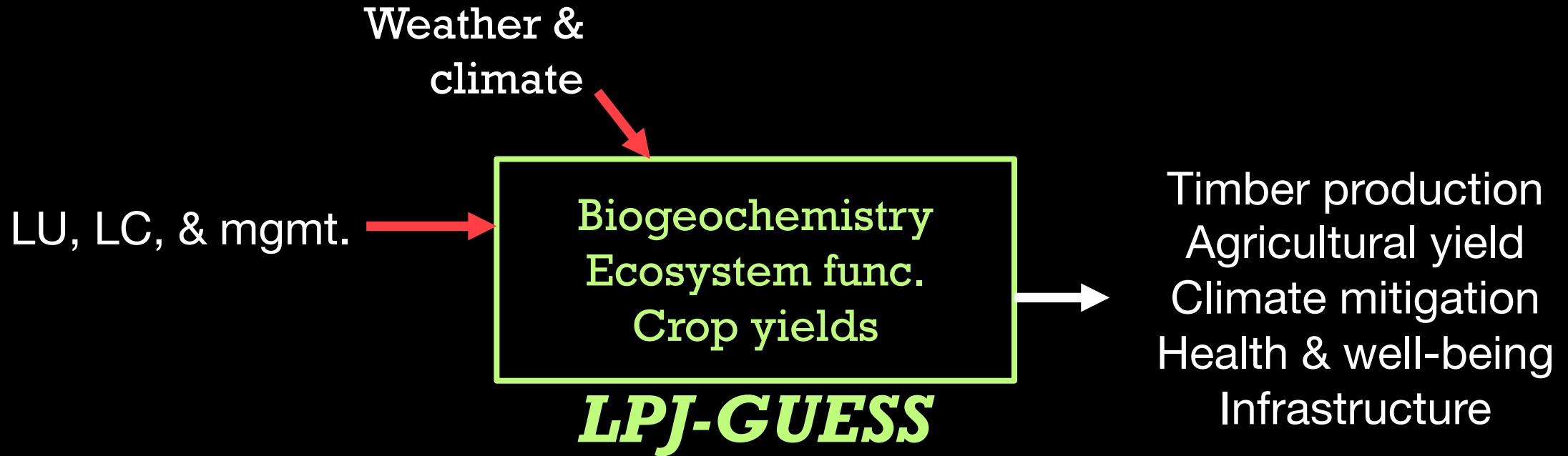


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 - Lower CO_2 concentration
 - Lower crop prices



LandSyMM



LandSyMM

Alexander et al. (2018, *GCB*)
Rabin et al. (2019, *ESD Disc.*)

Weather &
climate

Biogeochemistry
Ecosystem func.
Crop yields

Potential yield
(irrig. or not;
3 N levels)

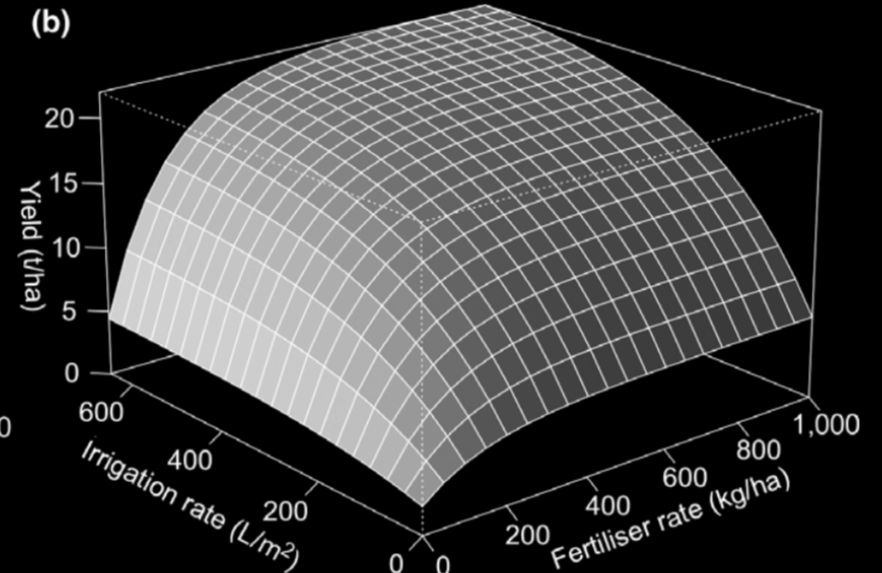
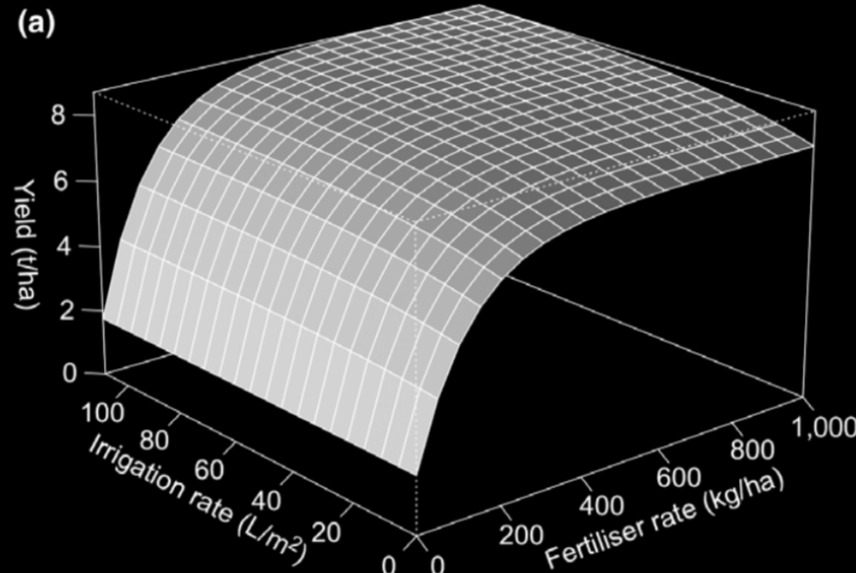
LU, LC, & mgmt.

LPJ-GUESS
Biogeochemistry

Timber production
Agricultural yield

Demography
Economics
Geography

PLUM



LandSyMM

(Climate
emulation)

IMOGEN

RCP
emissions

Weather &
climate

Land GHG
fluxes

Potential yield
(irrig. or not;
3 N levels)

LU, LC, & mgmt.

Biogeochemistry
Ecosystem func.
Crop yields

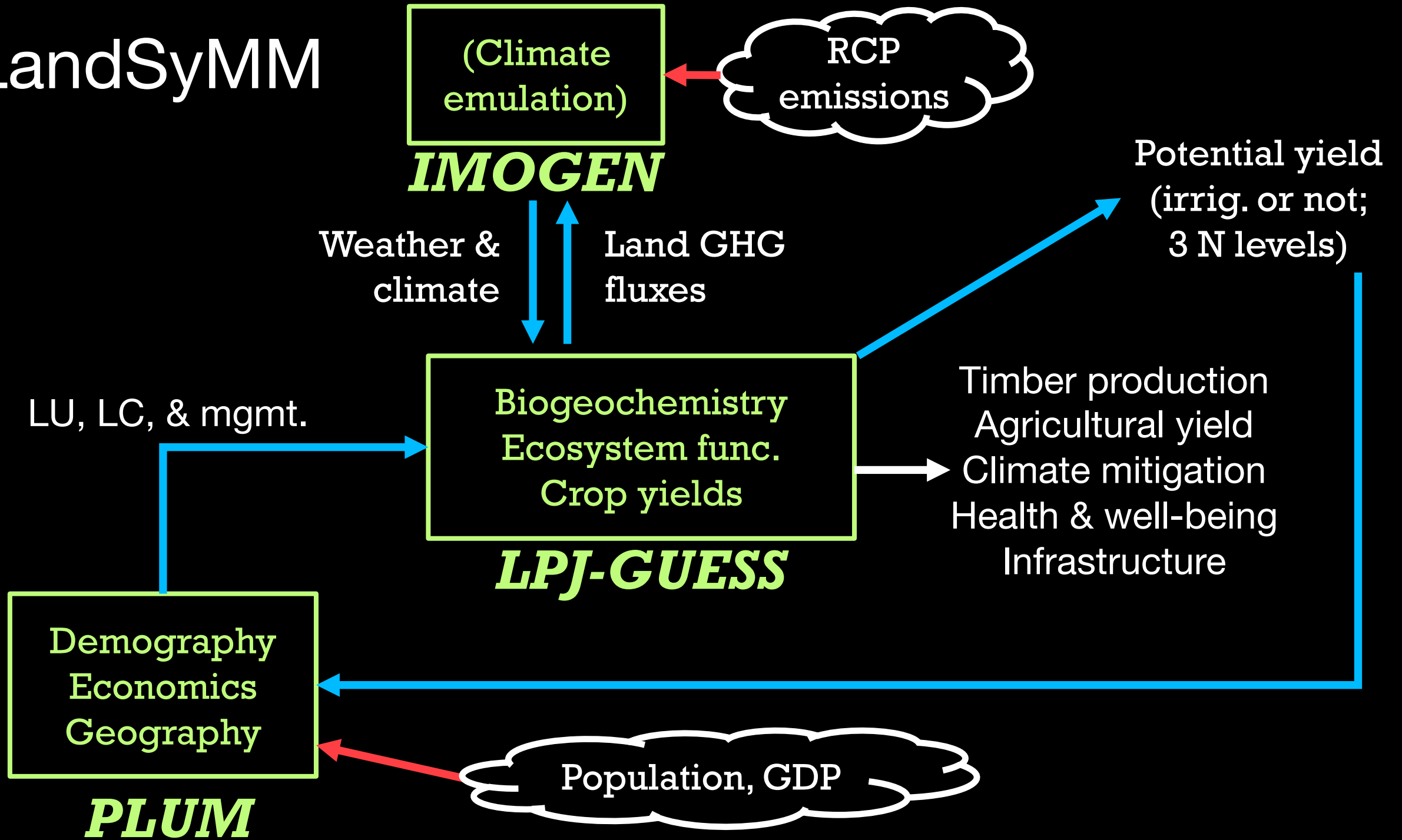
LPJ-GUESS

Timber production
Agricultural yield
Climate mitigation
Health & well-being
Infrastructure

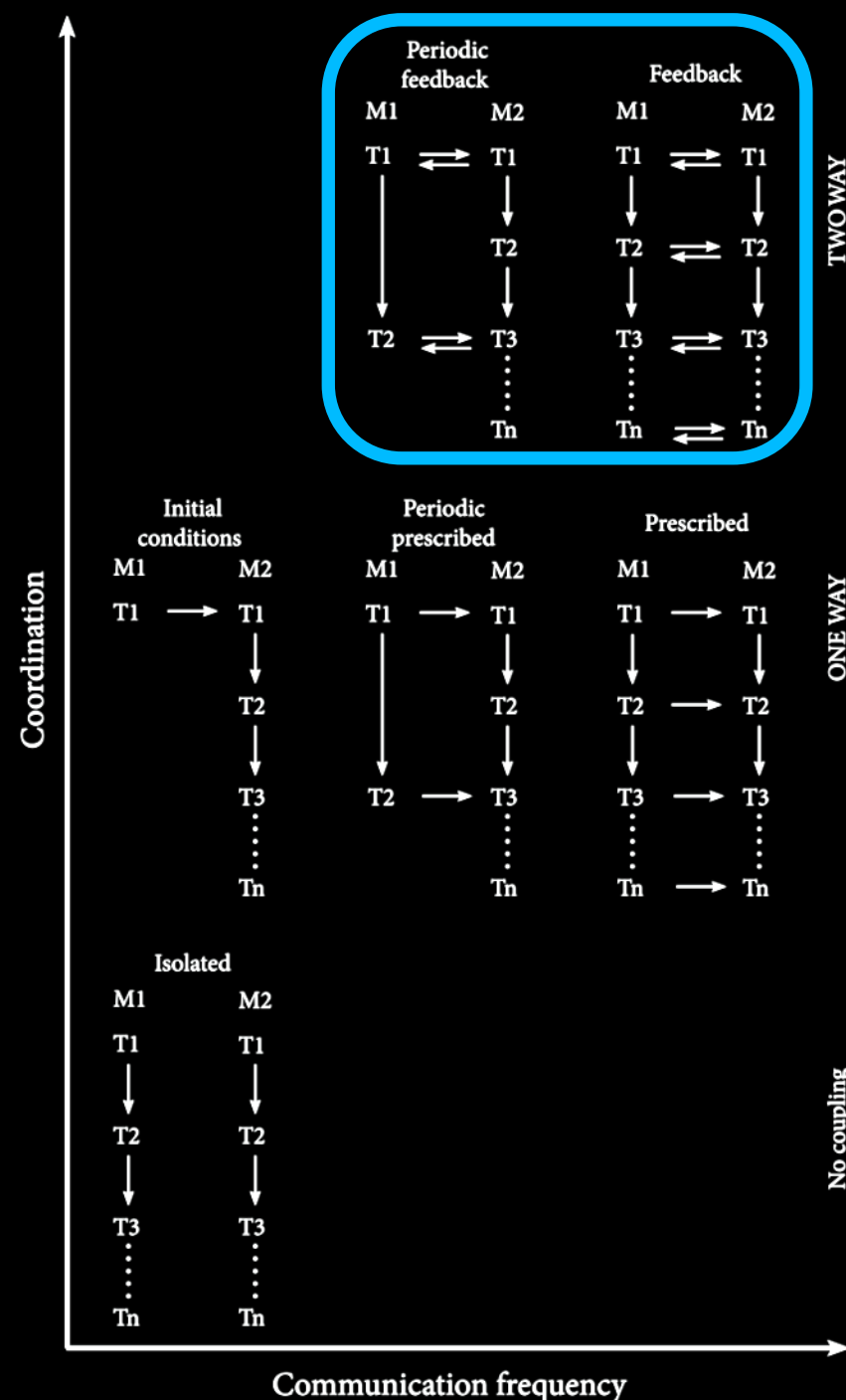
Demography
Economics
Geography

PLUM

Population, GDP



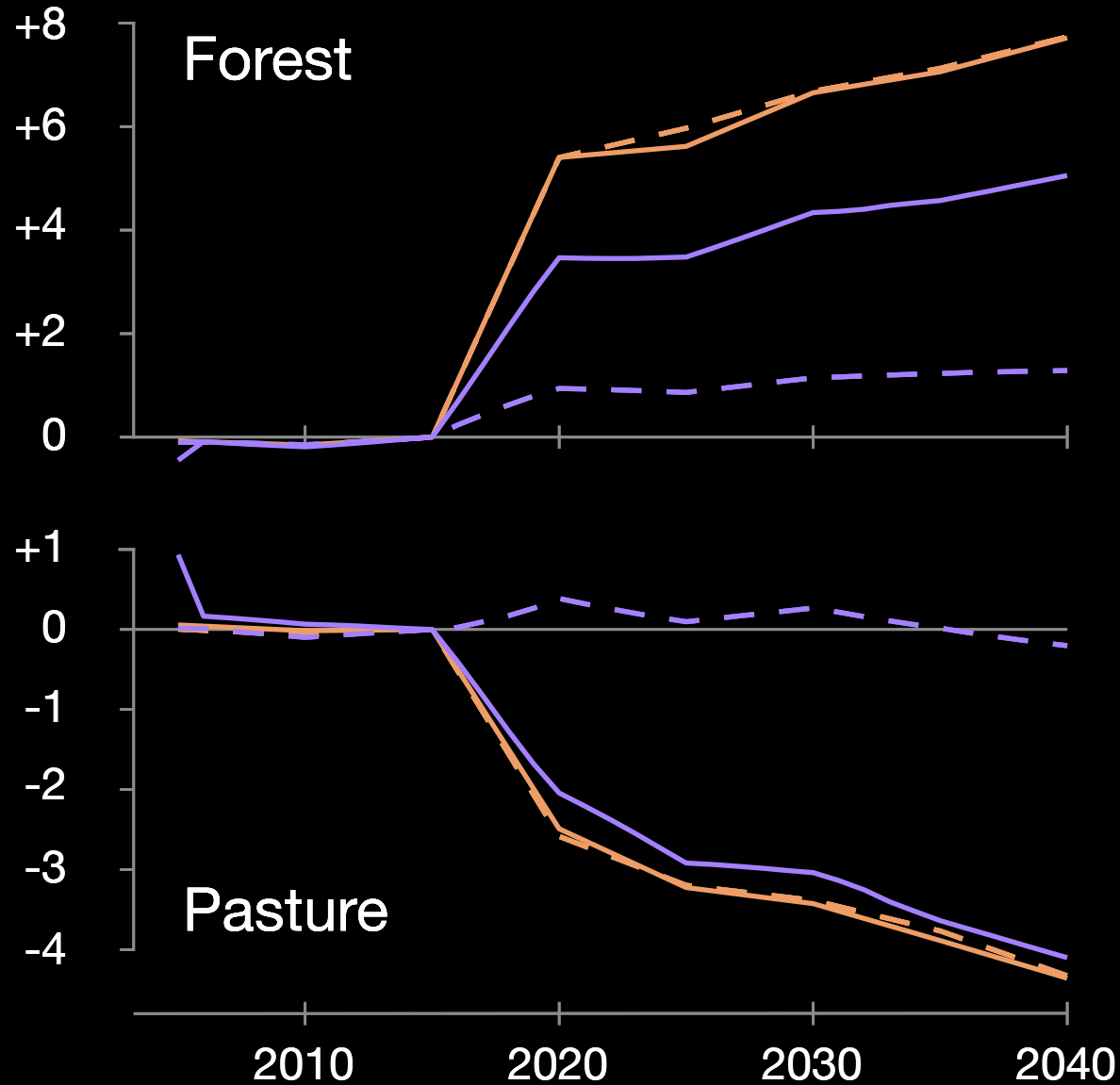
Modeling feedbacks



Two-way coupling enables...

- Representation of real-world feedbacks
- Exploration of system resilience / sensitivity, incl. thresholds
- More consistency between models

Global area changes by 2040 (relative to 2015), Mkm²



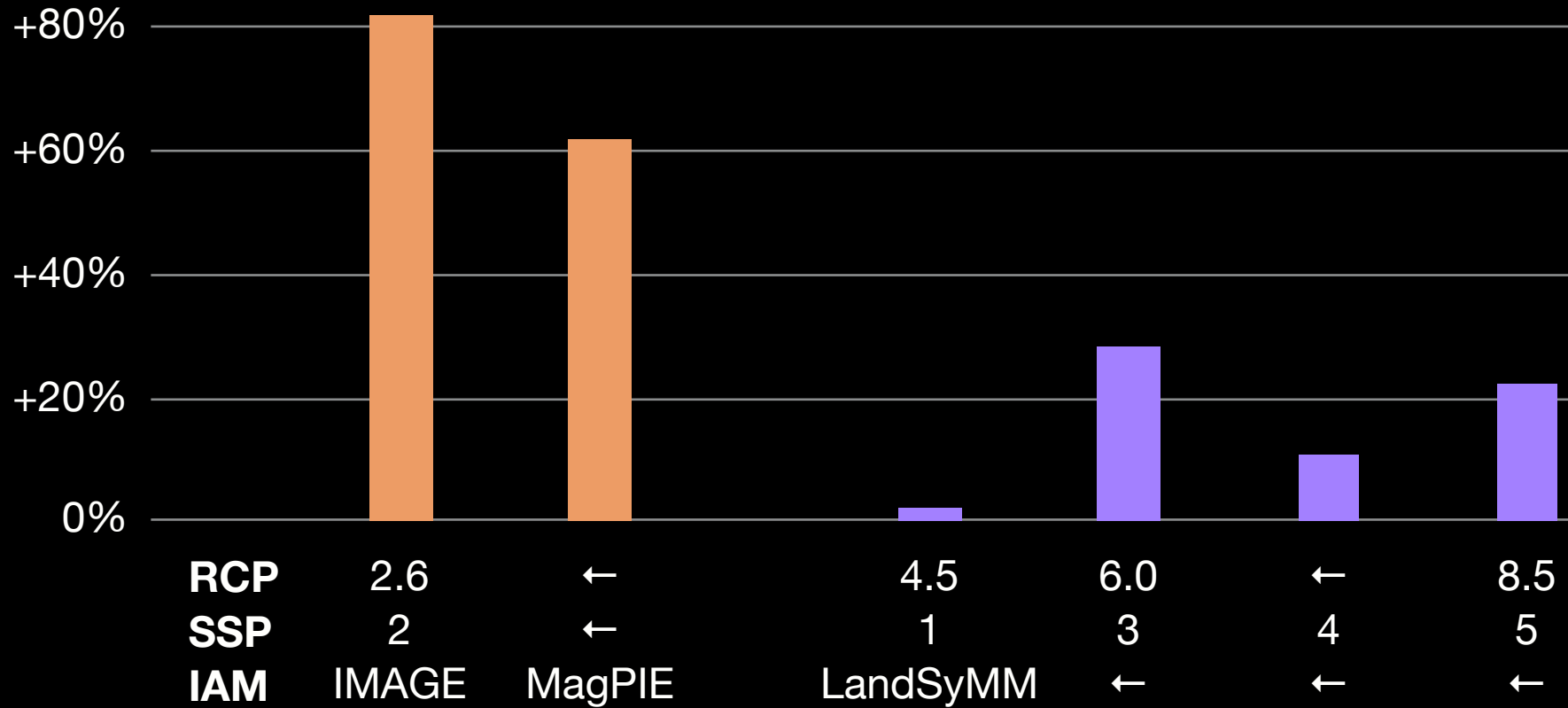
Old New

GCAM — —

CESM — —

• More consistency
between models

Global LPJ-GUESS N losses: 21st-century change



Krause et al. (2017)

Rabin et al. (2019)

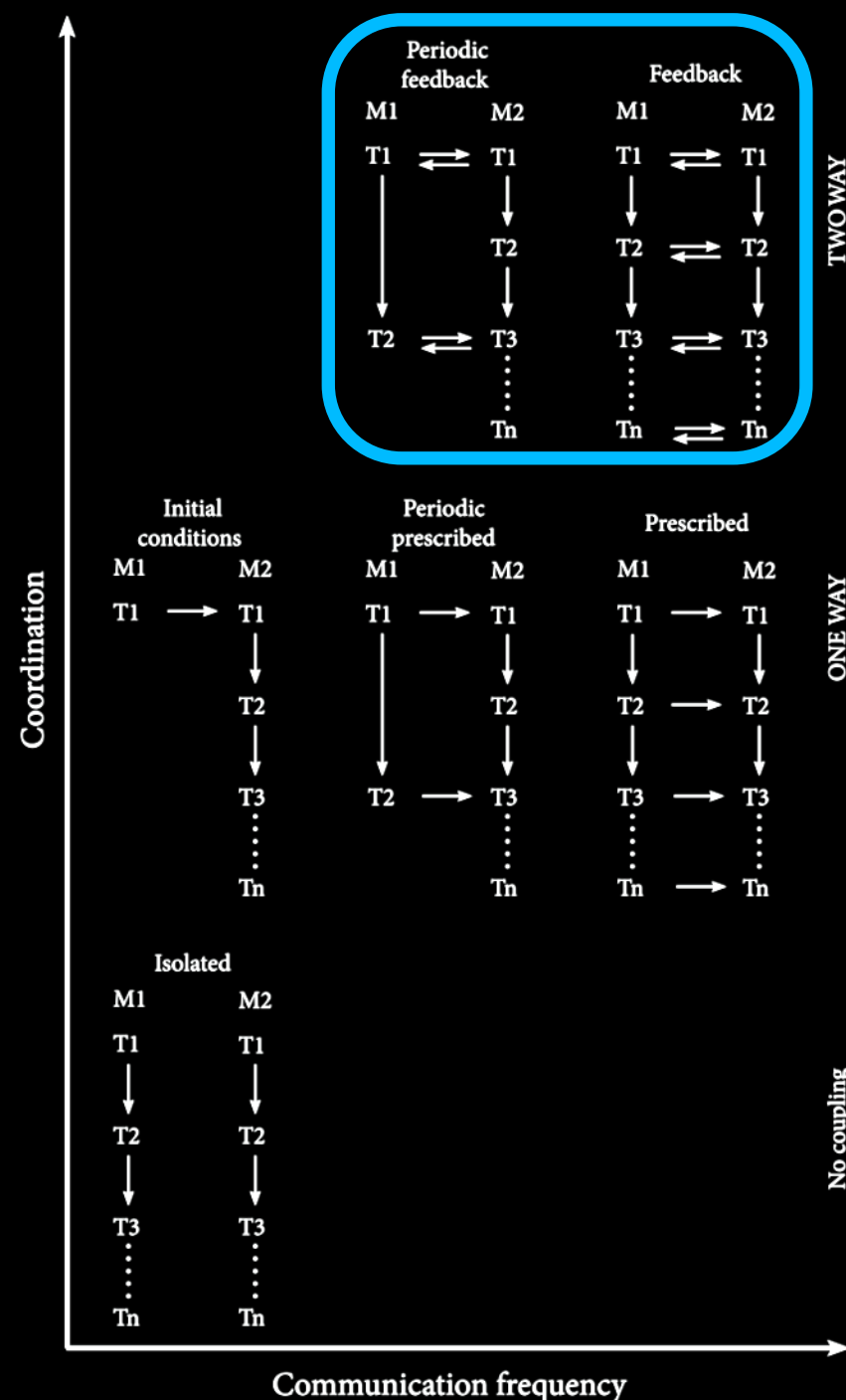
- More consistency between models

Modeling feedbacks

Coupling effect vs. actual feedback?

Hard to compare results from different model systems

Modular coupling



Two-way coupling enables...

- Representation of real-world feedbacks
- Exploration of system resilience / sensitivity, incl. thresholds
- More consistency between models

Strategies for modular coupling

Standardize outputs
definitions to aid cross-compatibility
API

```
for time in range(3000):
    waves.update()
    angle = waves.get_value('sea_surface_water_wave__azimuth_angle_of_opposite_of_phase_velocity')

    cem.set_value('sea_surface_water_wave__azimuth_angle_of_opposite_of_phase_velocity', angle)
    cem.set_value('land_surface_water_sediment-bedload__mass_flow_rate', qs)
    cem.update()

cem.get_value('sea_water__depth', out=z)
```

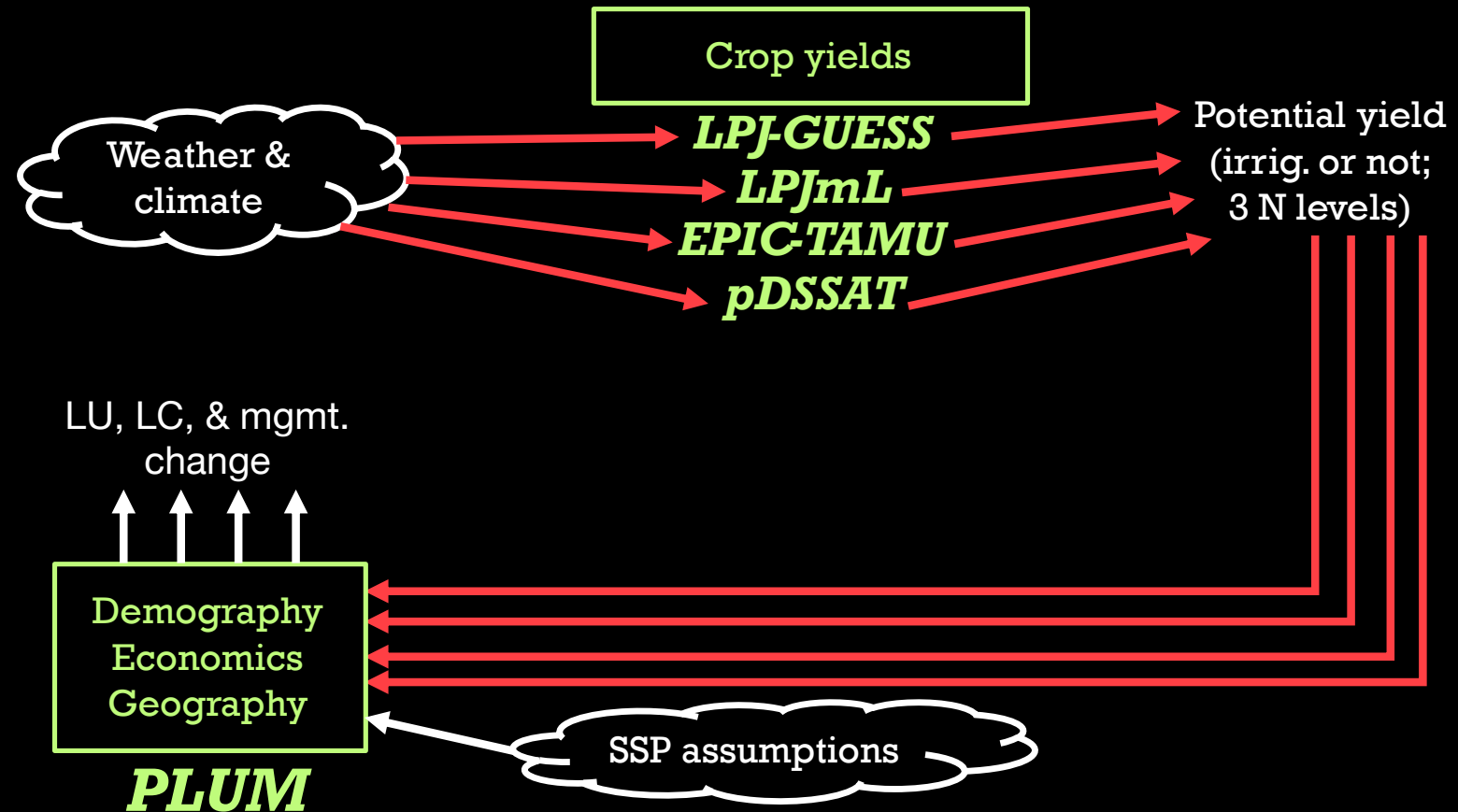
Issue tracker

self-describing and fully controllable by a modeling framework or application.

Strategies for modular coupling

Use wrapper/container software (e.g., Docker)
to make it easier for others to run a model
and ensure **portability**

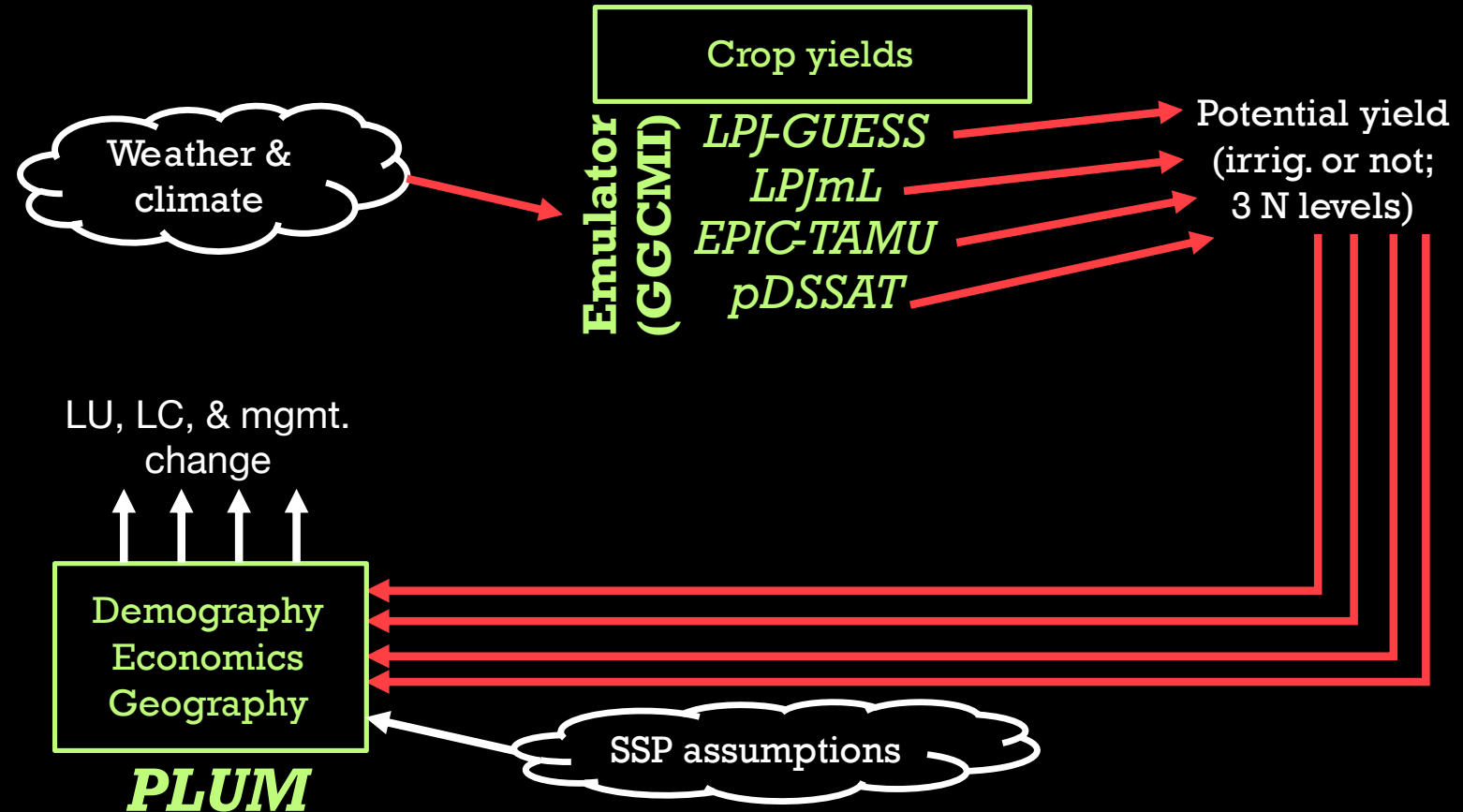
emulation
“run”



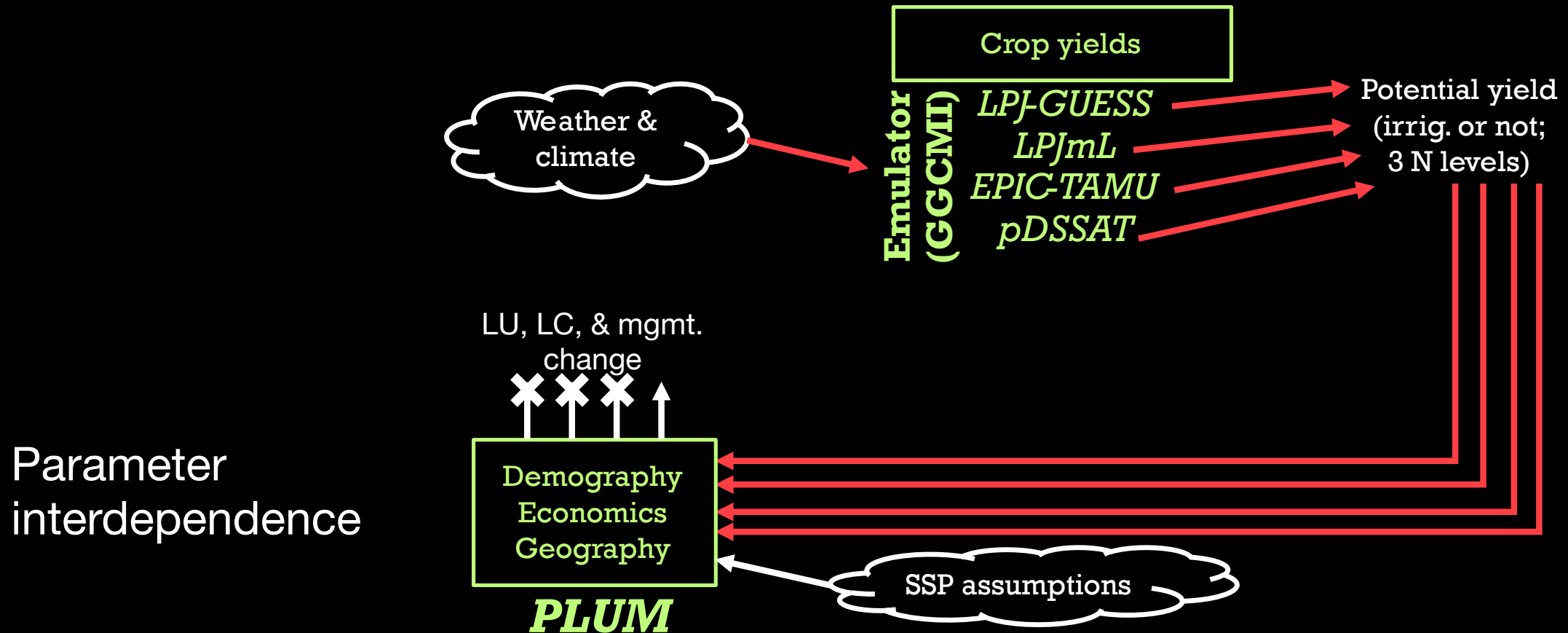
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emulation
“run”



Challenges for (modular) coupling



Challenges for (modular) coupling

Robinson et al. (2018, *ESD*)

Calvin et al. (2018, *ERL*)

Error propagation,
amplification

Technically
difficult

Stochastic vs.
deterministic
models

Takes *time*!

Parameter
interdependence

Thanks!

References

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