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DEMETER: A land use land cover disaggregation model

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CESM SDWG/LMWG

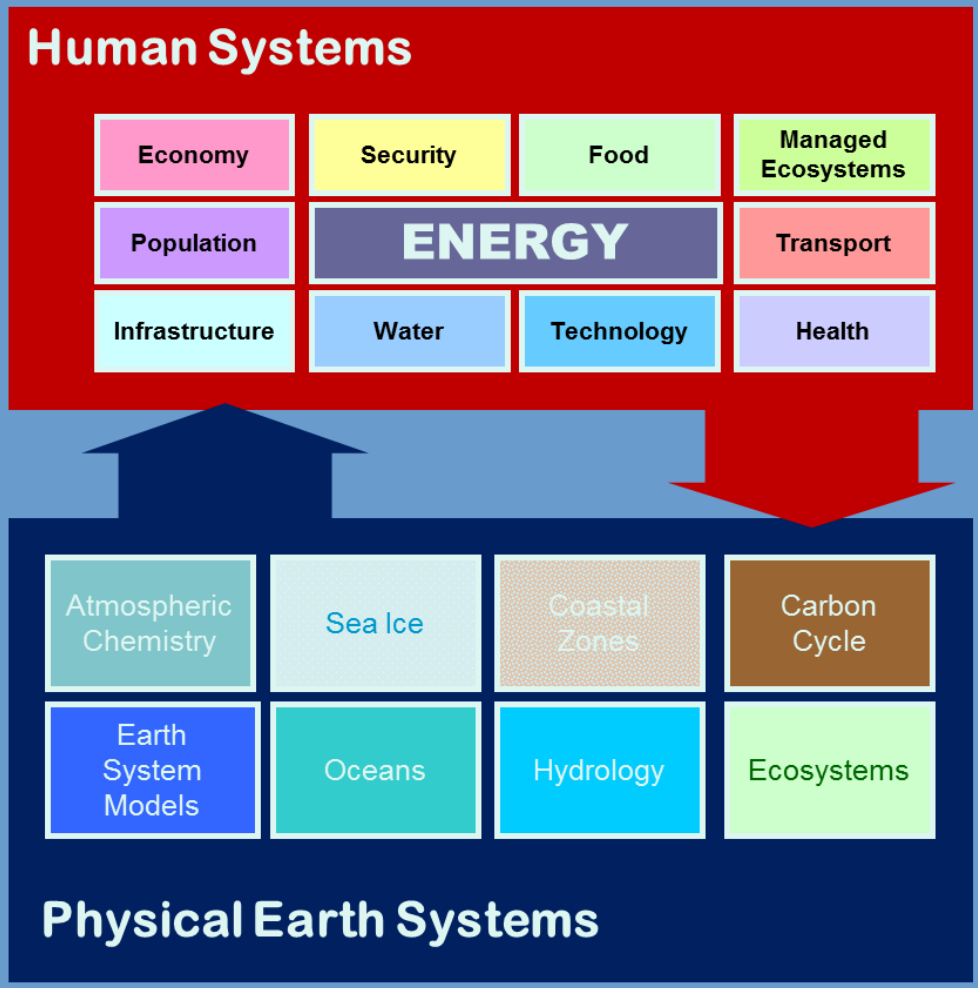
Integrated Assessment Models (IAMs)

IAMs integrate human and natural Earth system climate science.

- IAMs capture interactions between complex and highly nonlinear systems. IAMs provide insights that would be otherwise unavailable from disciplinary research.
- IAMs provide physical science researchers with information about human systems such as GHG emissions, land use and land cover.

IAMs provide important, science-based decision support tools.

- IAMs support national, international, regional, and private-sector decisions.



GCAM produced the RCP4.5 in CMIP5 and the SSP4-34 and SSP4-60 in CMIP6

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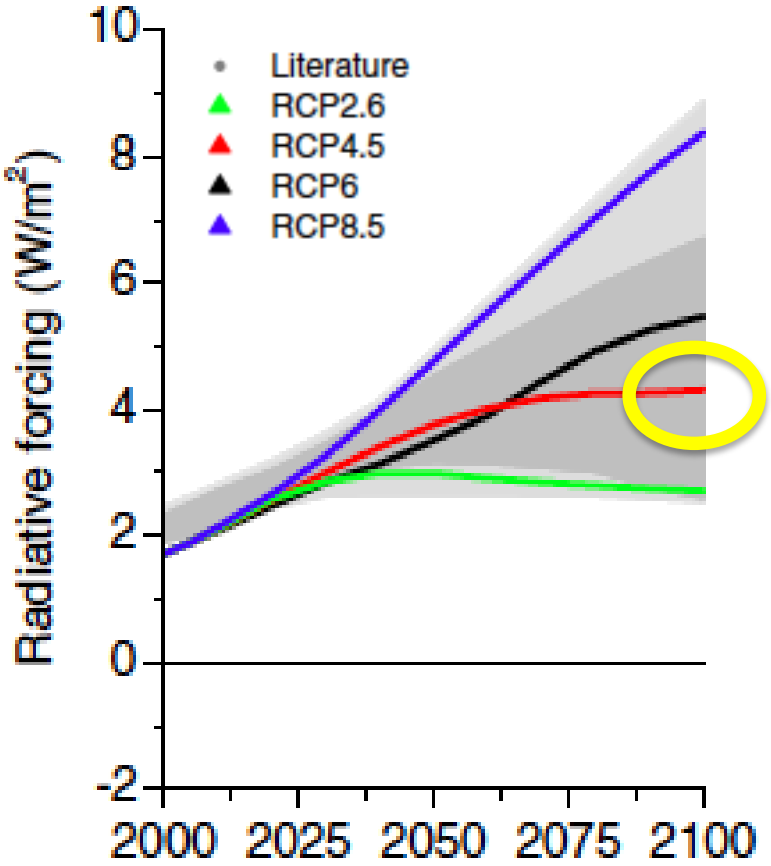
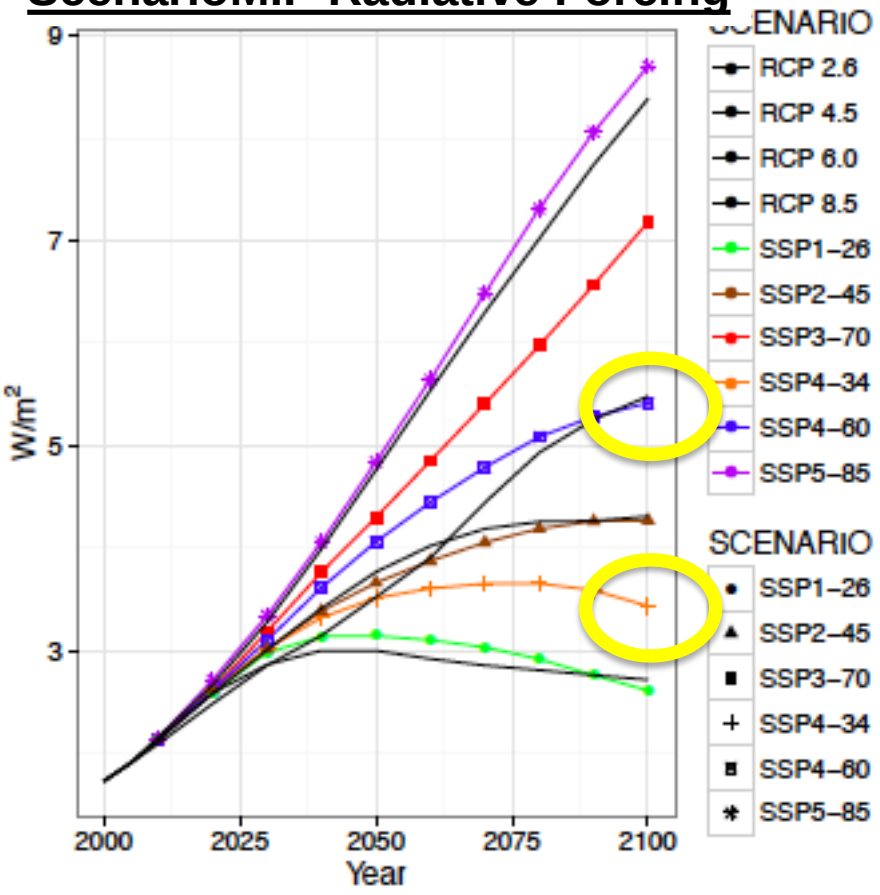
RCP Radiative Forcing



Source: van Vuuren et al. (2011)

ScenarioMIP Radiative Forcing



Source: O'Neill et al. (2017)

GCAM operates on a much coarser scale than Earth System Models

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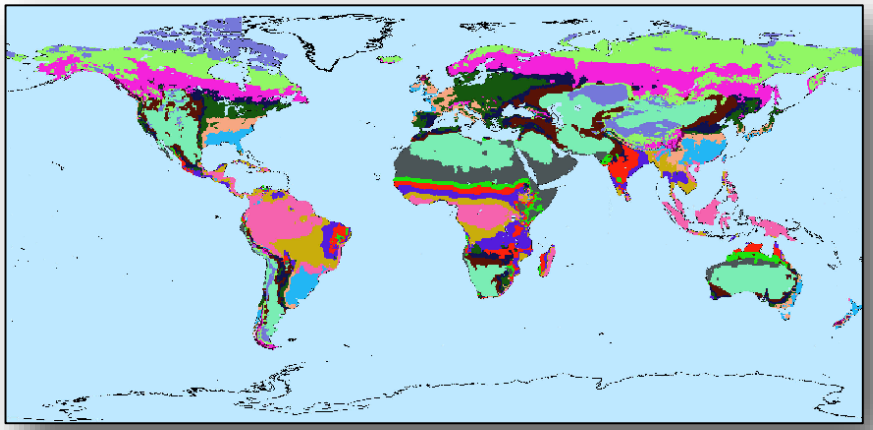
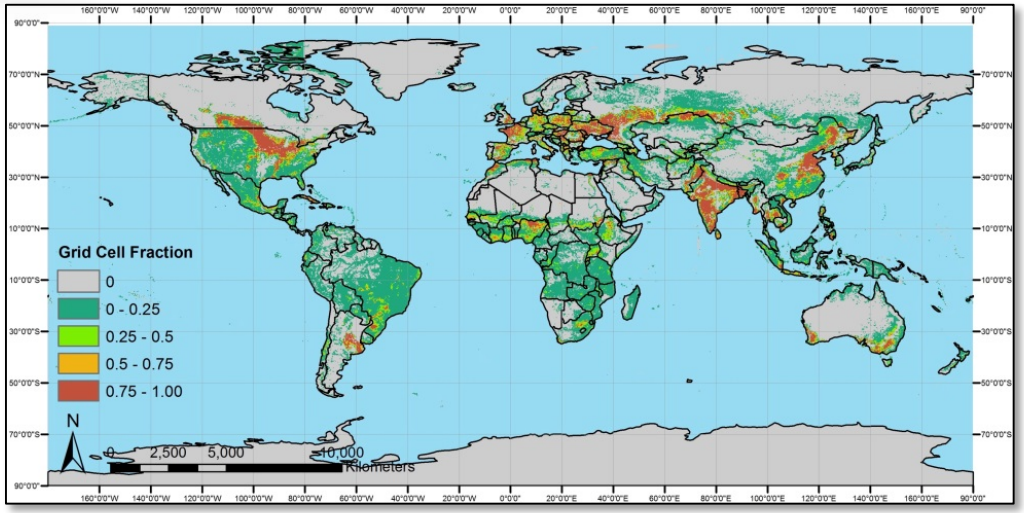
GCAM



~ 300 Global Regions

Demeter



0.05˚ to 0.25˚

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What is Demeter?

Demeter

- Built to downscale the Global Change Assessment Model (GCAM) sub-regional land projections to gridded formats for use with Earth System Models and impact assessment models;
- Generating downscaled products in a variety of formats at multiple scales (e.g., 500 m – 0.5º);
- Flexibility to accommodate regional differences, as well as to allow user-specification of various parameter and input configurations;
- Modular so that it can be integrated with other Integrated Assessment Models;
- Open-source for enabling community efforts toward new developments.

Code available at: **https://github.com/IMMM-SFA/demeter**

Demeter Foundation

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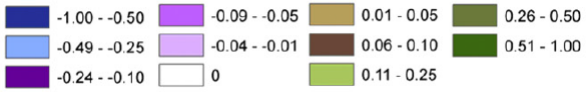
West et al. (2014)

RCP8.5
Business as usual

RCP4.5
Mitigation

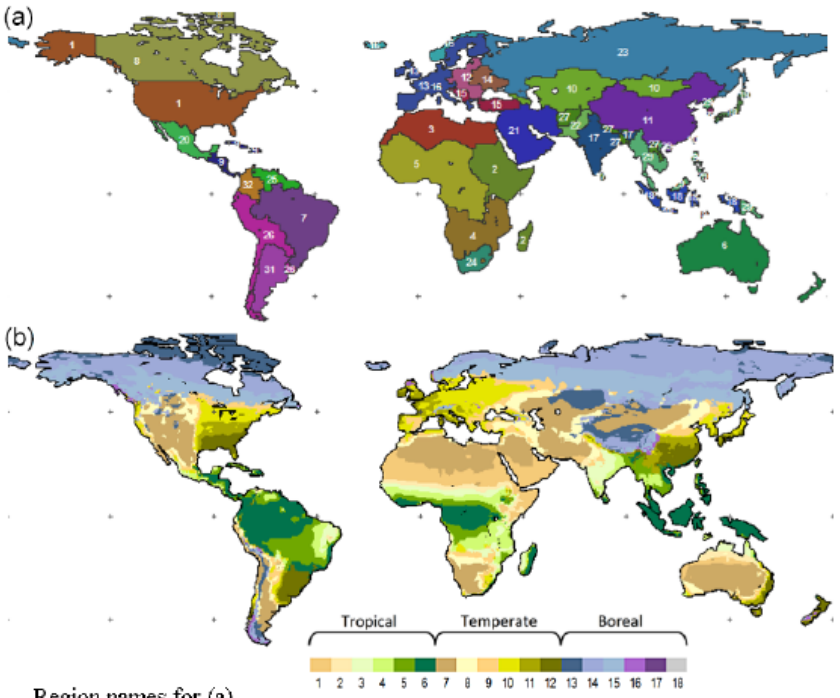
Crops

Forest



Projected % change in land cover by 2090 compared to the 2005 condition

Le Page et al. (2016)



Region names for (a)

1- USA	9- Central America and Caribbean	17- India	25- South America Northern
2- Africa Eastern	10- Central Asia	18- Indonesia	26- South America Southern
3- Africa Northern	11- China	19- Japan	27- South Asia
4- Africa Southern	12- EU-12	20- Mexico	28- South Korea
5- Africa Western	13- EU-15	21- Middle East	29- Southeast Asia
6- Australia NZ	14- Europe Eastern	22- Pakistan	30- Taiwan
7- Brazil	15- Europe Non EU	23- Russia	31- Argentina
8- Canada	16- European Free Trade Association	24- South Africa	32- Colombia

GCAM represents the world terrestrial biosphere into 283 spatial units, the result of the intersection of regions and agro-ecological zones

Demeter Inputs

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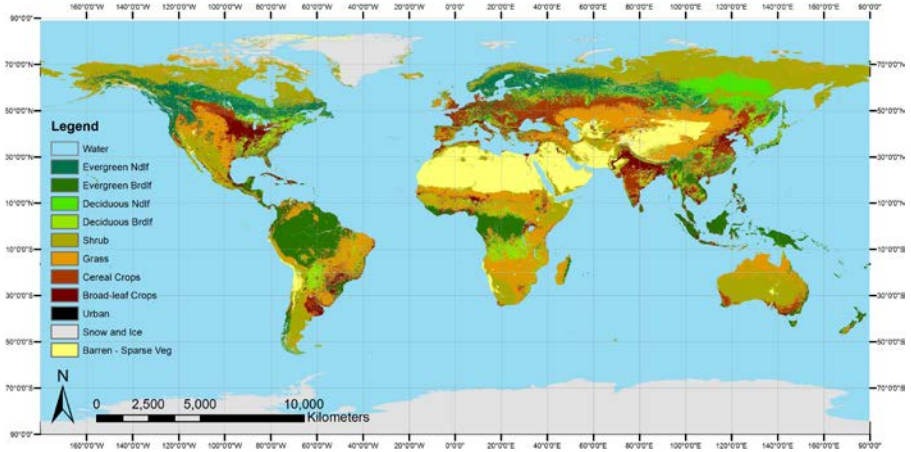
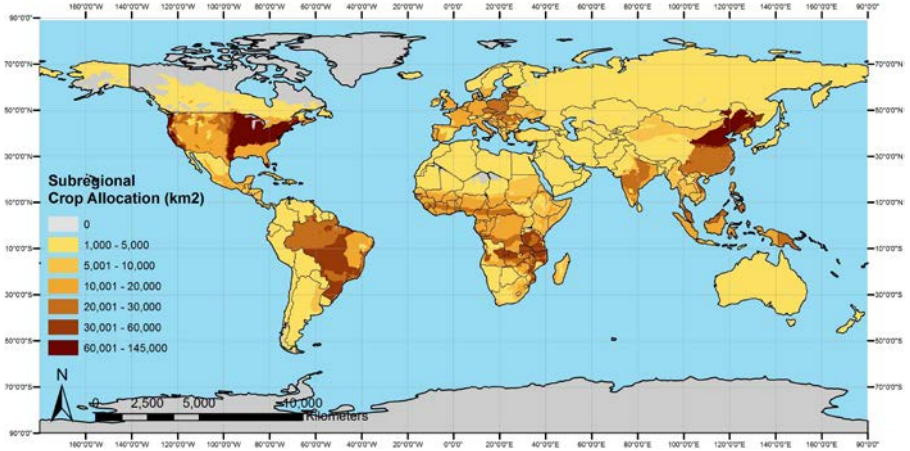
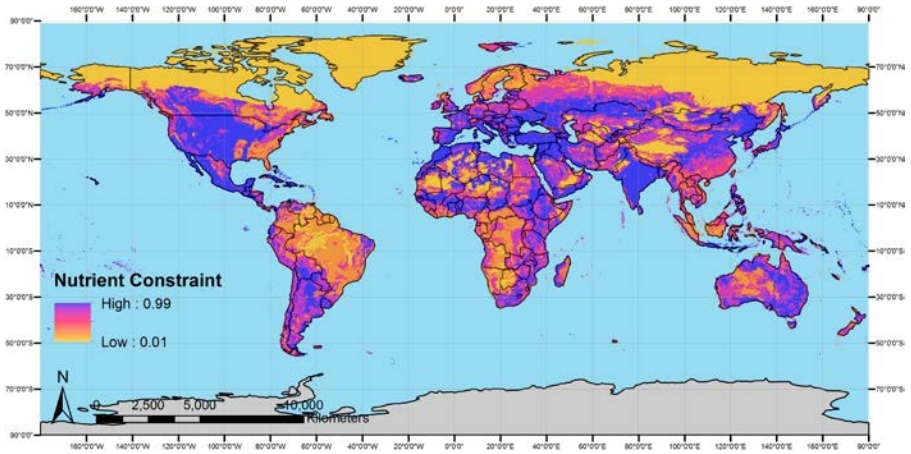
Observed land cover as the initial condition (MODIS)



GCAM subregional projection



Spatial Constraints (optional)



Other Inputs:

- User-defined aggregation of base-layer and GCAM land cover types;
- User-defined intensification ratios;
- User-defined transition priorities
- User-defined treatment orders

Nutrient availability. 0 = full constraint; 1 = no constraint

Demeter Land Allocation Processes

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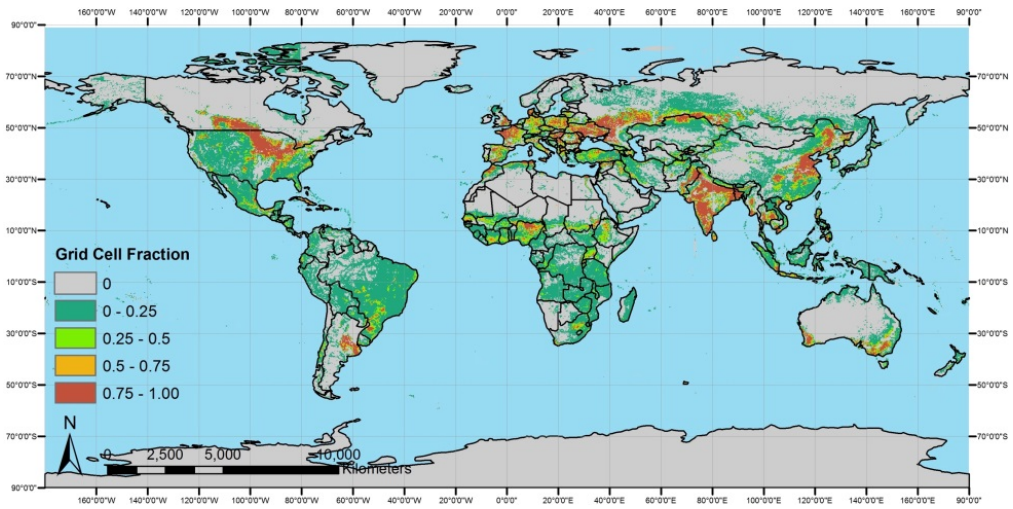
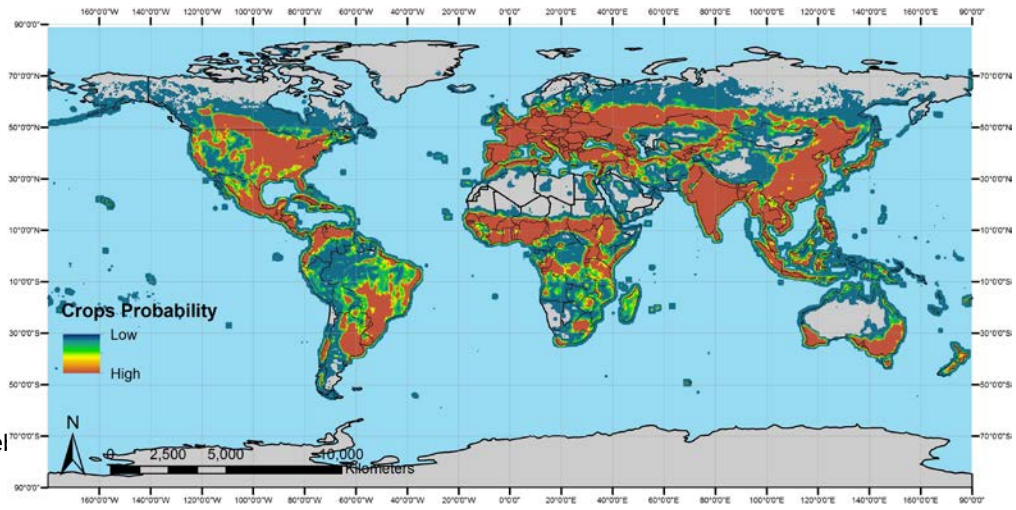
Fractional coverage in the base year



Kernel density distribution



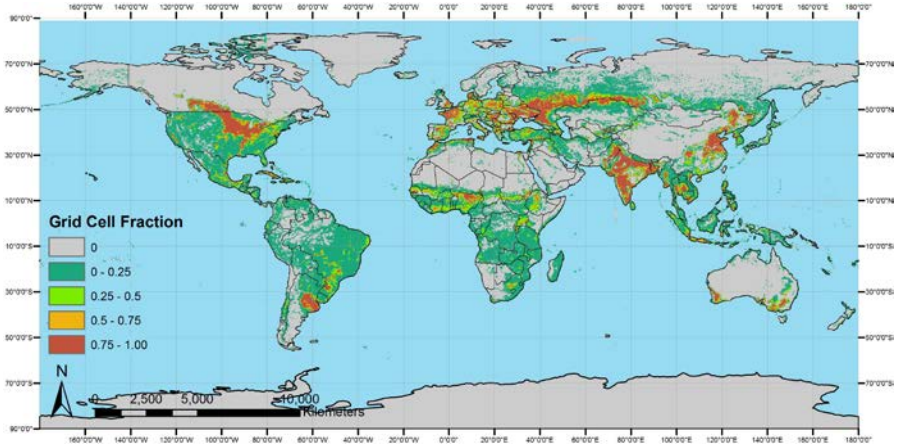
Intensification: increase the fractional area of a land cover type by applying GCAM projections in grid cells where it exists

Extensification: apply remaining GCAM projected areas to grid cells located where the land cover type does not exist using customized kernel density distributions.

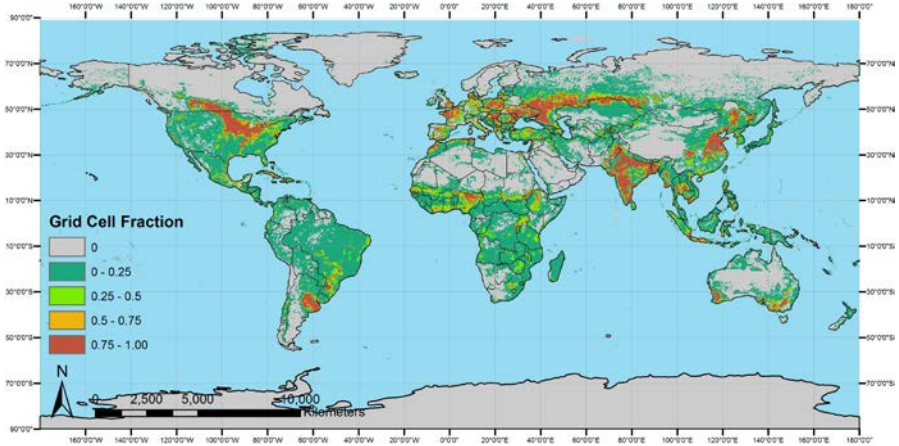
Fel

Downscaled land cover (example)

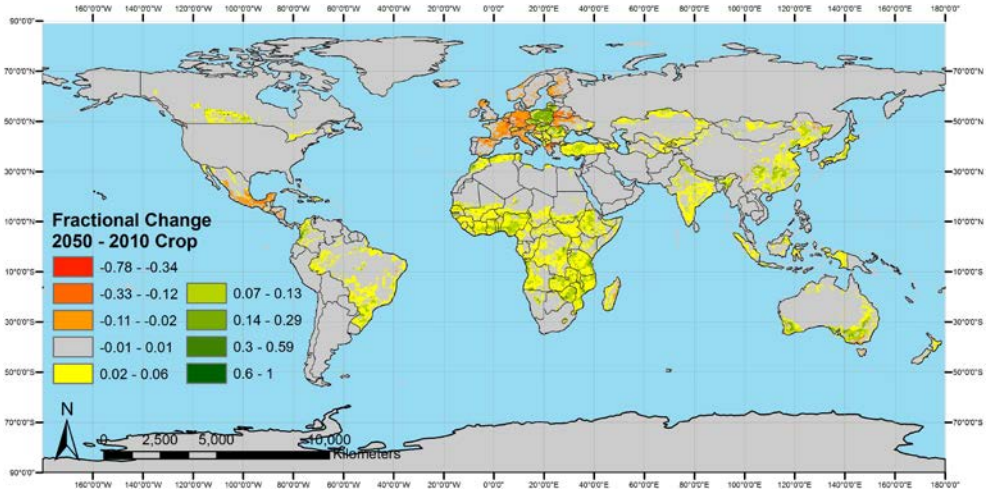
2010 cropland distribution - reference



2050 cropland distribution - reference



2050-2010 cropland change



We can explore uncertainty in downscaled LULCC by varying parameters.

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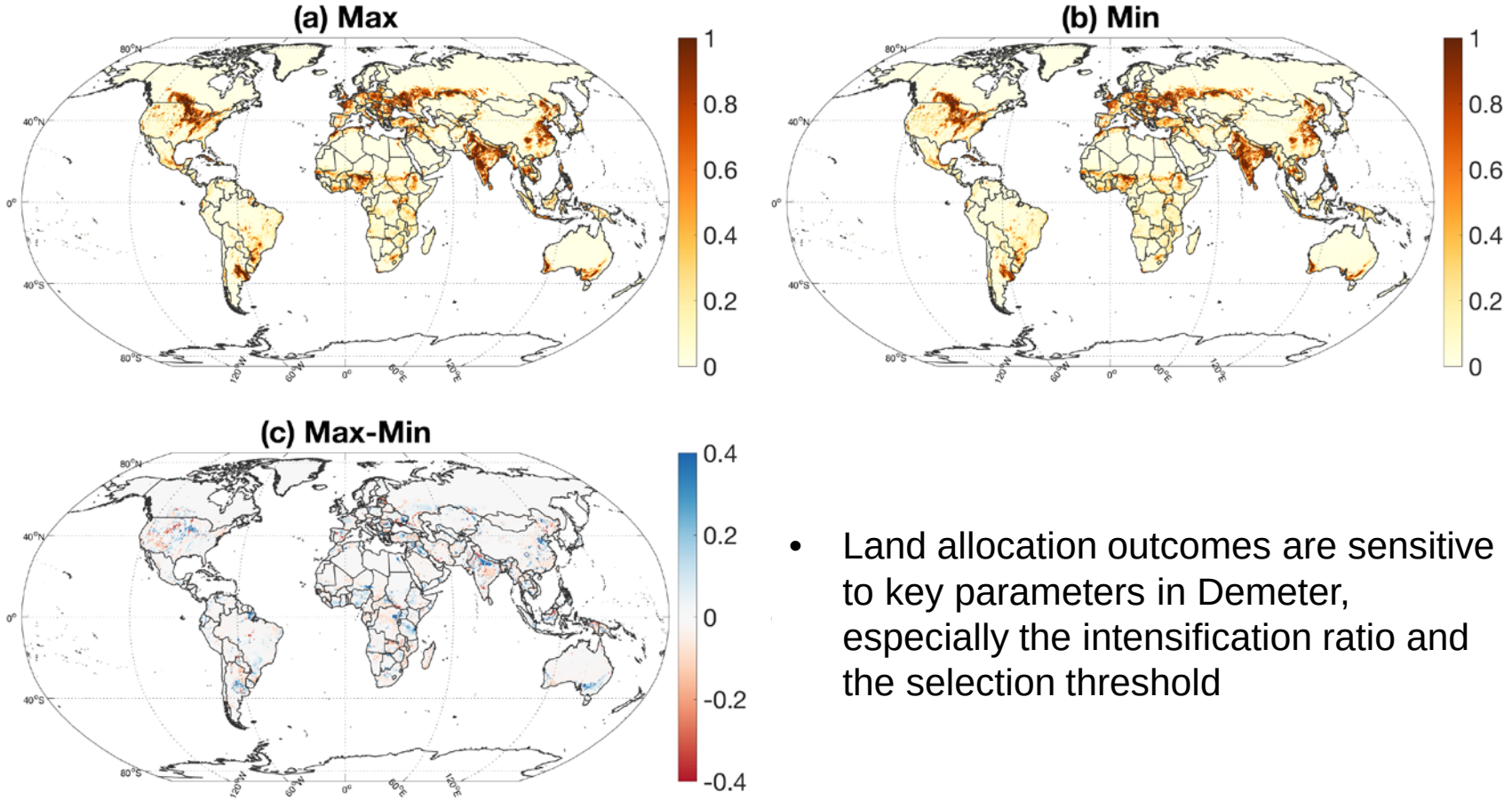
Downscaled cropland fraction (max and min in the above figure), and their differences at 0.25-degree resolution



- Land allocation outcomes are sensitive to key parameters in Demeter, especially the intensification ratio and the selection threshold

Chen et al. (in prep)

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How does Demeter compare to other downscaled land use land cover change products?

The SSP4-34 is a world of inequality, with mitigation efforts focused on bioenergy and afforestation in the developed world.

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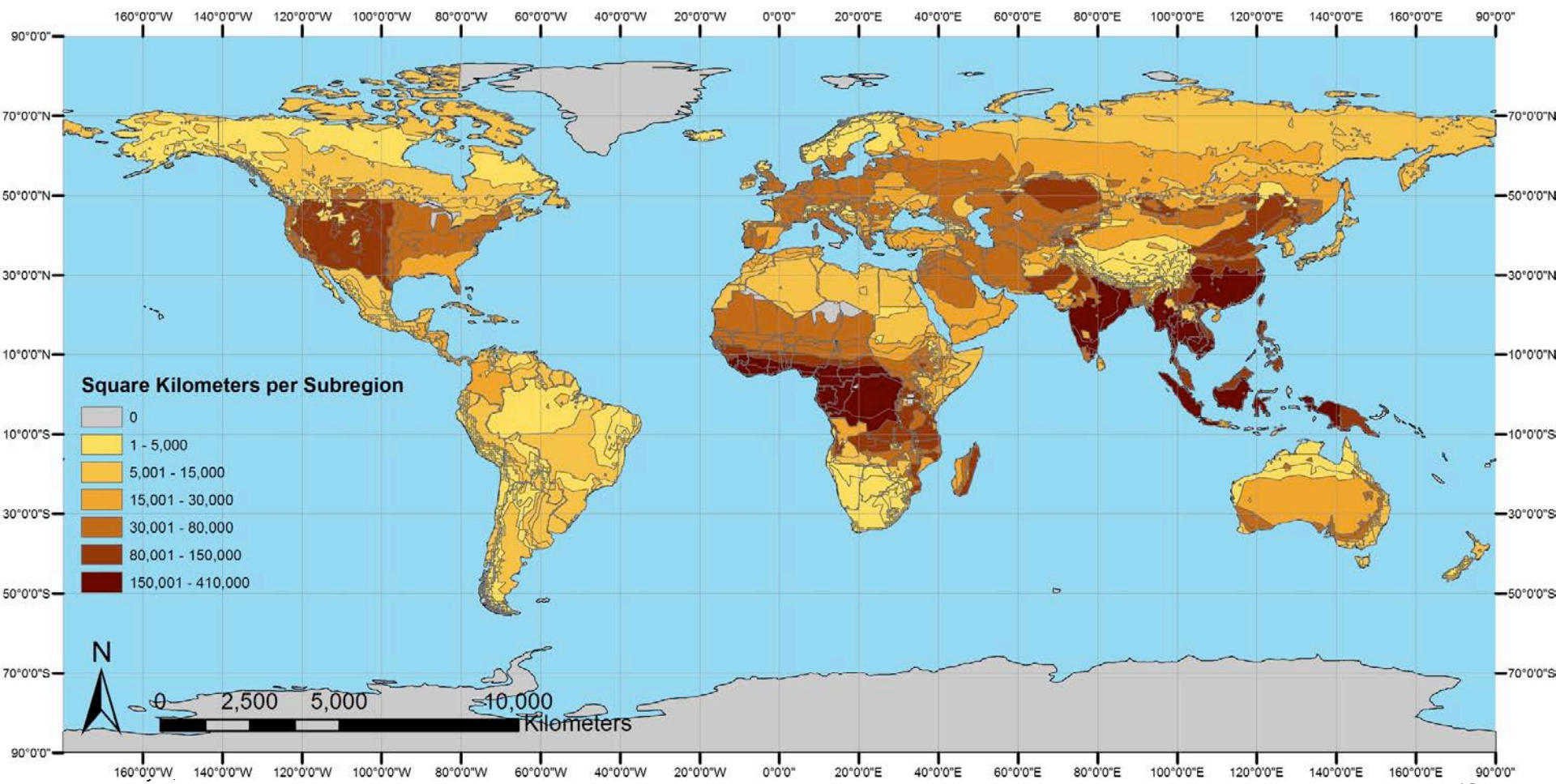
C3 Crops in 2050 in GCAM's SSP4-34



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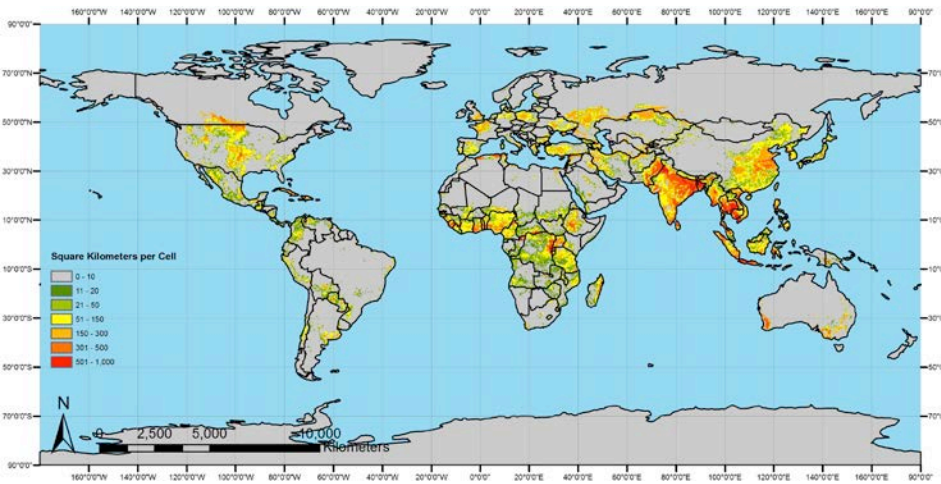
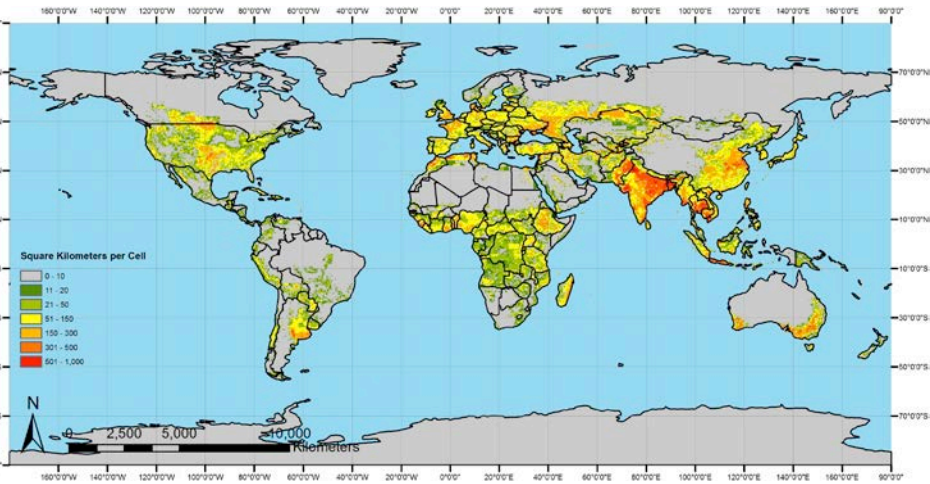
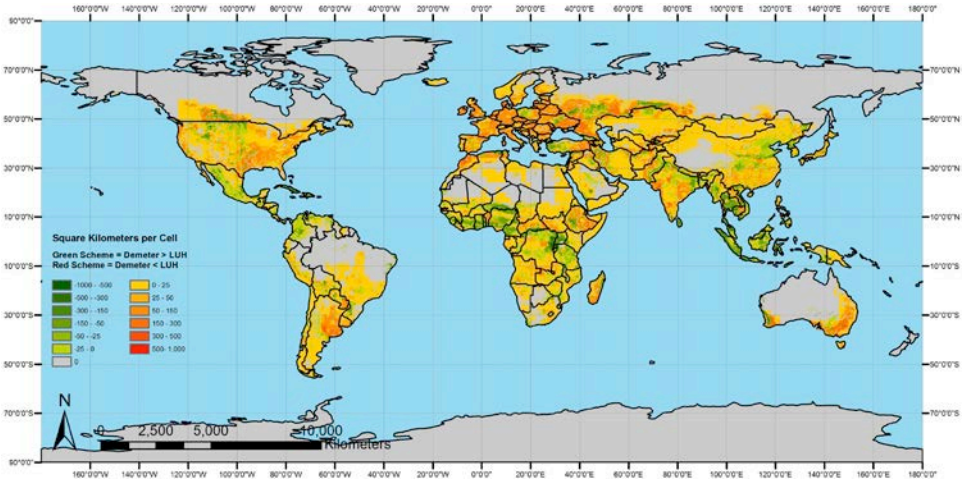
C3 Crops in 2050 in Demeter



C3 Crops in 2050 in LUH2



Difference (LUH2 – Demeter)



The SSP4-34 is a world of inequality, with mitigation efforts focused on bioenergy and afforestation in the developed world.

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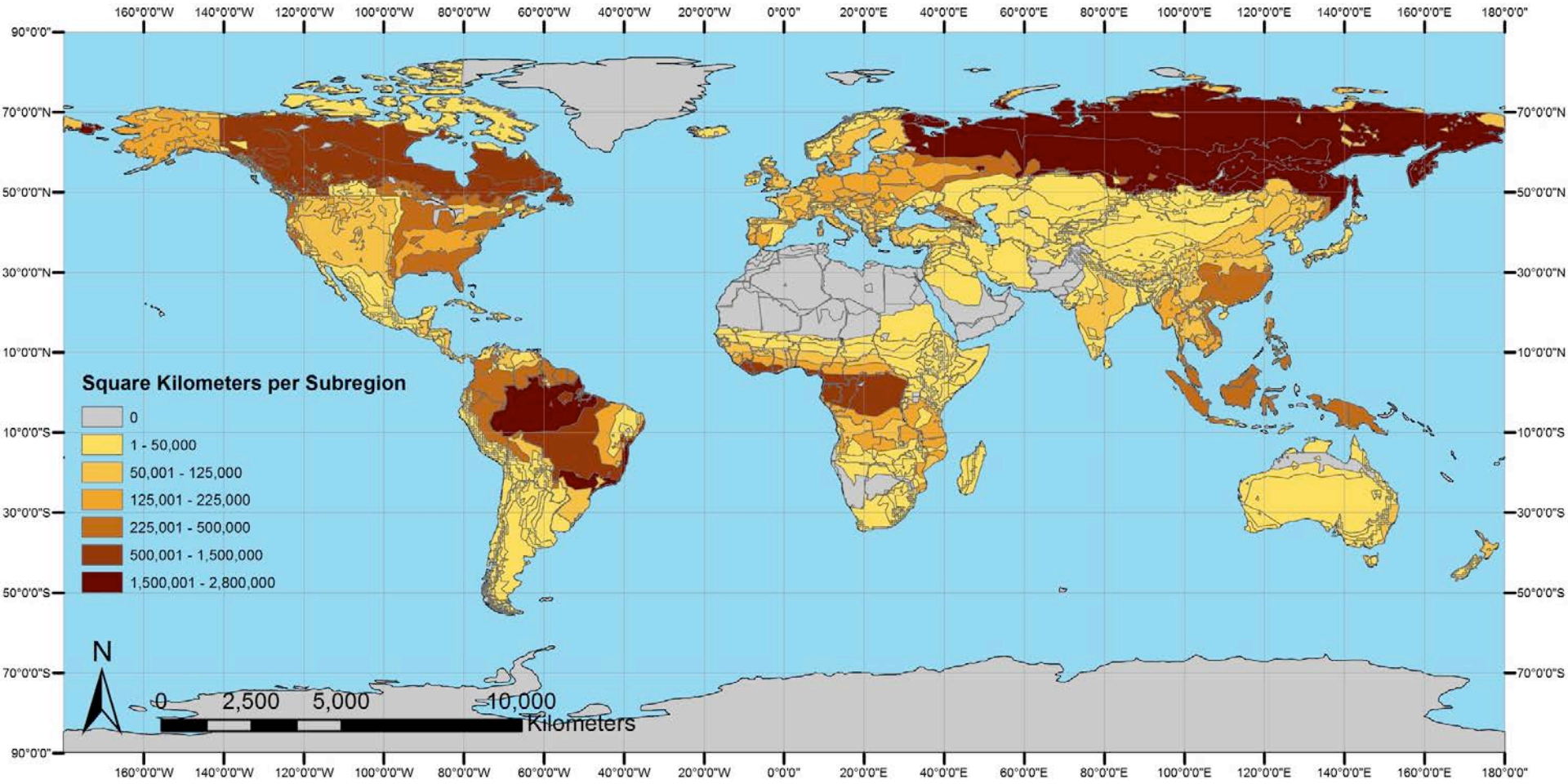
Forest in 2050 in GCAM's SSP4-34



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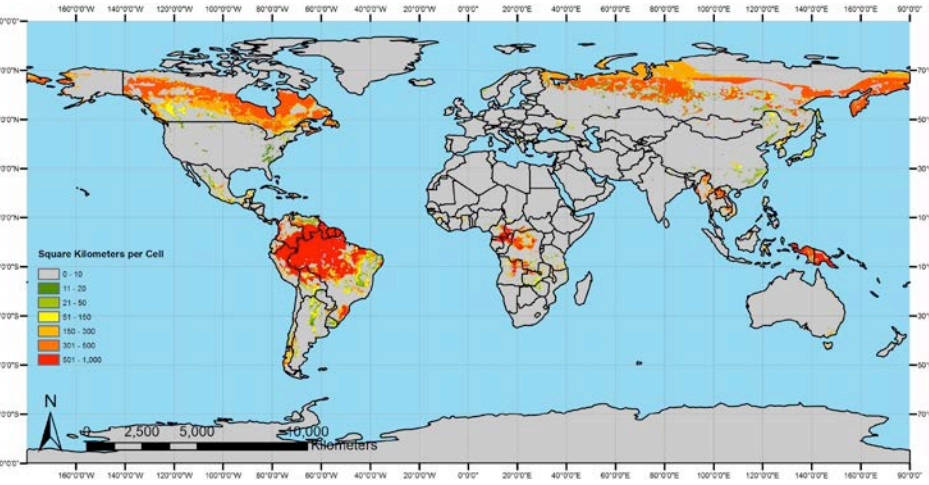
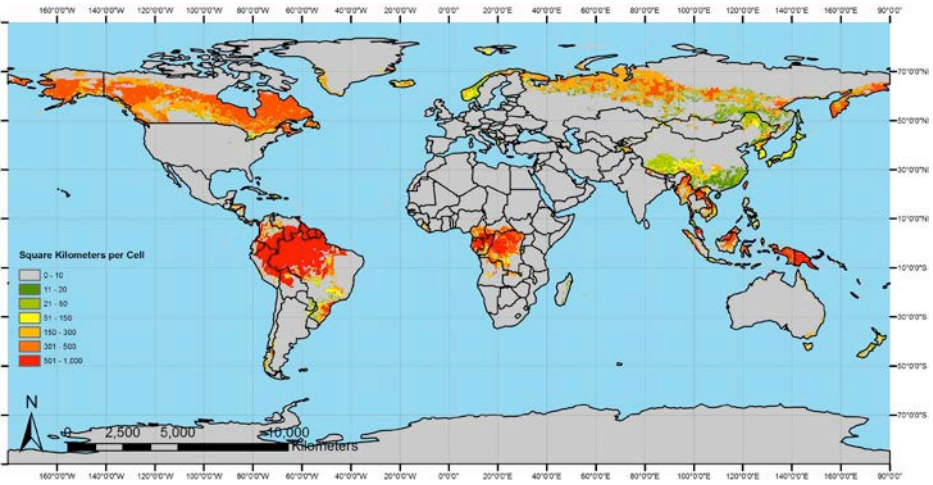
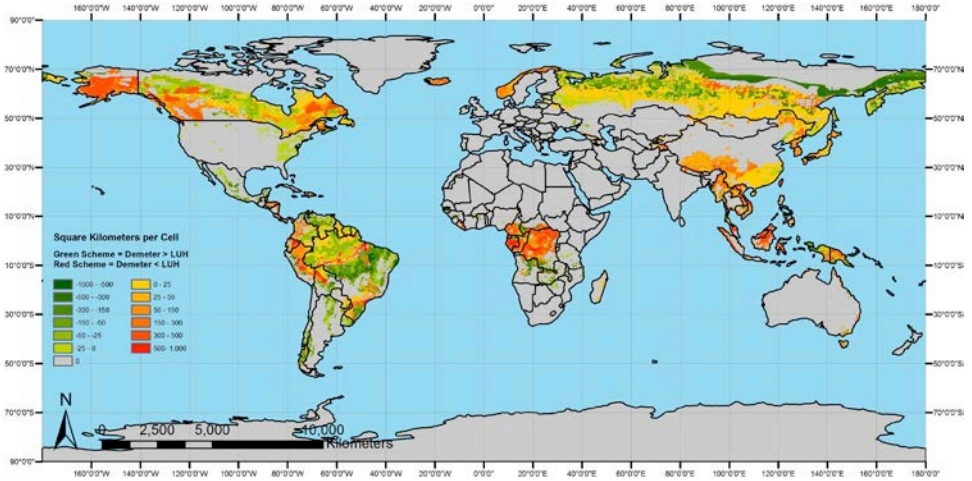
Forest in 2050 in Demeter



Forest in 2050 in LUH2



Difference (LUH2 – Demeter)



Demeter preserves the underlying GCAM regional land areas.

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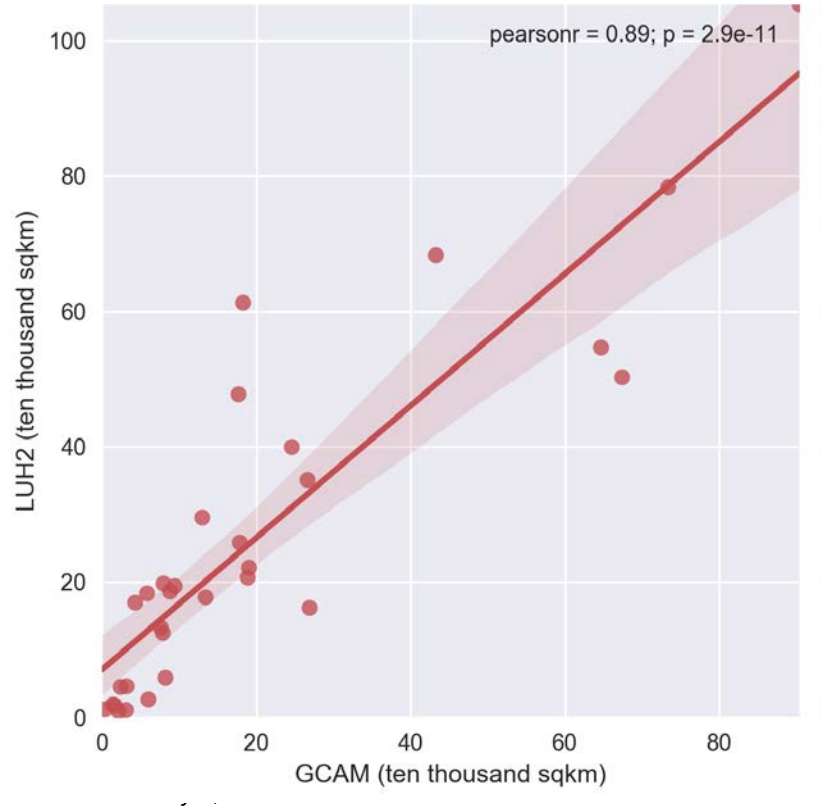
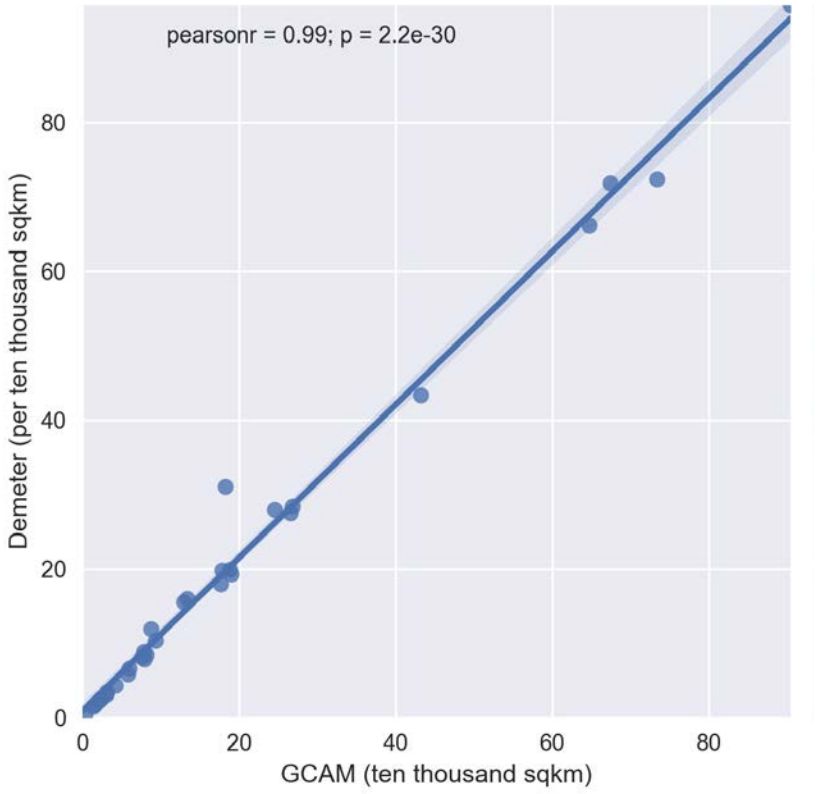
C3 Crops in LUH2 (left) and Demeter (right) compared to GCAM





Demeter Summary

- Demeter's land-use change modeling:
  - High spatial resolution, facilitating linkages with ESMs
  - Constrained by GCAM's regional land area
  - Inclusion of other physical constraints (e.g., nutrient limitation, soil quality)

- Future directions include:
  - Region-specific parameters and constraints
  - Potentially including local economic considerations
  - Adding other management layers, like wood harvest, irrigation, fertilizer
  - Embedding directly within GCAM for easier use (including visualization and coupling to other models)
  - Providing feedbacks/constraints on the regional scale LULCC estimates in GCAM

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Thank you!