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Spatial land use in the GCAM integrated assessment model

Kate Calvin, Marshall Wise, Page Kyle, Louise Chini

July 23, 2012

Outline

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- Brief overview of GCAM
- Land allocation decisions in GCAM at the 151 region-level
- Sample results
- Downscaling GCAM results to the 0.5° x 0.5° level

The Global Change Assessment Model

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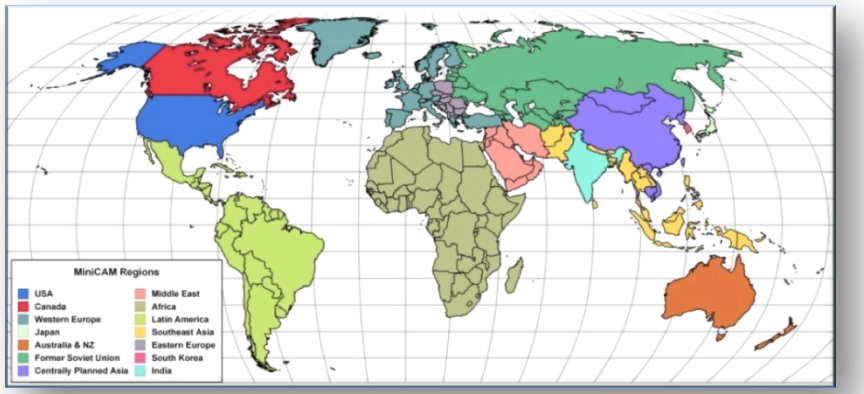
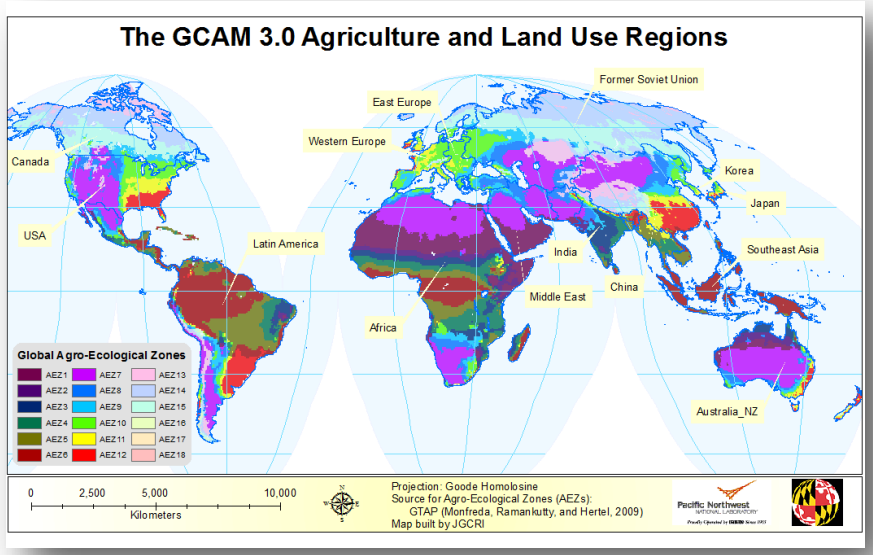
14 Region Energy/Economy Model



151 Agriculture and Land Use Model



- GCAM is a **global integrated assessment model**
- GCAM links **Economic, Energy, Land-use,** and **Climate** systems
- Technology-rich model
- Emissions of 16 greenhouse gases and short-lived species: CO_2, CH_4, N_2O, halocarbons, carbonaceous aerosols, reactive gases, sulfur dioxide.
- Runs through **2095** in **5-year time-steps.**
- Dynamic Recursive
- Open Source
- Documentation available at: **wiki.umd.edu/gcam**

The Global Change Assessment Model

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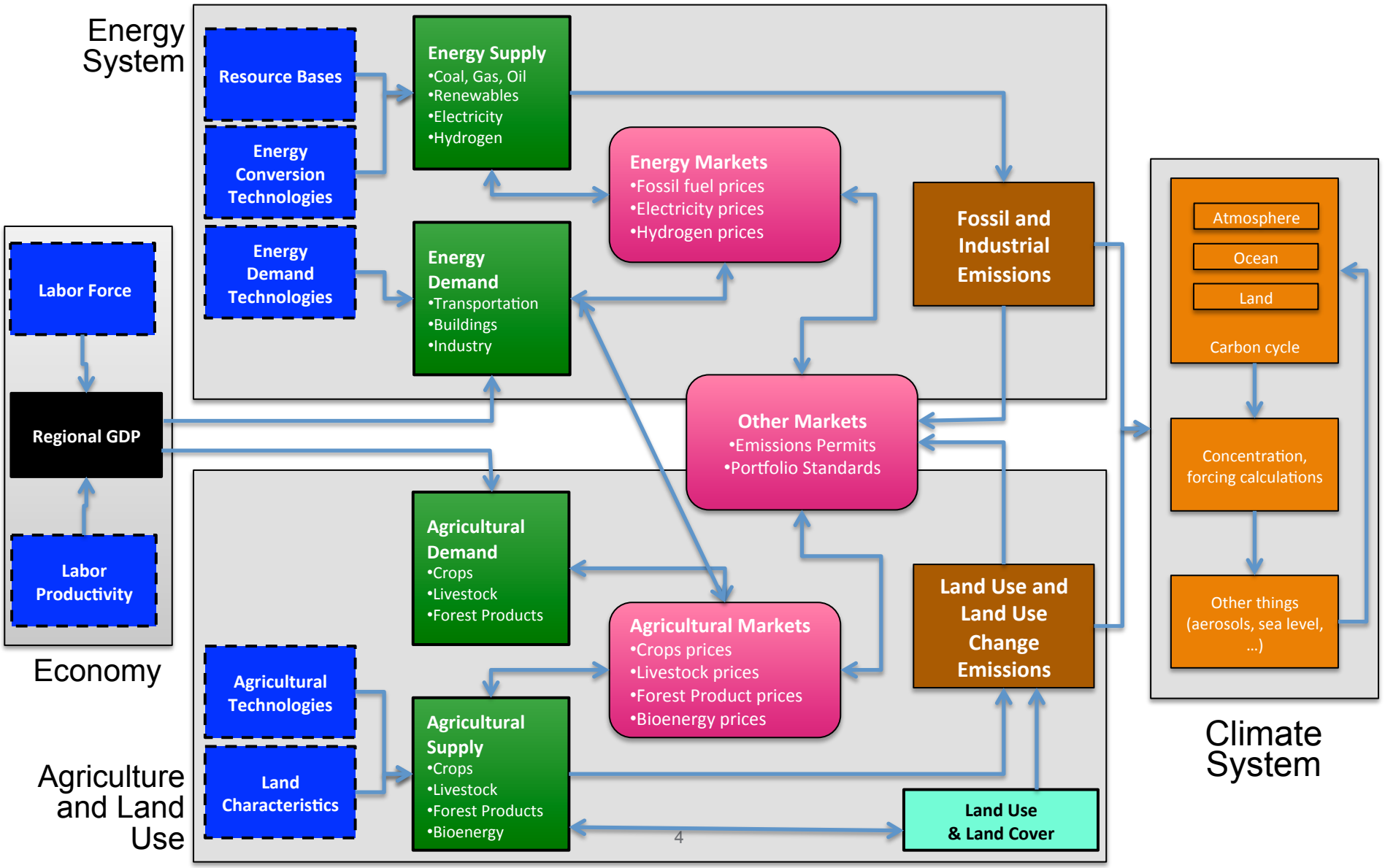

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AGRICULTURE & LAND-USE MODEL

Basic Assumptions

- The world is divided into **151** regions

GCAM Regions

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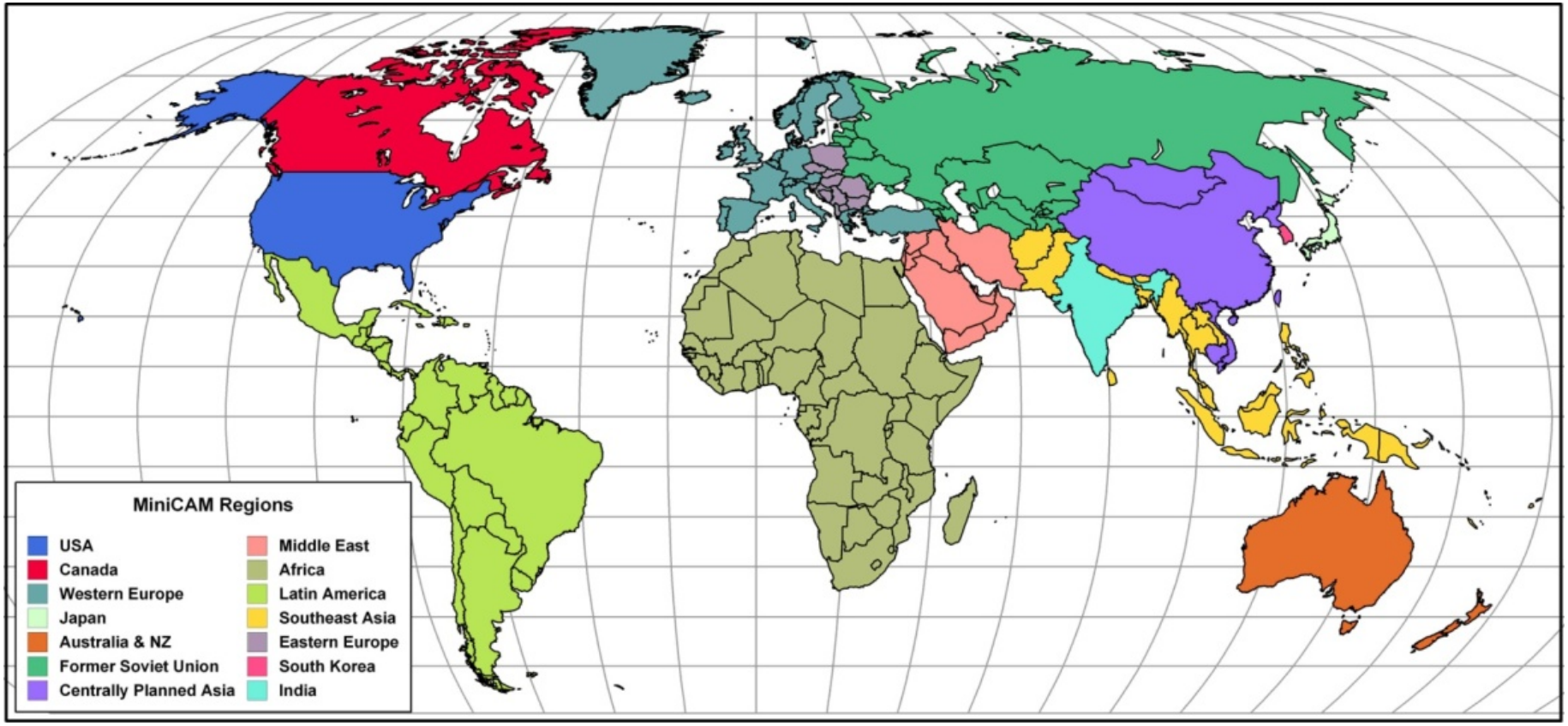
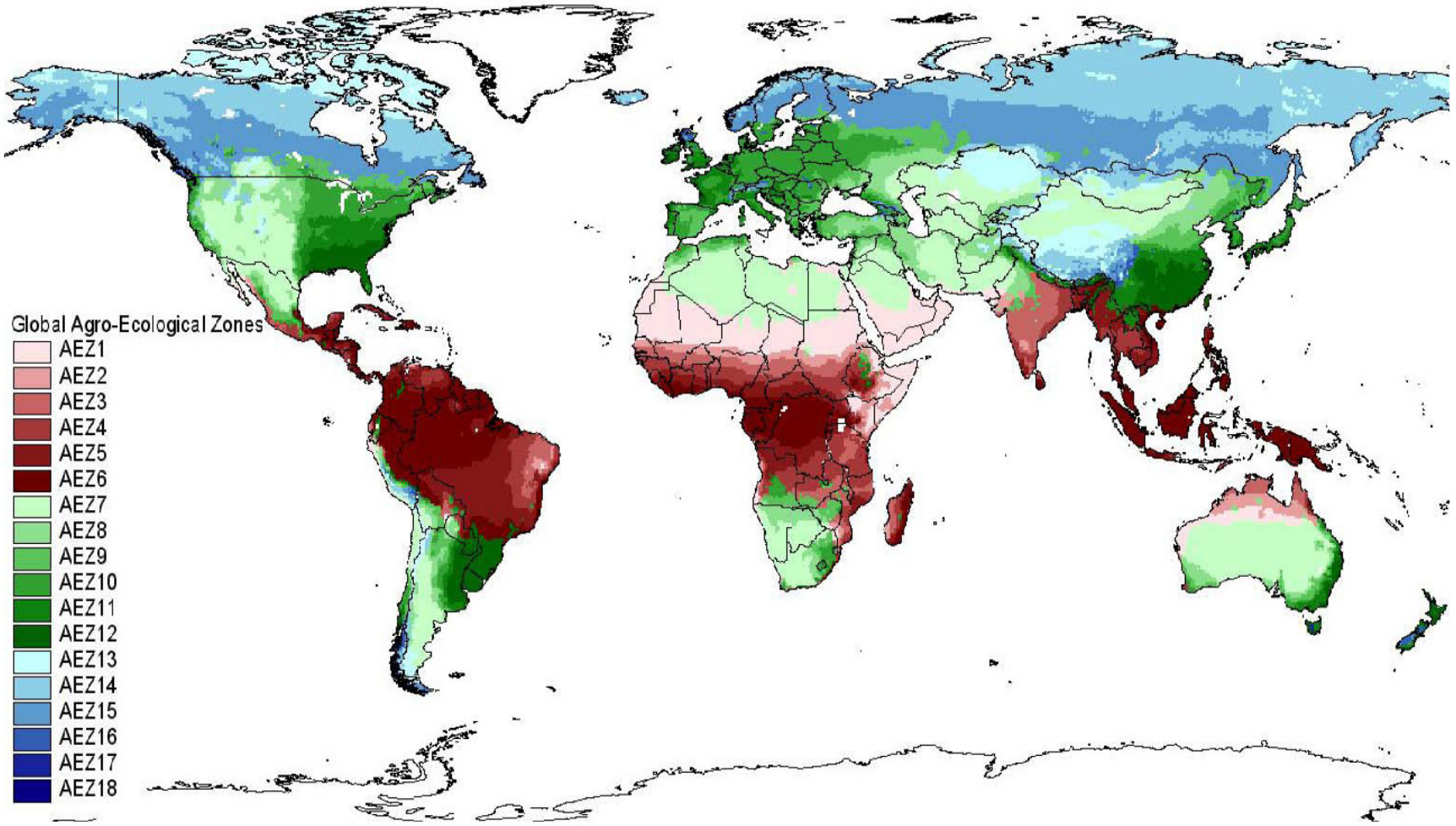


GTAP-AEZs



Monfreda et al. (2009)

151 Different AgLU Supply Regions

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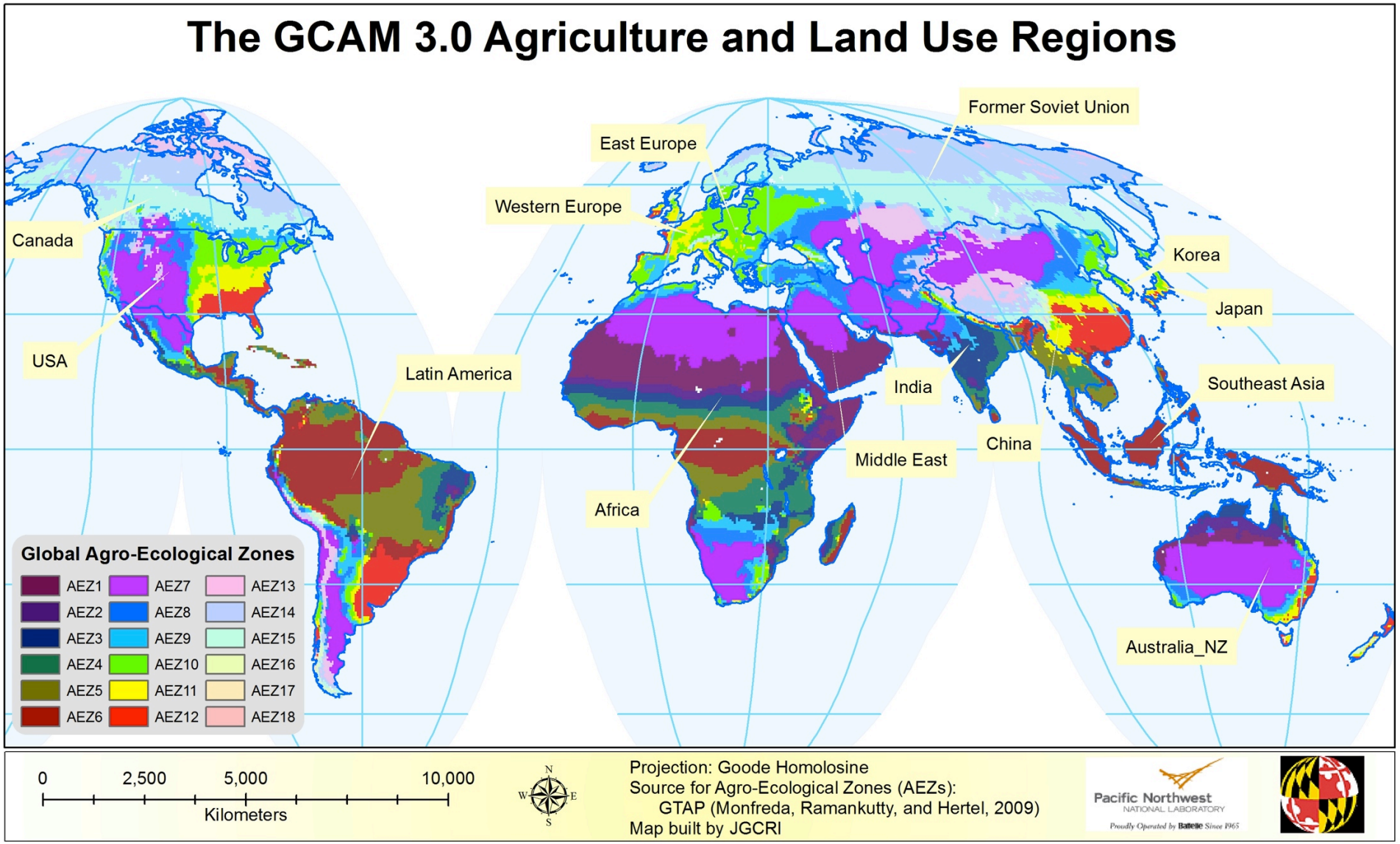
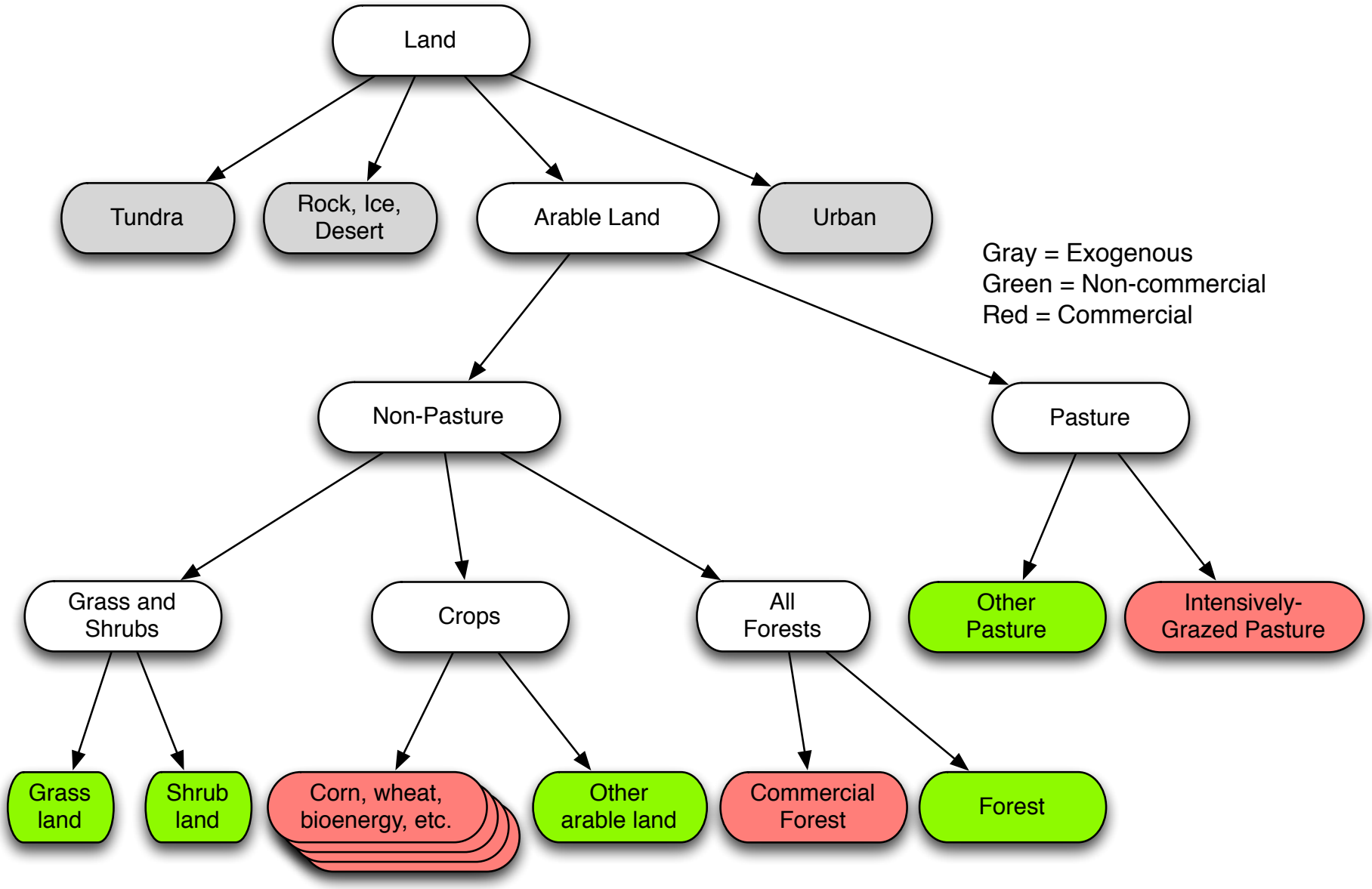


Basic Assumptions

- The world is divided into **151** regions
- Farmers allocate land across a variety of uses in order to maximize profit
- There is a distribution of profits for each land type across each of the 151 regions
- The actual share of land allocated to a particular use is the probability in which that land type has the highest profit
- The variation in profit rates is due to variation in the cost of production
  - As the area devoted to a particular land use expands, cost increases
  - Yield is fixed within each region for each crop management practice

GCAM Nesting Structure



USA Wheat Yield

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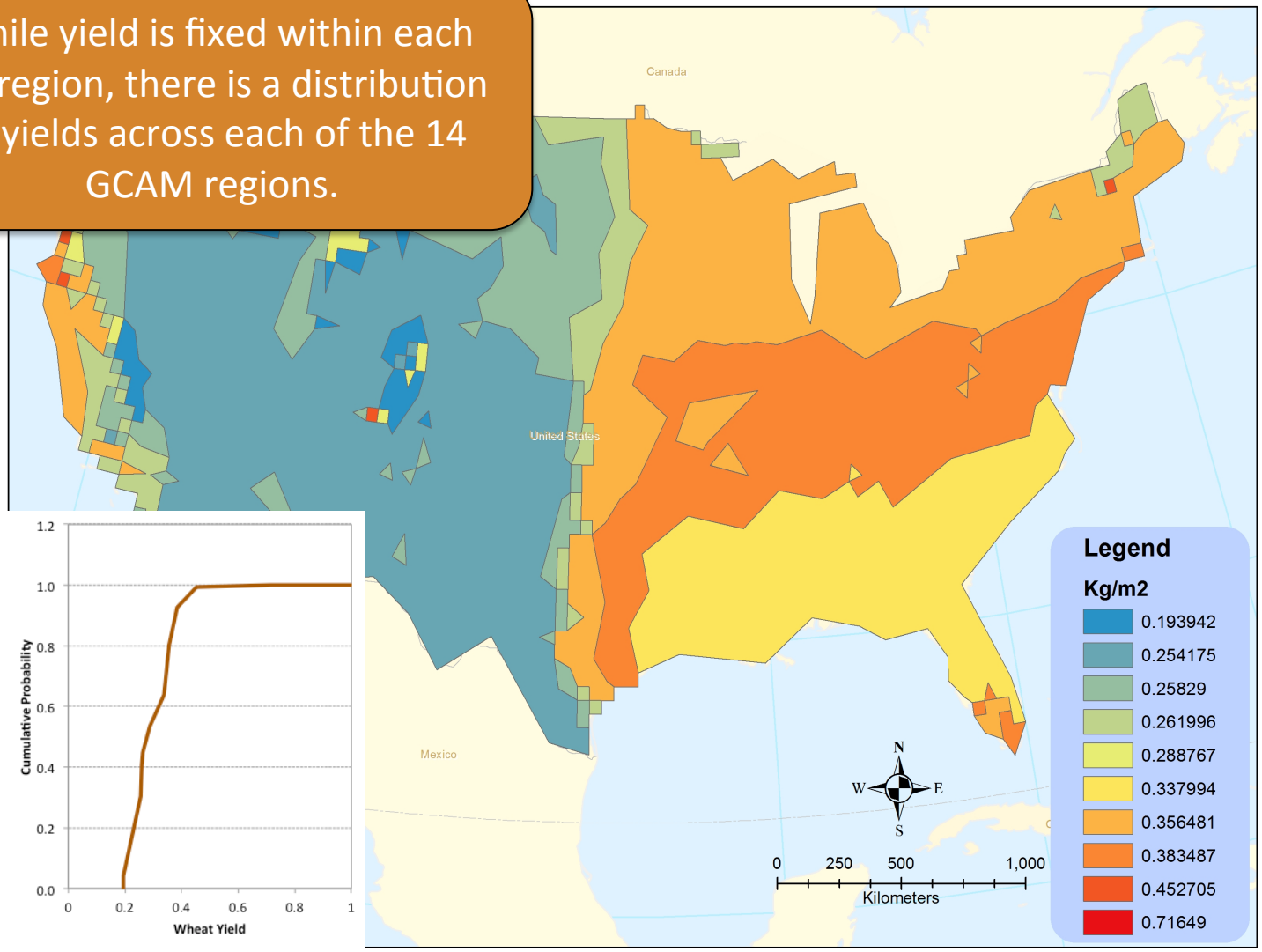
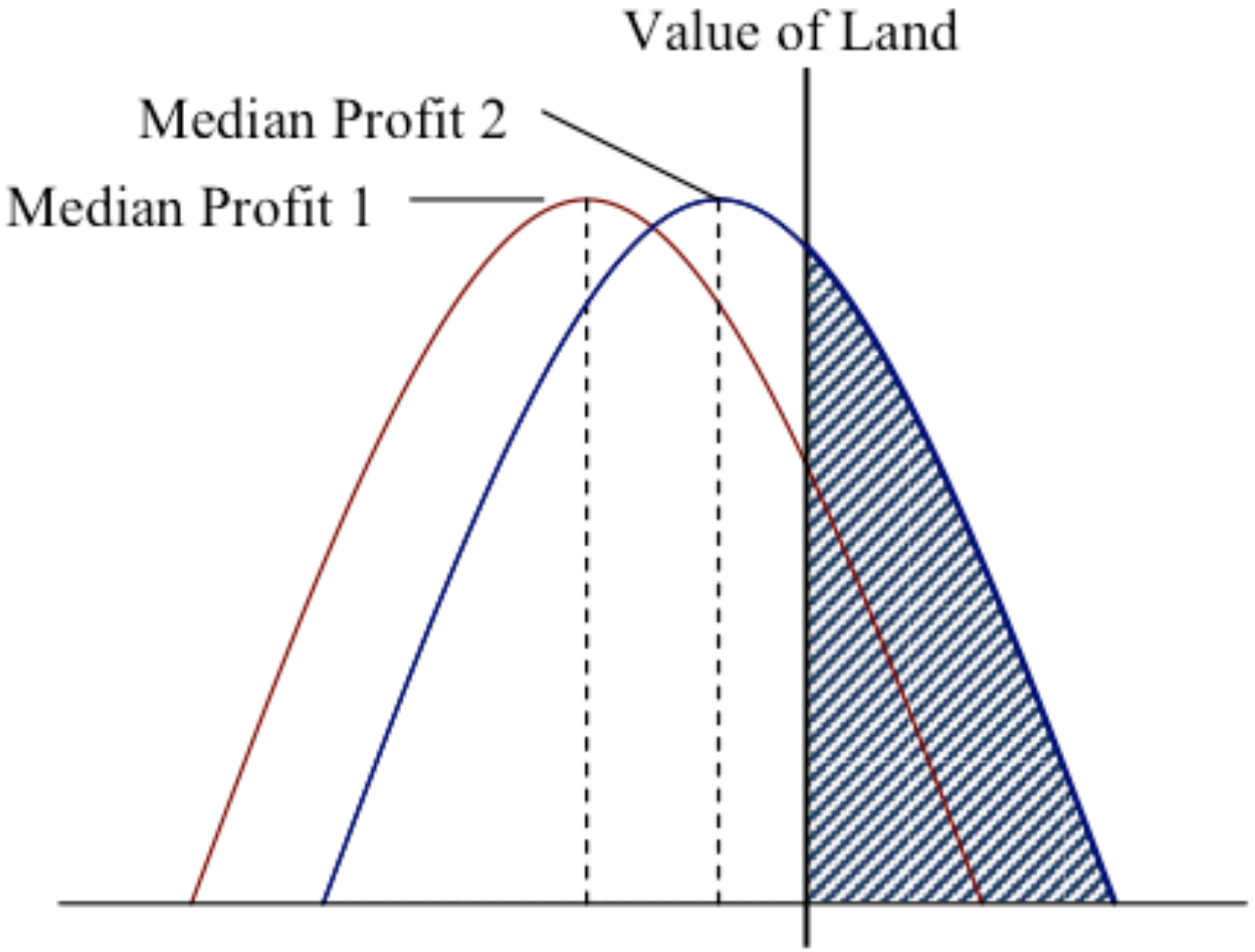
While yield is fixed within each subregion, there is a distribution of yields across each of the 14 GCAM regions.



GCAM Land Competition



GCAM Land Competition

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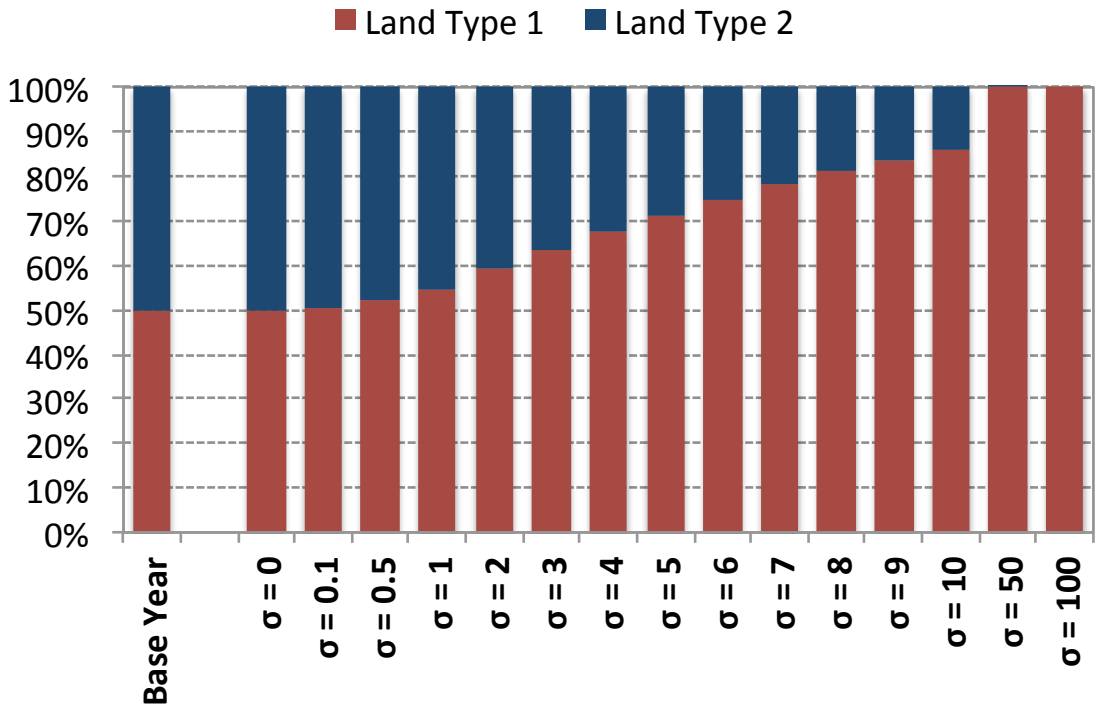
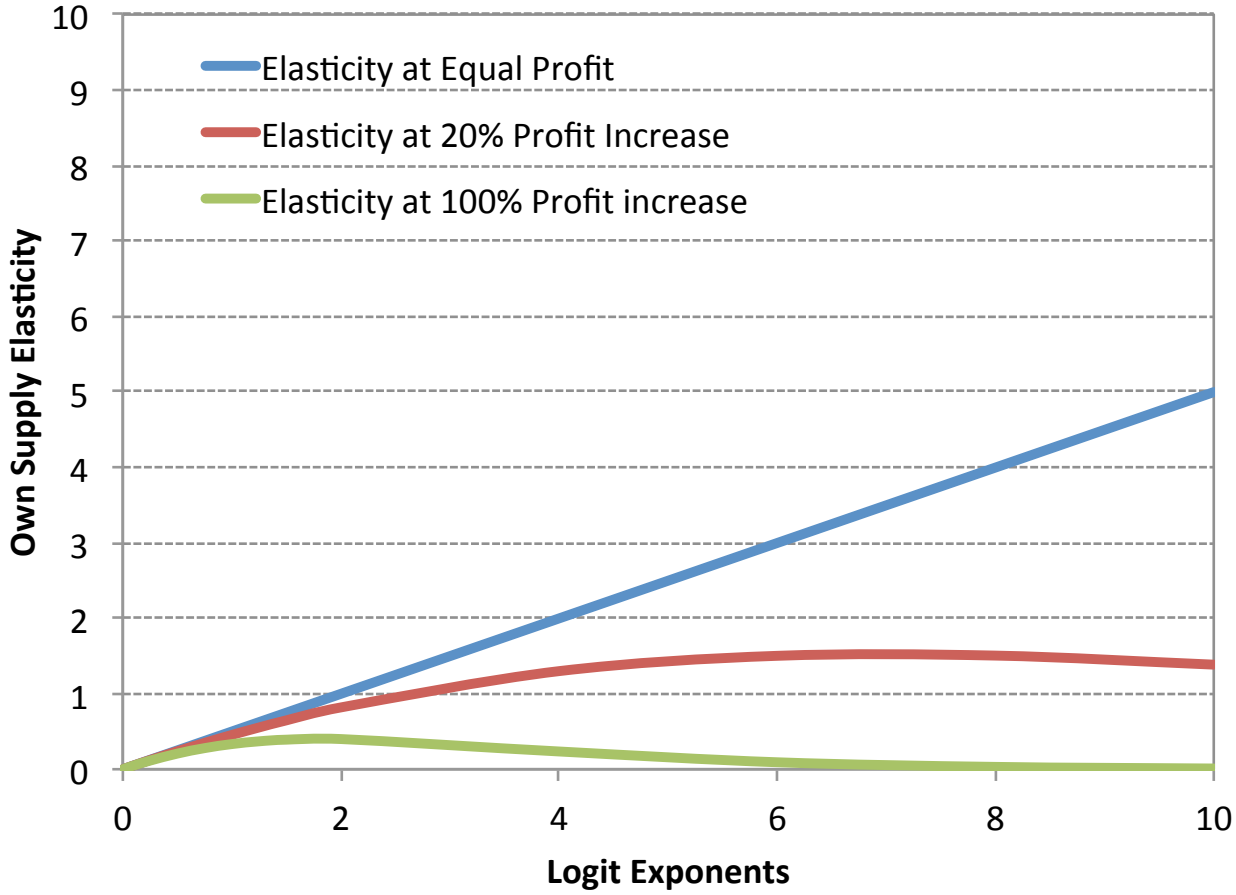
$$s_i = \frac{\left(\alpha_i \pi_i\right)^{\sigma}}{\sum_j \left(\alpha_j \pi_j\right)^{\sigma}}$$

Source: Clarke and Edmonds (1993), McFadden (1974)

Change in land shares when land type 1's profit increases by 20%



GCAM Land Competition



Supply elasticities are not constant with the logit formulation. Elasticity is highest when a land type's share is low.

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SAMPLE RESULTS

Global Land Cover in a Reference

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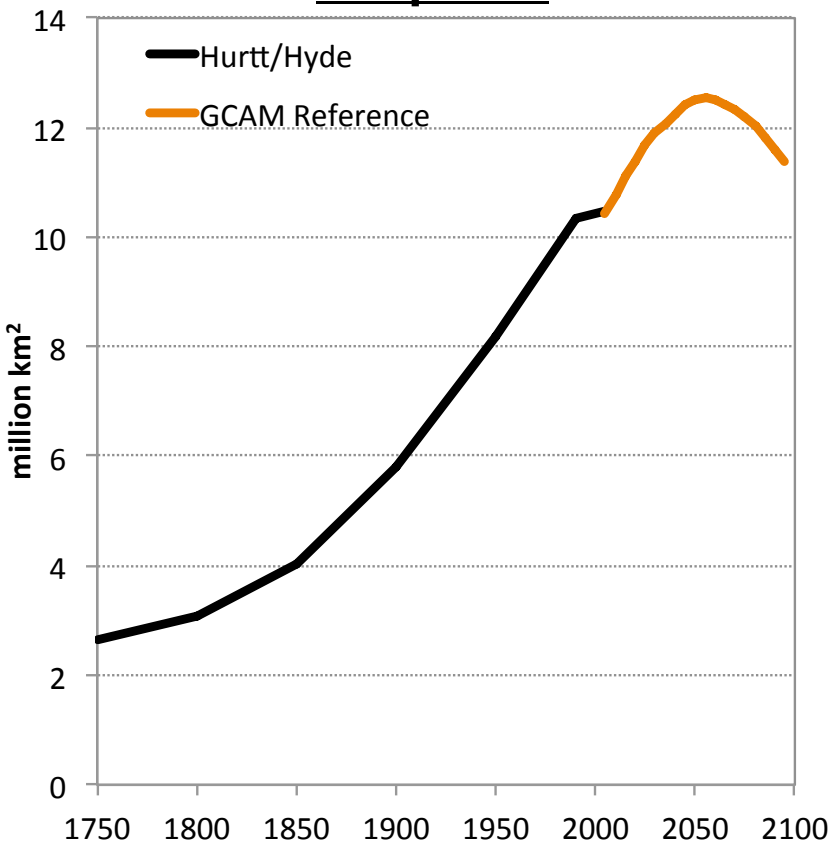
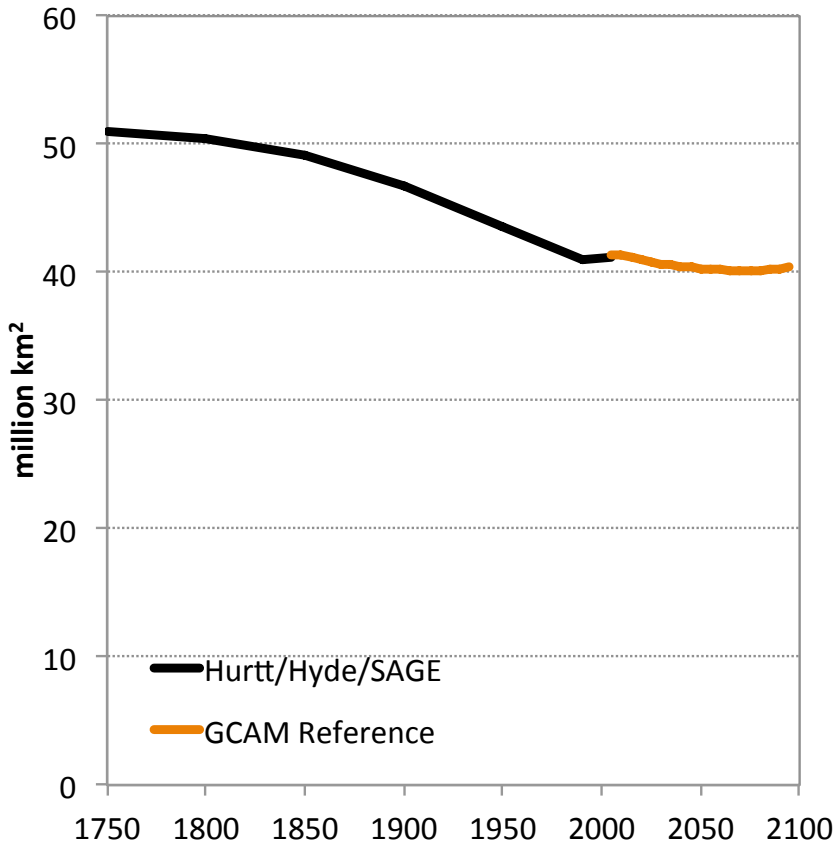
Cropland



Forest



Global Land Cover in a Reference

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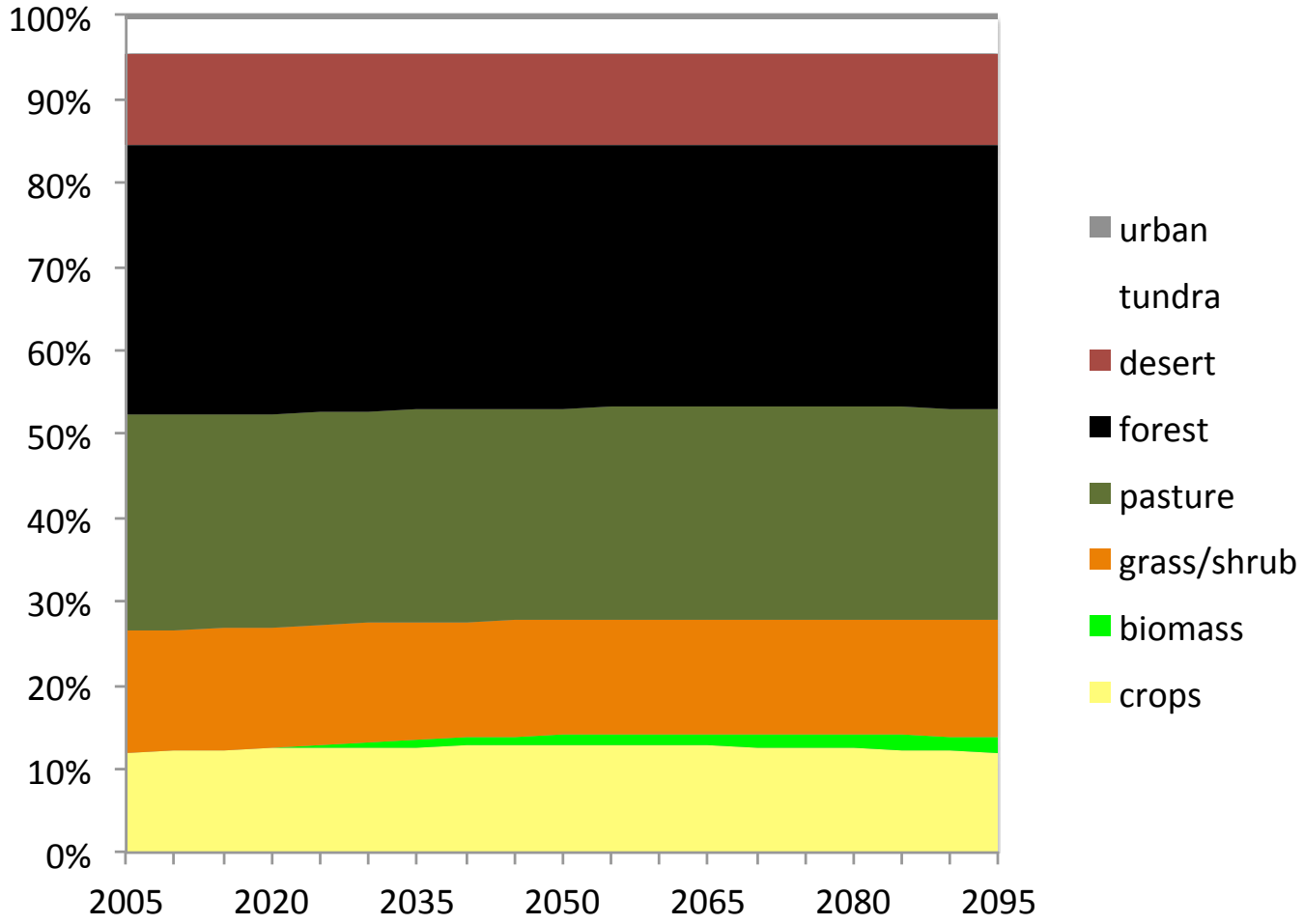

Global Forest Cover in 2005

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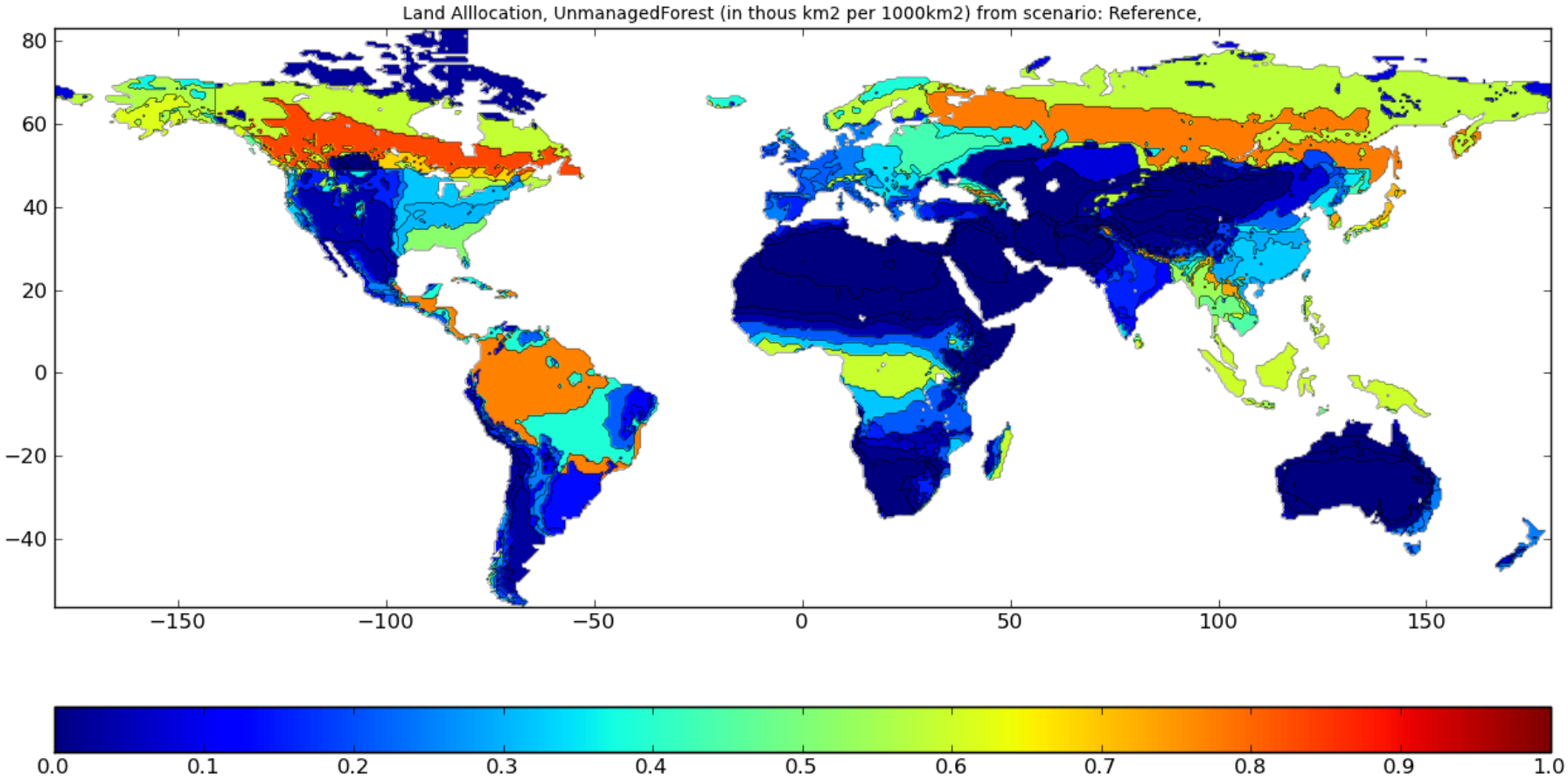

Global Forest Cover in 2095 (Reference)

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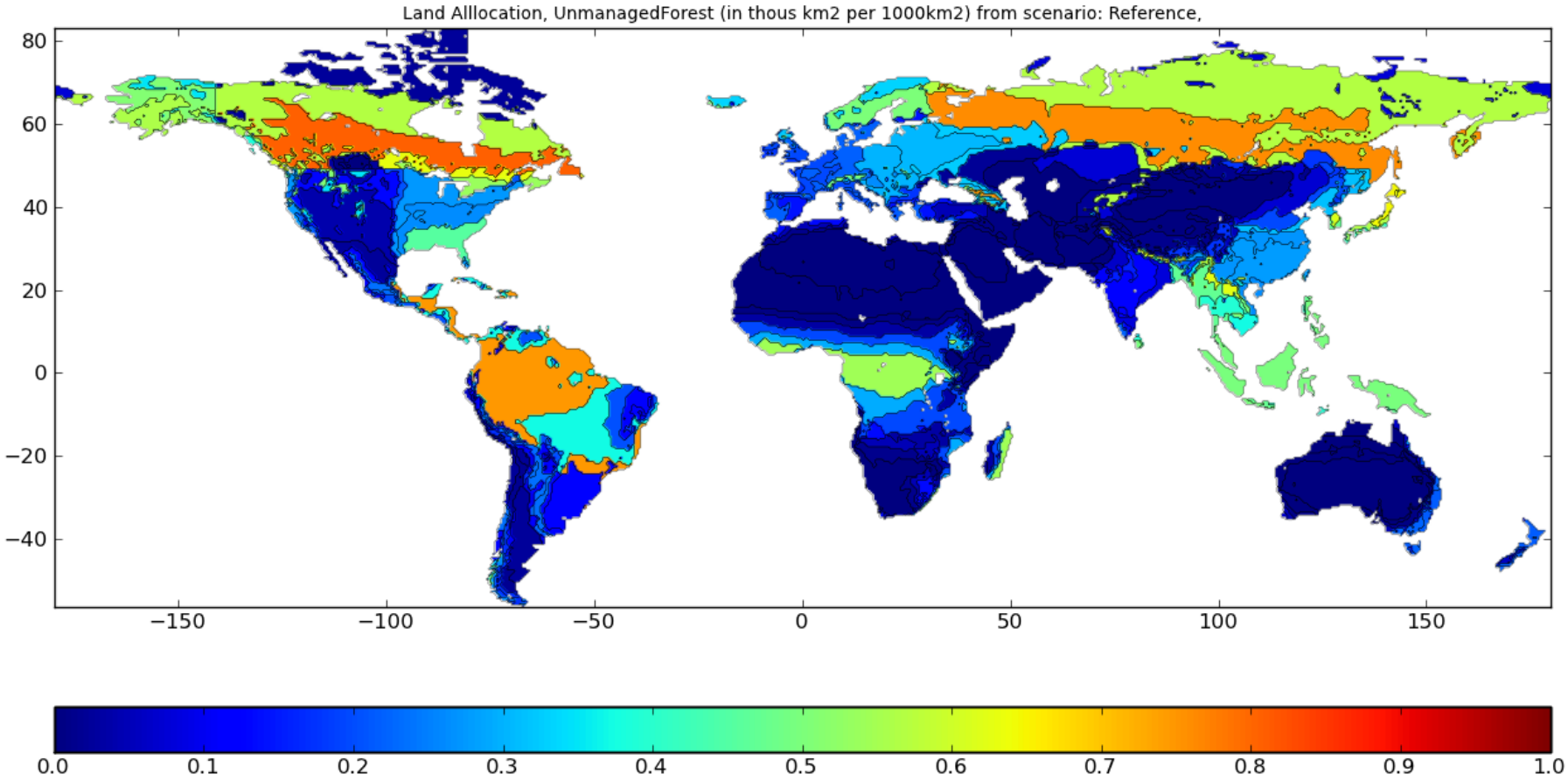

Land Policy Scenarios

Name	Climate Policy	Bioenergy	Land Policy	Protected Areas
Reference	None	No Constraints	None	None
Carbon Price on Land	≤ 3.7 W/m^2	No Constraints	Full Carbon Tax	None
Carbon Price on Land, 10%	≤ 3.7 W/m^2	No Constraints	10% Carbon Tax	None
No Land Policy	≤ 3.7 W/m^2	No Constraints	None	None
Bio Constraint, 100 EJ	≤ 3.7 W/m^2	≤ 100 EJ/yr	None	None
Bio Constraint, 300 EJ	≤ 3.7 W/m^2	≤ 300 EJ/yr	None	None
Protected Land, 99%	≤ 3.7 W/m^2	No Constraints	None	99% of all natural ecosystems
Protected Forest, 99%	≤ 3.7 W/m^2	No Constraints	None	99% of forests
Protected Forest, 50%	≤ 3.7 W/m^2	No Constraints	None	50% of forests
Protected Forest, 10%	≤ 3.7 W/m^2	No Constraints	None	10% of forests
Bio Tax, Coal	≤ 3.7 W/m^2	Treated as Coal	None	None
Bio Tax, Oil	≤ 3.7 W/m^2	Treated as Oil	None	None
Bio Tax, Gas	≤ 3.7 W/m^2	Treated as Gas	None	None

Global Forest Cover in the Land Policy Scenarios

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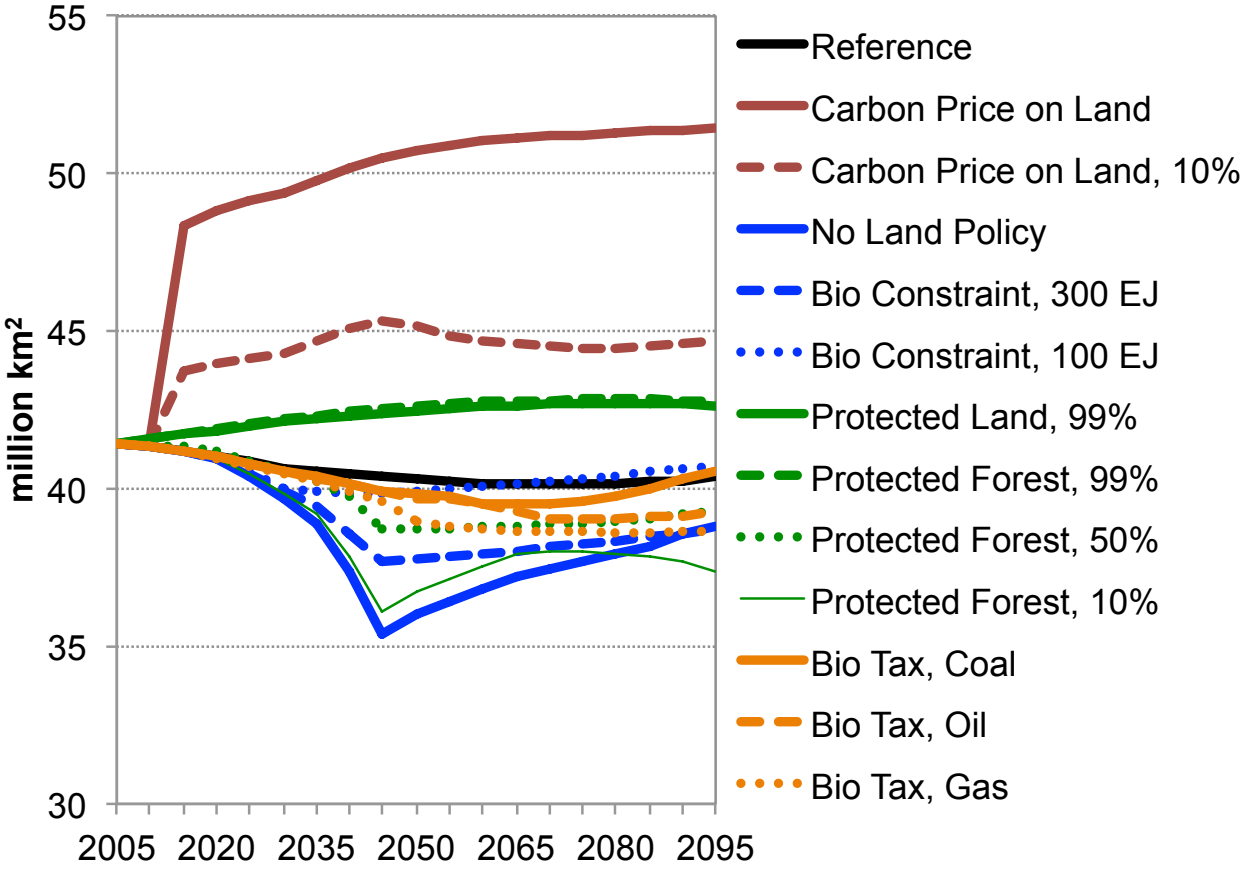

Global Forest Cover in 2095 (Carbon Price)

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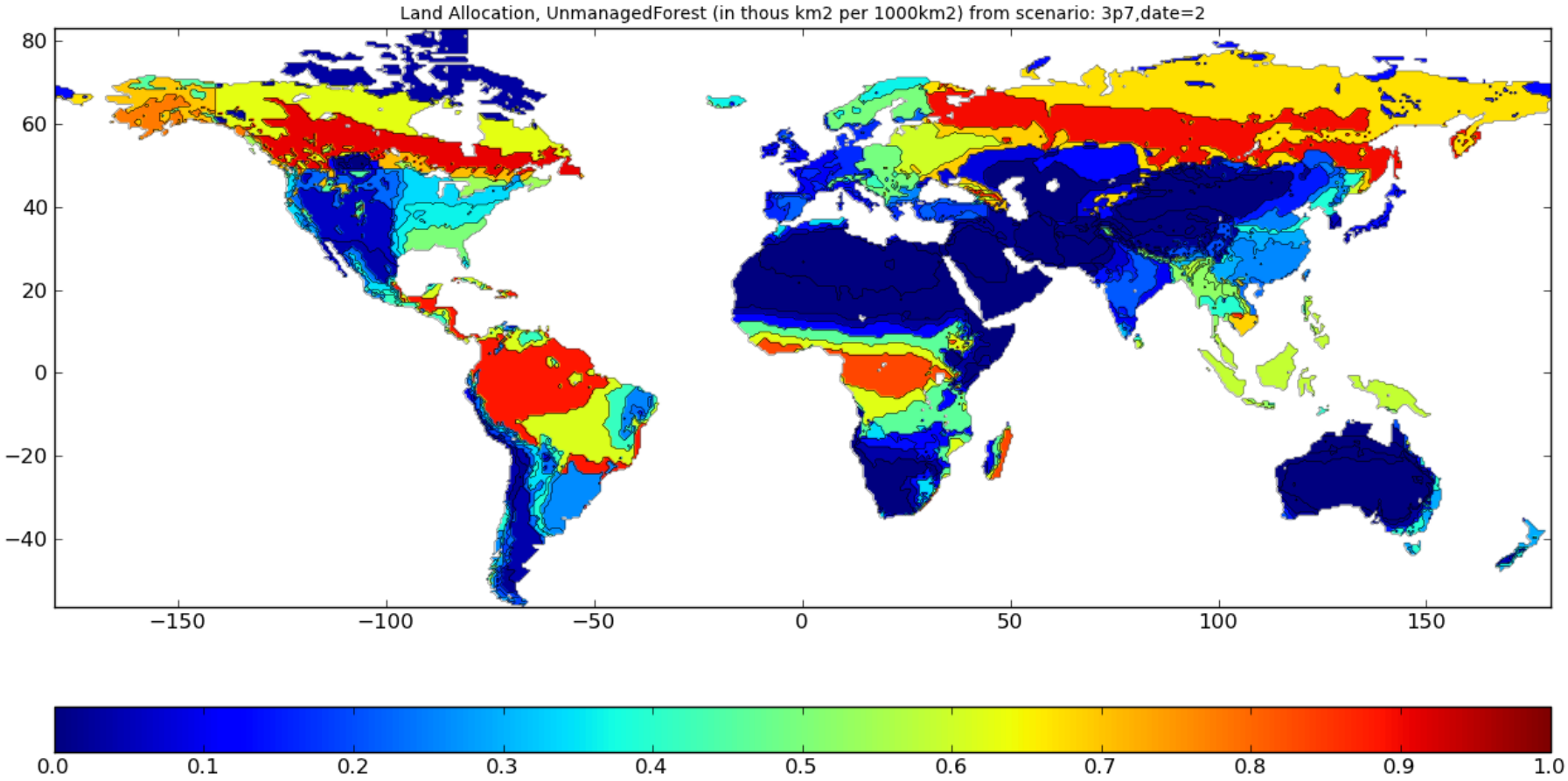

Global Forest Cover in 2095 (No Land Policy)

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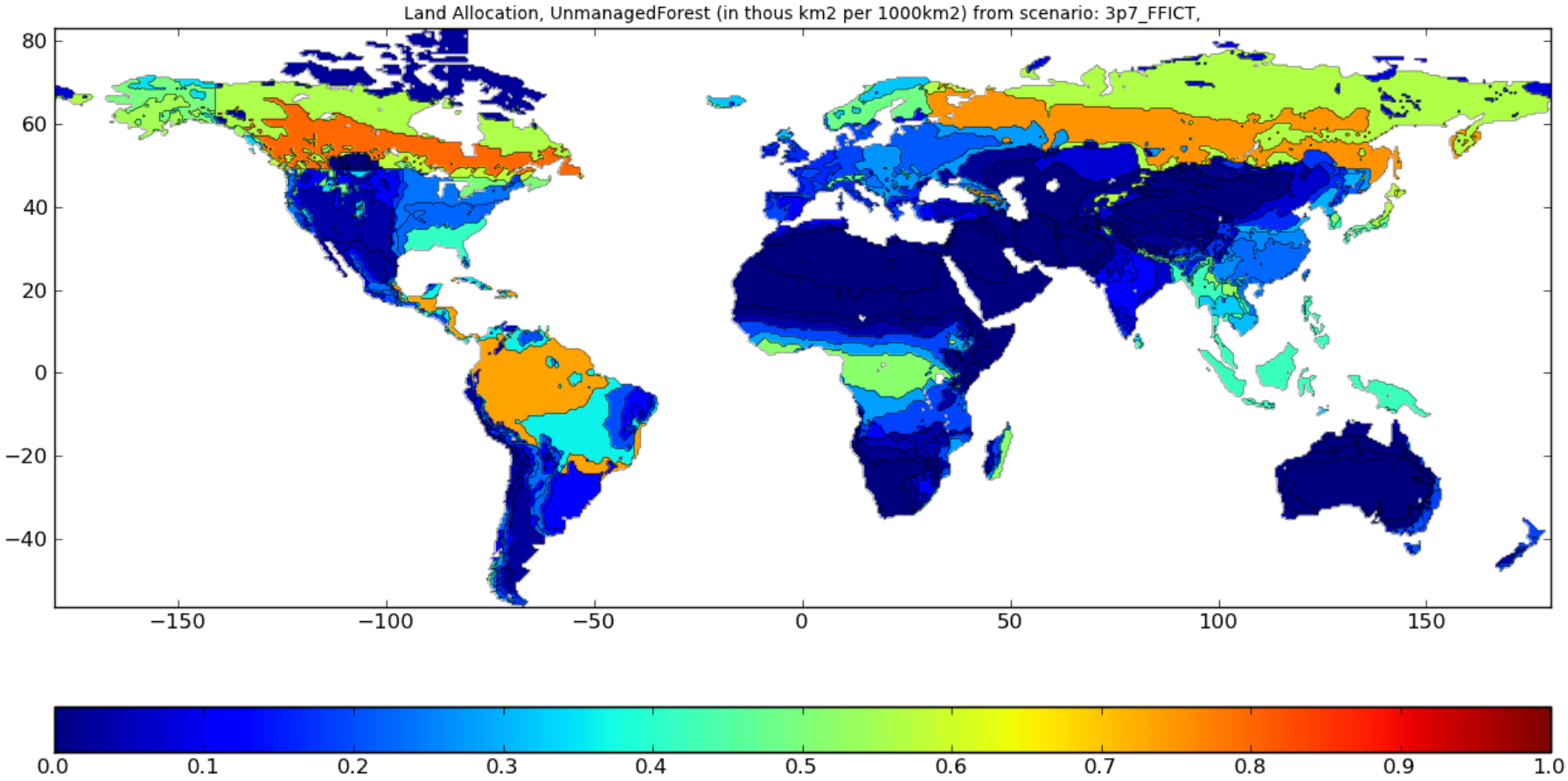

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GRIDDED LAND USE USING THE GLOBAL LAND-USE MODEL (GLM)

Harmonization Steps

1. Develop consensus land-use history reconstruction

2. Minimize differences between end of historical reconstruction and beginning of future projections

3. Preserve as much information from IAMs on future as possible

4. Compute all land-use states and associated transitions

Overview of Harmonization Algorithms (for GCAM Data)

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- Preserve regional/AEZ land-use *changes* from GCAM as much as possible (since these are directly related to GCAM emissions scenarios)
- Apply future regional/AEZ changes to historical map (2005), using new map that allocates each gridcell to an AEZ
- Spatially allocate cropland/pasture *abandonment* by computing percentage of land abandoned in each iteration (for each AEZ) and applying this percentage to all cropland/pasture-containing grid-cells
- Spatially allocate cropland/pasture *expansion* by first increasing agriculture within grid-cells that already contain agriculture and then in neighboring grid-cells (within each AEZ)
- Attempt to meet wood harvest demand from GCAM exactly (i.e. we are using actual wood harvest values from GCAM, not “changes” in wood harvest)
- Unmet WH – apply to other AEZs within region

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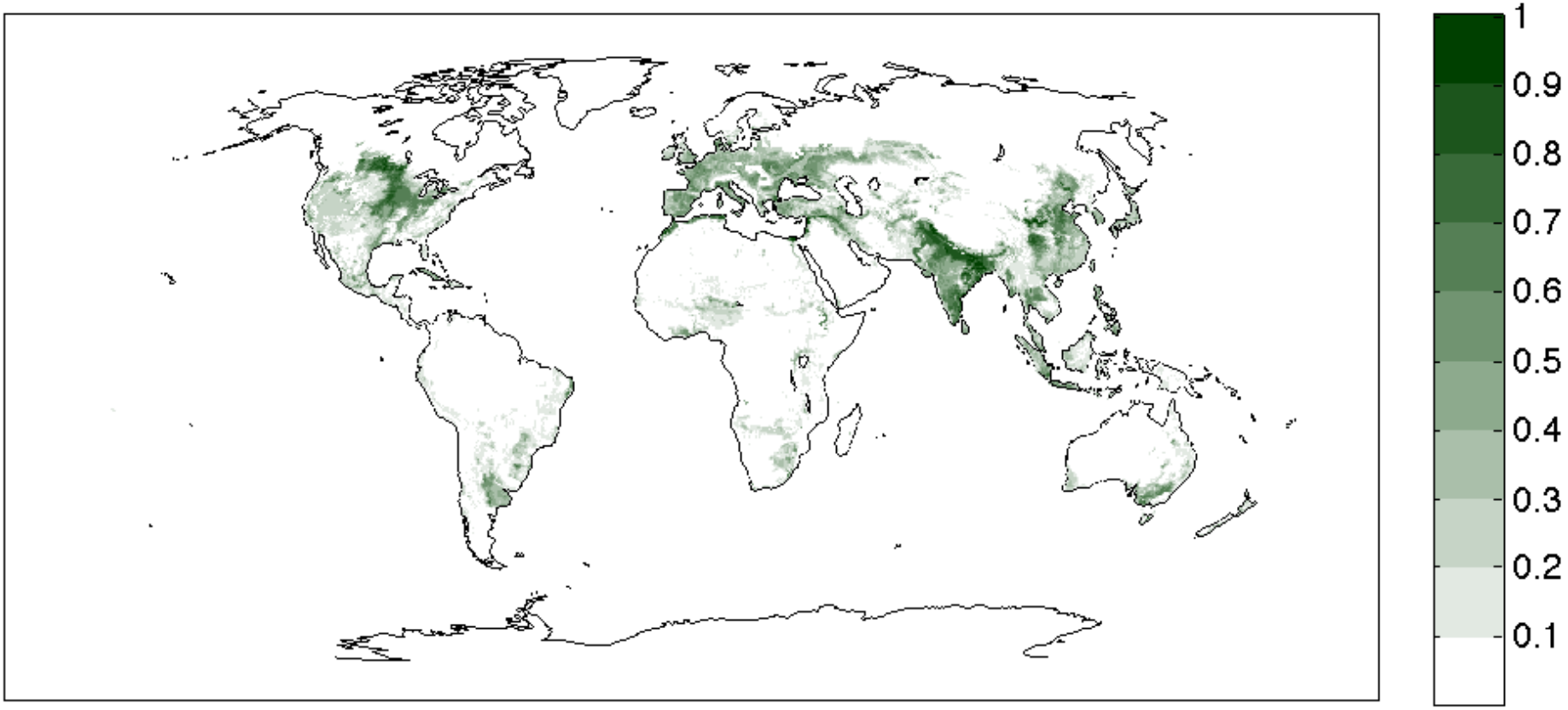
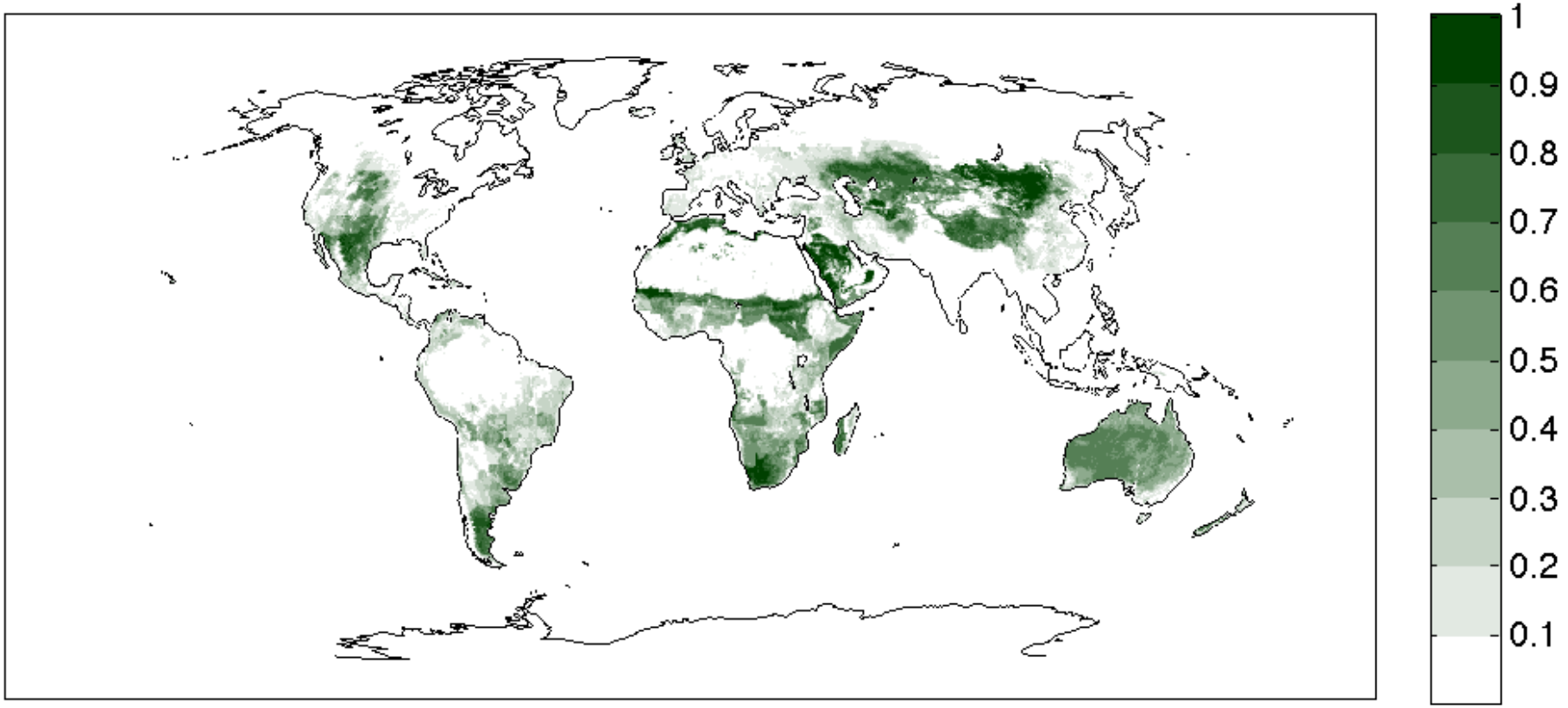
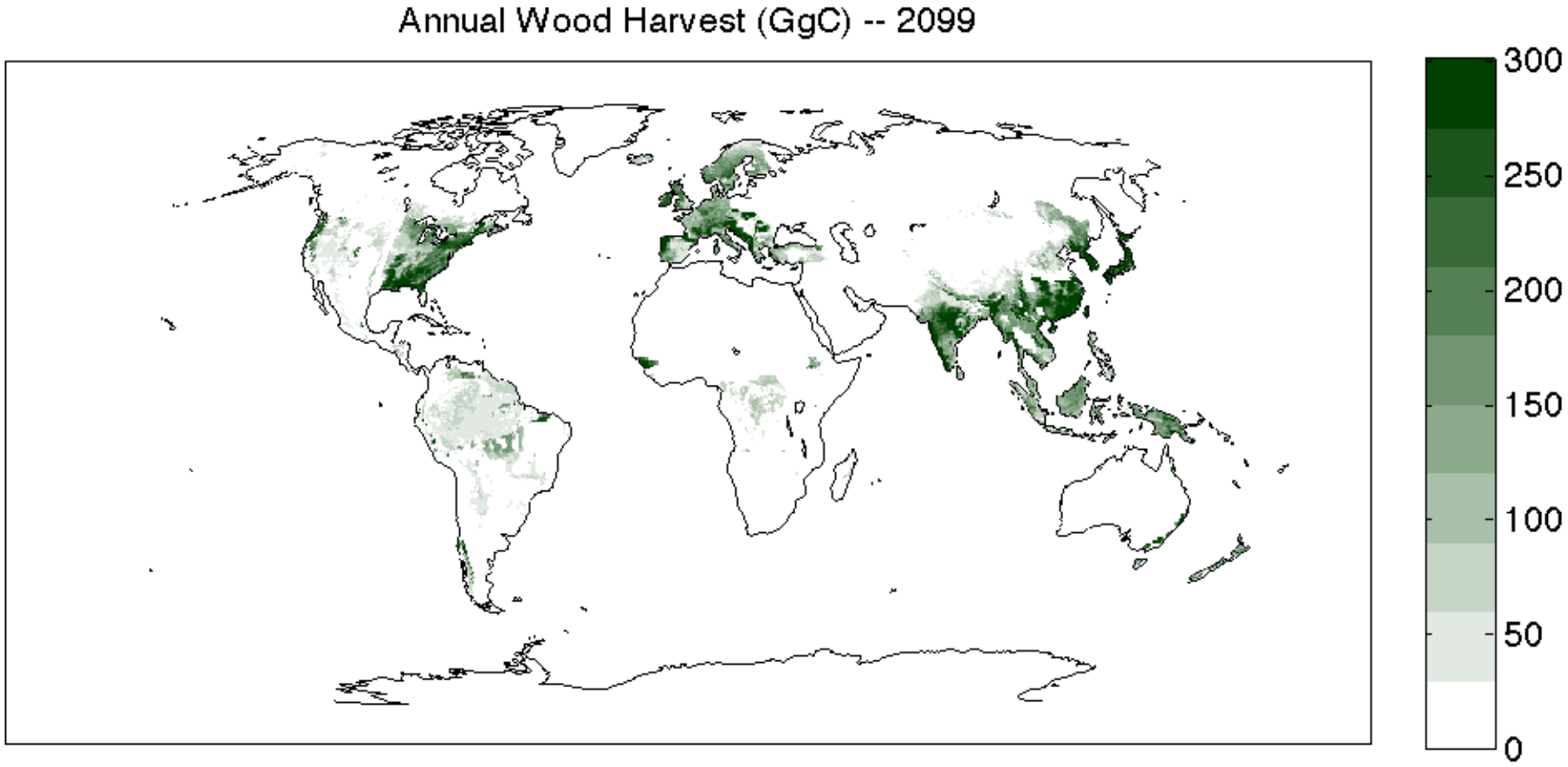
Cropland Fraction -- 2100



Pasture Fraction -- 2100




Annual Wood Harvest (GgC) -- 2099
300
250
200
150
100
50
0

DISCUSSION