The Global Land-Use Model (GLM) and Harmonization of Land-Use Scenarios for the 5th IPCC Assessment Report

Louise Parsons Chini

University of Maryland

Overview

- GLM is a key technology for communicating IAM results with climate models. Developed with partial DOE support.

- For the land-use harmonization project we established a multi-year working group to bridge LU history, carbon cycle, integrated assessment, and ESM communities.

- Collaborative approach involves end-users and ensures that developed products would have wide usage.

- GLM data products now being used by all teams for AR5 and CMIP5 simulations and in several key applications (Thomson et al. 2010 *PNAS* and Pereira et al. 2010 *Science*).

- Technology now being used in iESM and undergoing further development.

Collaborators

- George Hurtt[1,8]
- Steve Frolking[2]
- Richard Betts[3]
- Johannes Feddema[4]
- Guenther Fischer[5]
- Kees Klein Goldewijk[6]
- Kathy Hibbard[7]
- Anthony Janetos[8]
- Chris Jones[3]
- Georg Kindermann[5]
- Tsuguki Kinoshita[9]
- Keywan Riahi[5]
- Elena Shevliakova[10]
- Steve Smith[8]
- Elke Stehfest[6]
- Allison Thomson[8]
- Peter Thornton[11]
- Detlef van Vuuren[6]
- Yingping Wang[12]

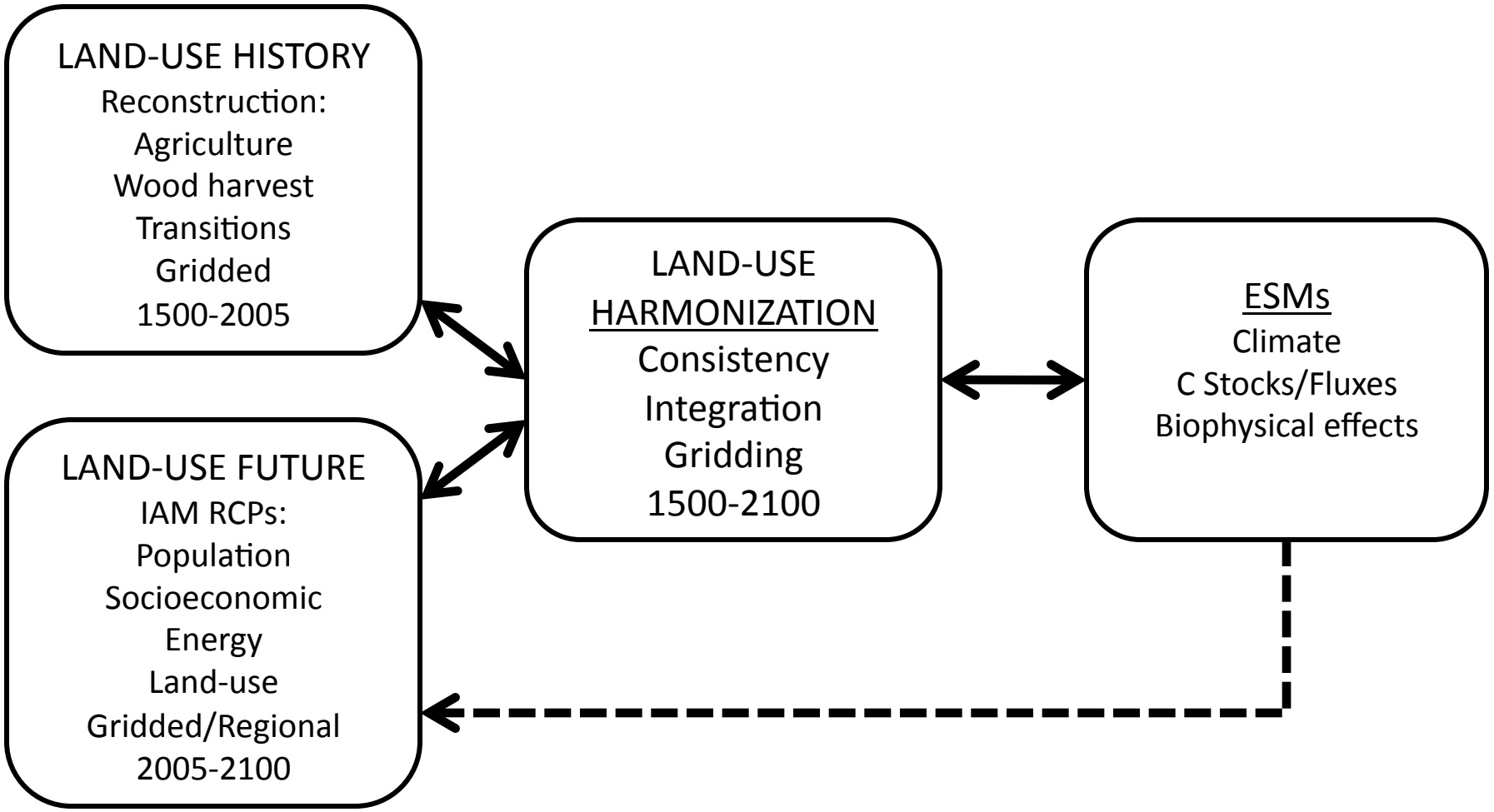
(1) University of Maryland (2) University of New Hampshire (3) Met Office Hadley Centre, Germany (4) University of Kansas (5) International Institute for Applied Systems Analysis and Graz University of Technology, Austria (6) Netherlands Environmental Assessment Agency (7) National Center for Atmospheric Research (8) Pacific Northwest National Laboratory—Joint Global Change Research Institute (9) National Institute for Environmental Studies, Japan
(10) Princeton/GFDL (11) Oak Ridge National Lab (12) CSIRO, Australia

Global Land-Use Model (GLM)

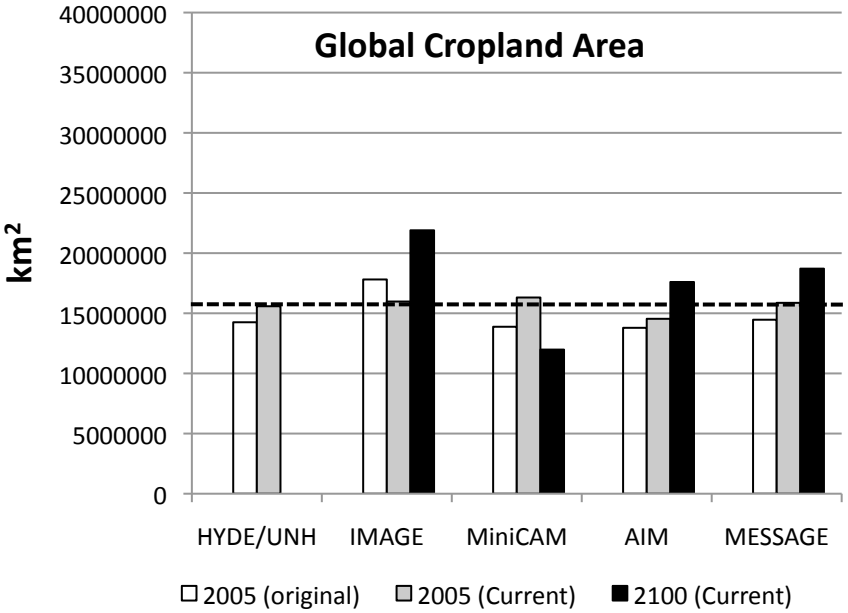
- Global Land-Use Model (GLM) computes estimates of annual, gridded, fractional:
  - land-use activities
  - land-use conversions/transitions
  - patterns and dynamics of recovering lands (including secondary land area, age, and mean biomass)
- Land-use transitions – annual (gridded) rates of change of land-use. Includes the establishment and abandonment of agricultural lands, afforestation and wood harvesting, shifting cultivation, etc.
- Developed with goal of implementation within an ESM: Land-use states and transitions have been used in Princeton GFDL Climate Model
- Key findings from original version of GLM
  - 42-68% of land surface impacted by human land-use activities (agriculture + wood harvest) 1700-2000.
  - Total secondary land area increased 10-44 x 10^6 km^2 during this period; about half is forested.
  - Wood harvesting and shifting cultivation generated 70-90% of secondary land; permanent agriculture changes generated the rest.

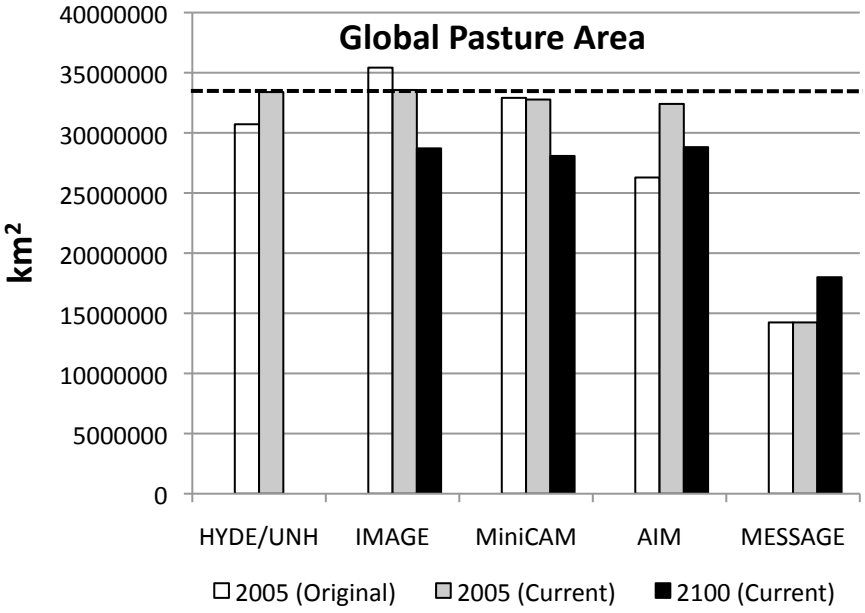
Hurtt et al. (2006)

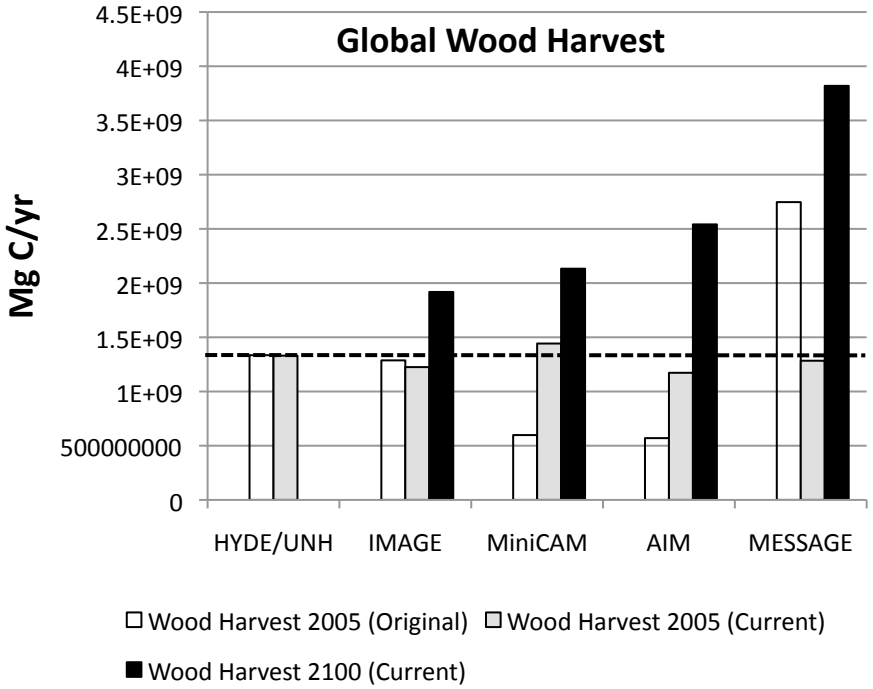
Proposed Scheme for IPCC AR5 (Land-use)

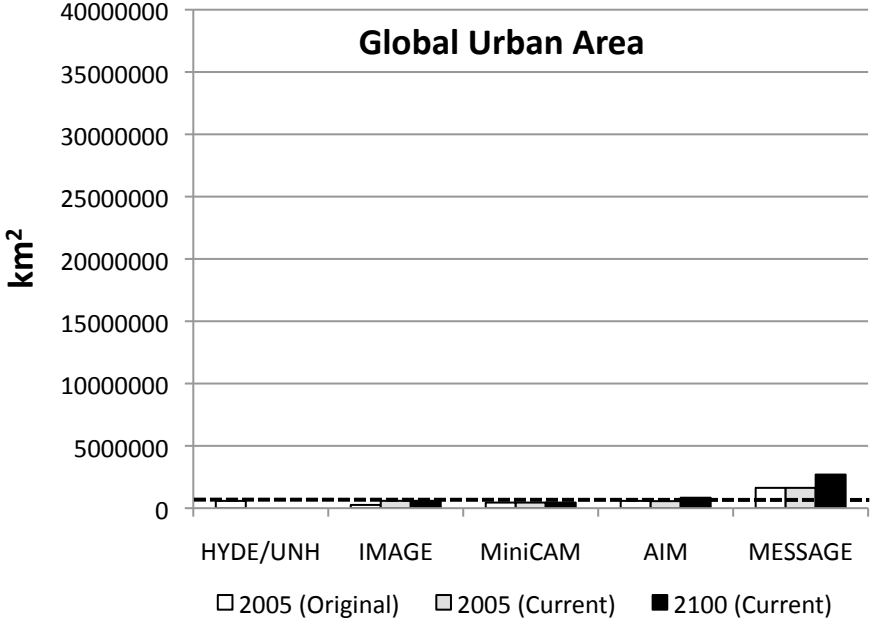


Hurtt et al. 2009


Global Cropland Area
km²
40000000
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
HYDE/UNH
IMAGE
MiniCAM
AIM
MESSAGE
2005 (original)
2005 (Current)
2100 (Current)

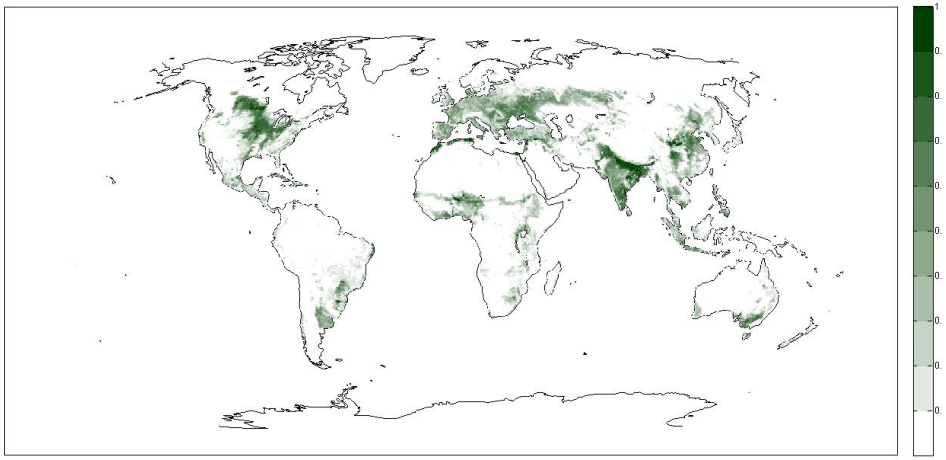

Global Pasture Area
km²
40000000
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
HYDE/UNH
IMAGE
MiniCAM
AIM
MESSAGE
2005 (Original)
2005 (Current)
2100 (Current)


Global Wood Harvest
Mg C/yr
4.5E+09
4E+09
3.5E+09
3E+09
2.5E+09
2E+09
1.5E+09
1E+09
500000000
0
HYDE/UNH
IMAGE
MiniCAM
AIM
MESSAGE
Wood Harvest 2005 (Original)
Wood Harvest 2005 (Current)
Wood Harvest 2100 (Current)

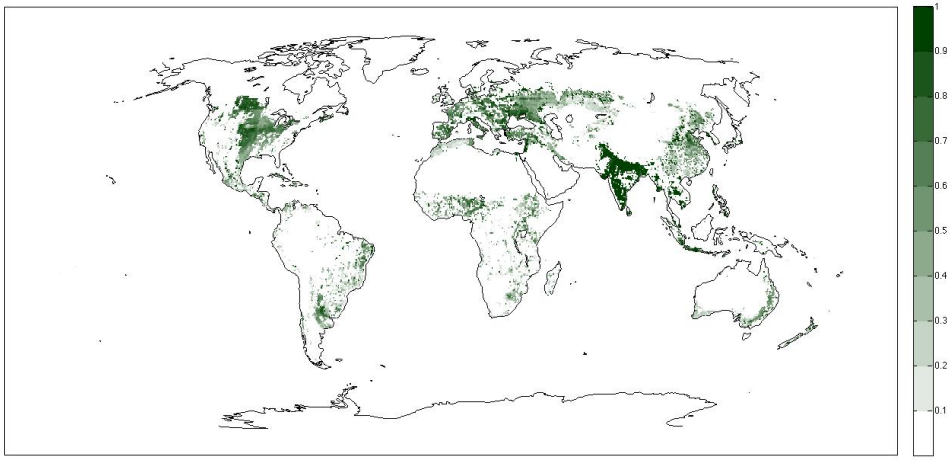

Global Urban Area
km²
40000000
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
HYDE/UNH
IMAGE
MiniCAM
AIM
MESSAGE
2005 (Original)
2005 (Current)
2100 (Current)

Cropland in 2005

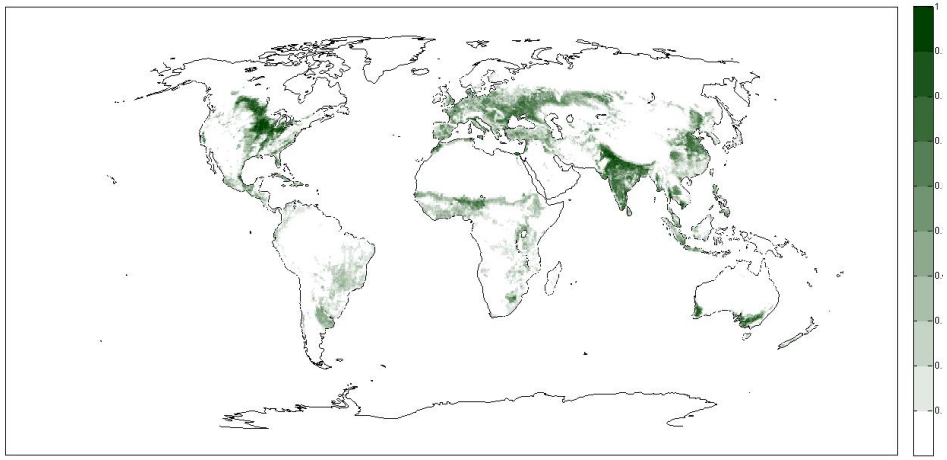
HYDE



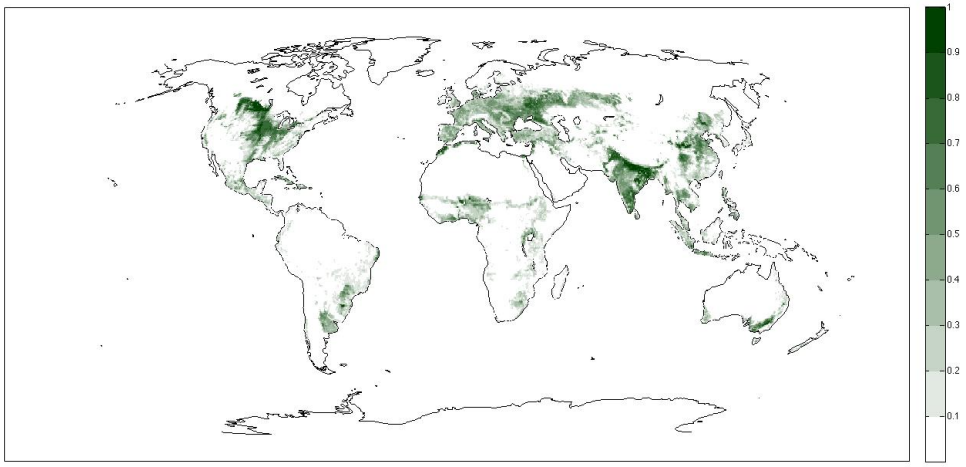
IMAGE



MESSAGE



AIM



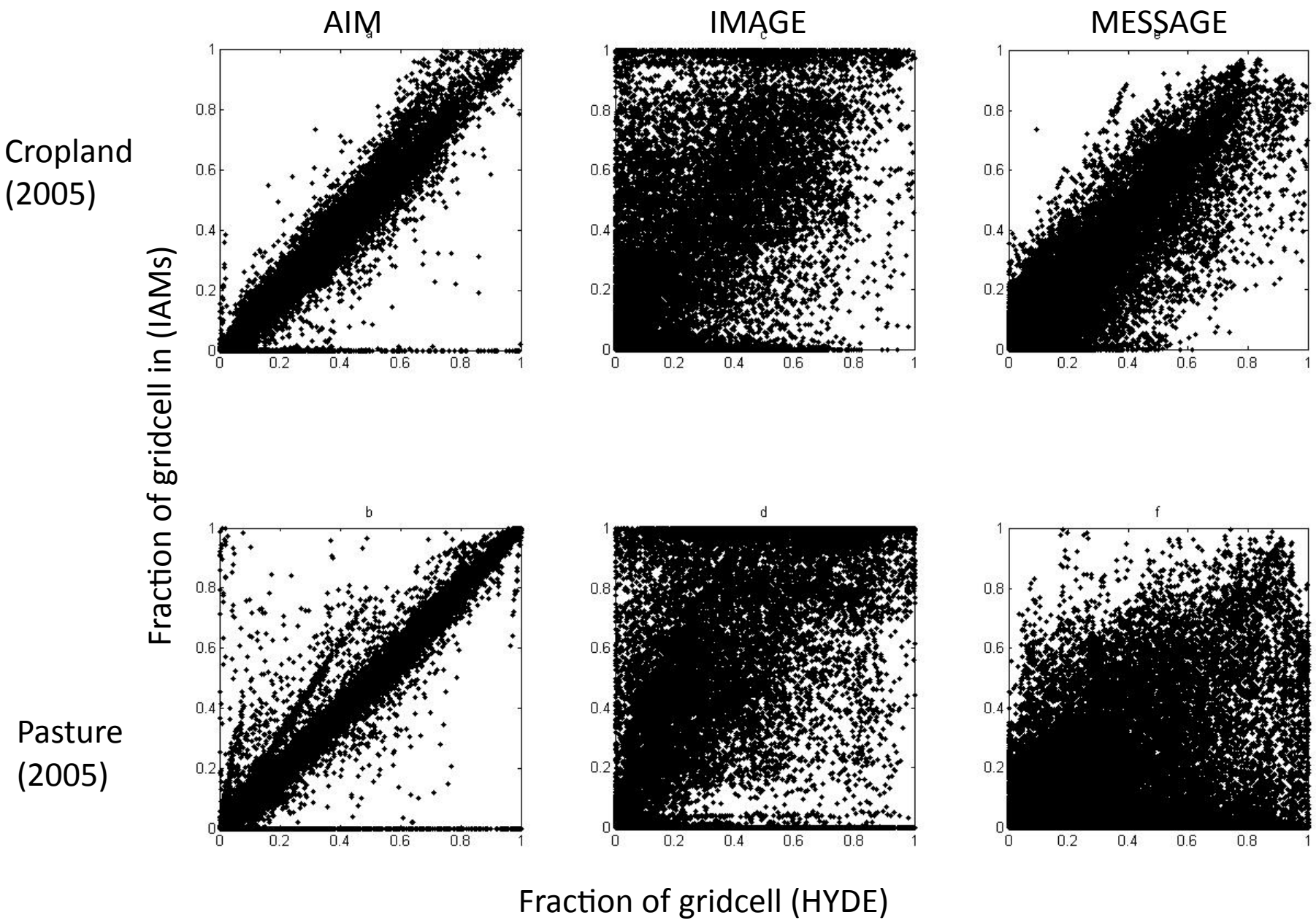
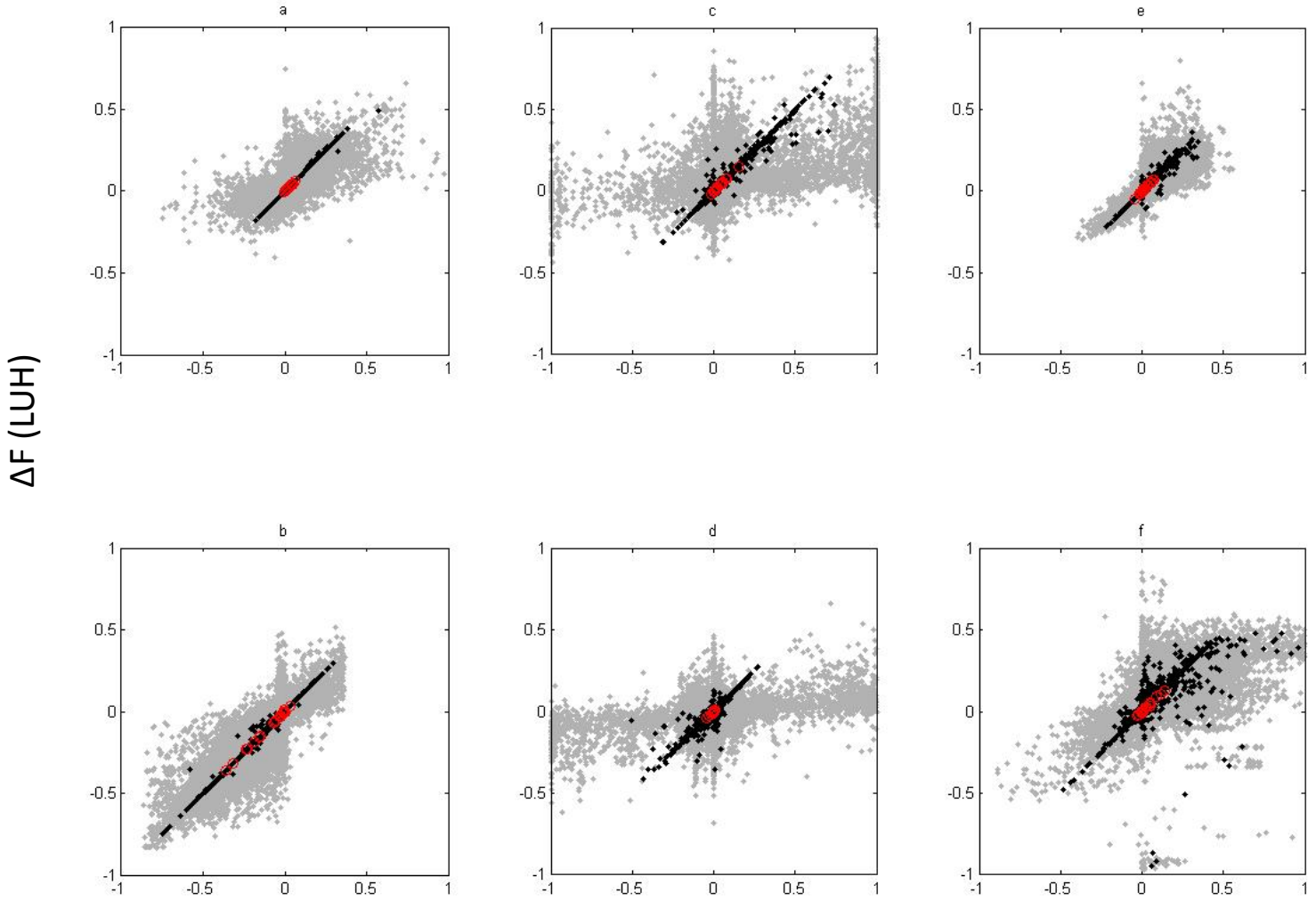

AIM
IMAGE
MESSAGE
Cropland (2005)
Pasture (2005)
Fraction of gridcell in (IAMs)
Fraction of gridcell (HYDE)
a
b
c
d
e
f
0
0.2
0.4
0.6
0.8
1

IMAGE AIM MESSAGE

crop

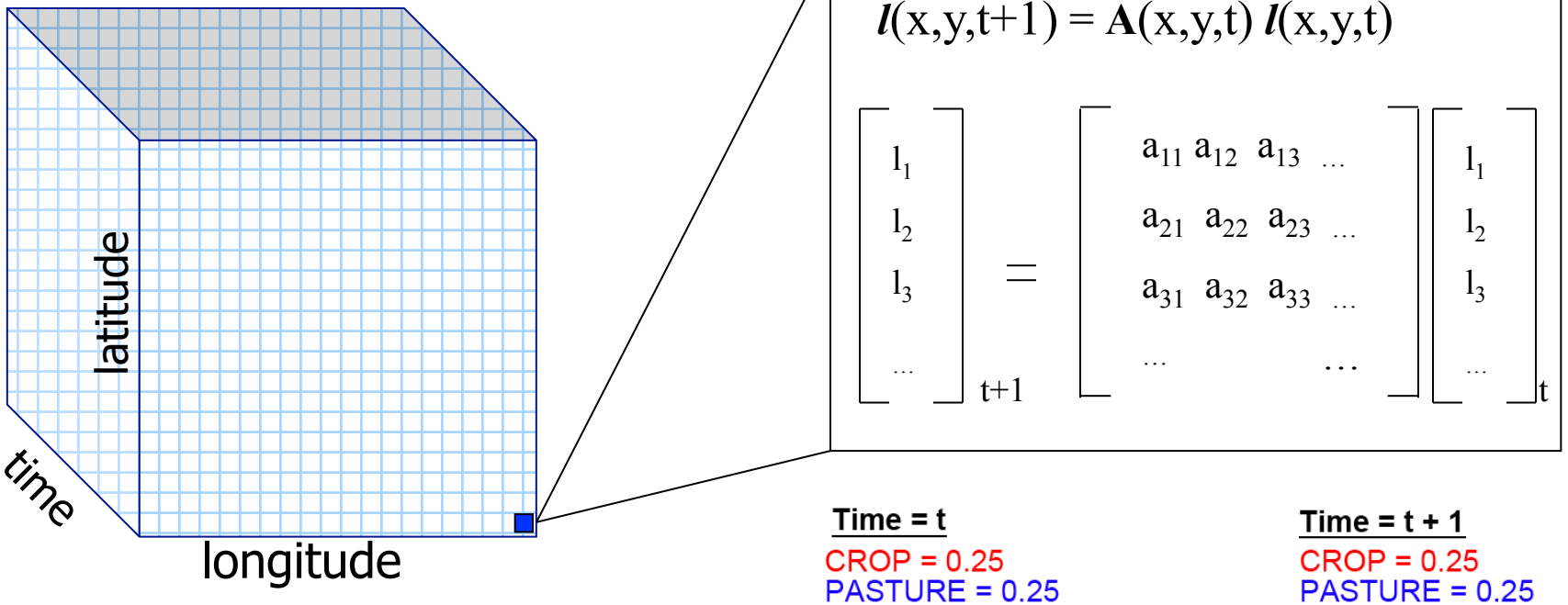
pasture



ΔF (LUH)

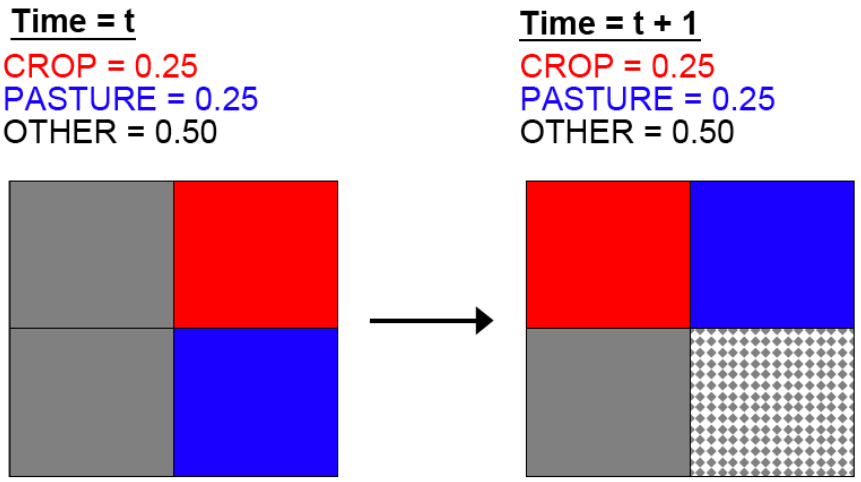
ΔF (IAM)

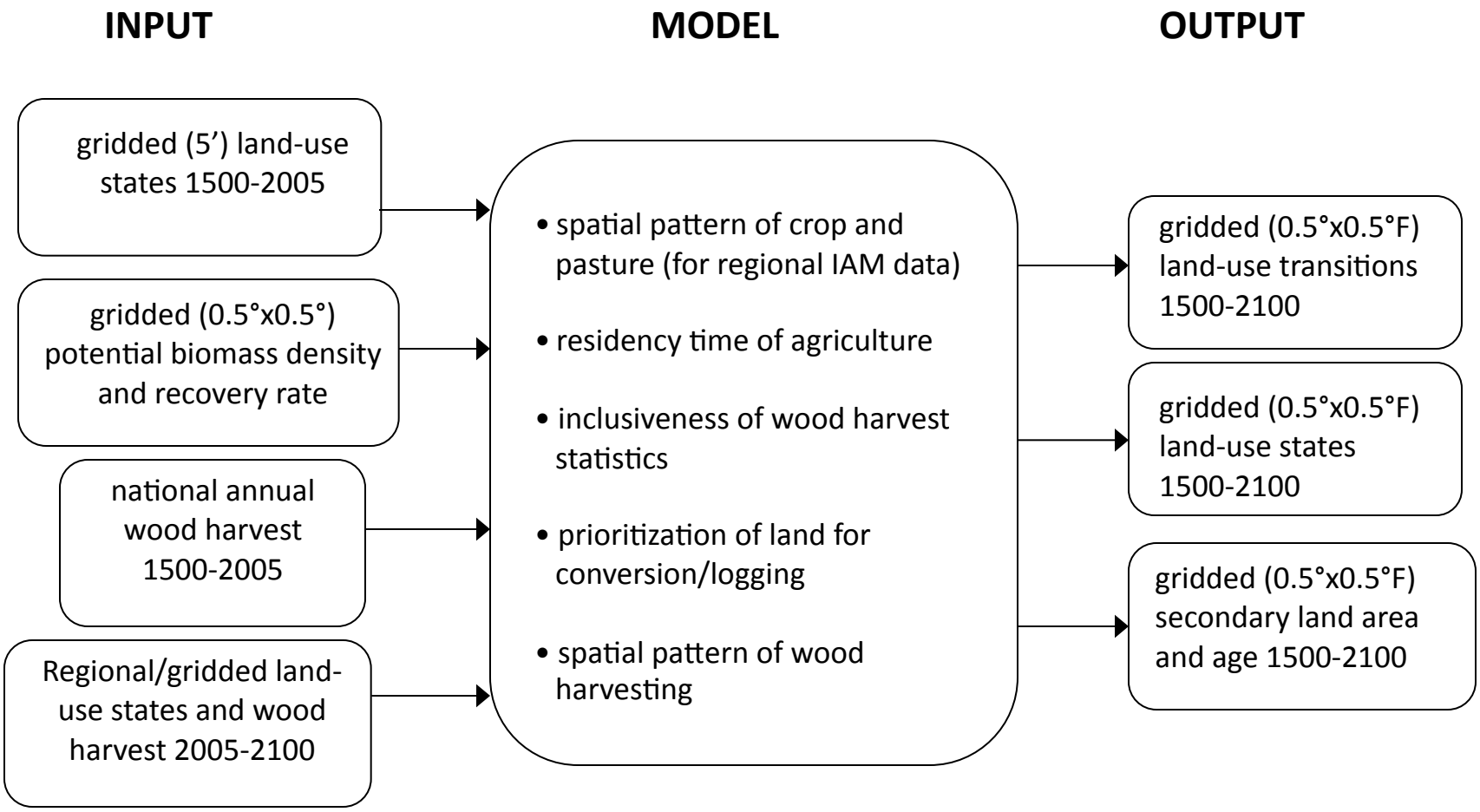
Mathematical Structure for Computing Land-use Transitions



Global, 0.5 deg, 600y, 4D:
~10^9 unknowns!

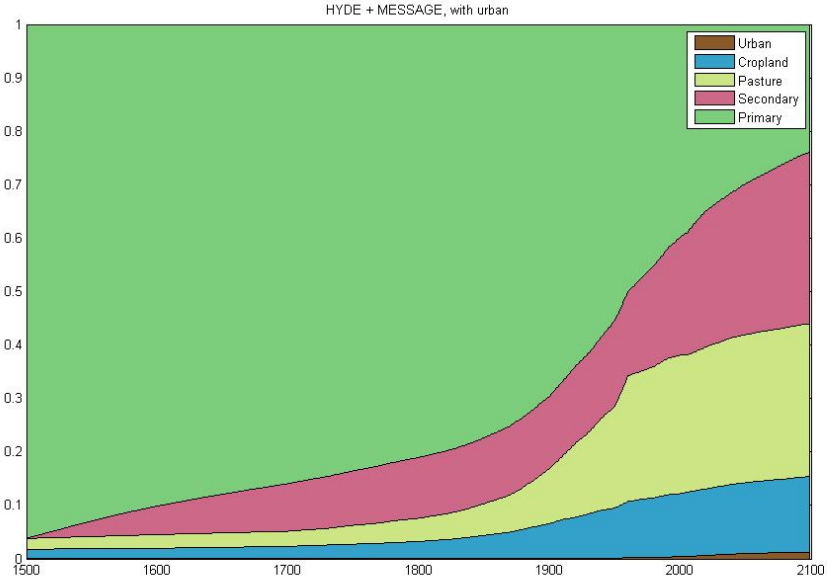
Hurtt et al. (2011)



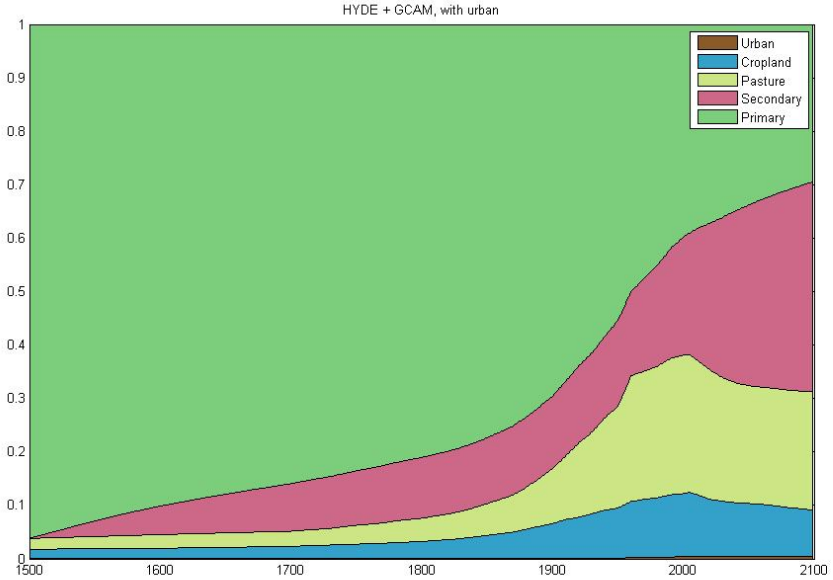


Hurtt et al. 2009

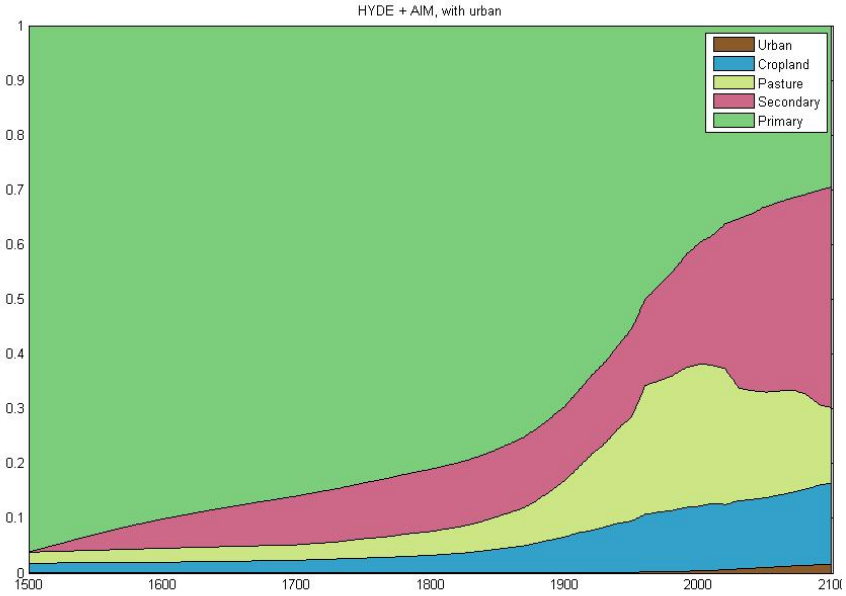
LUH-MESSAGE



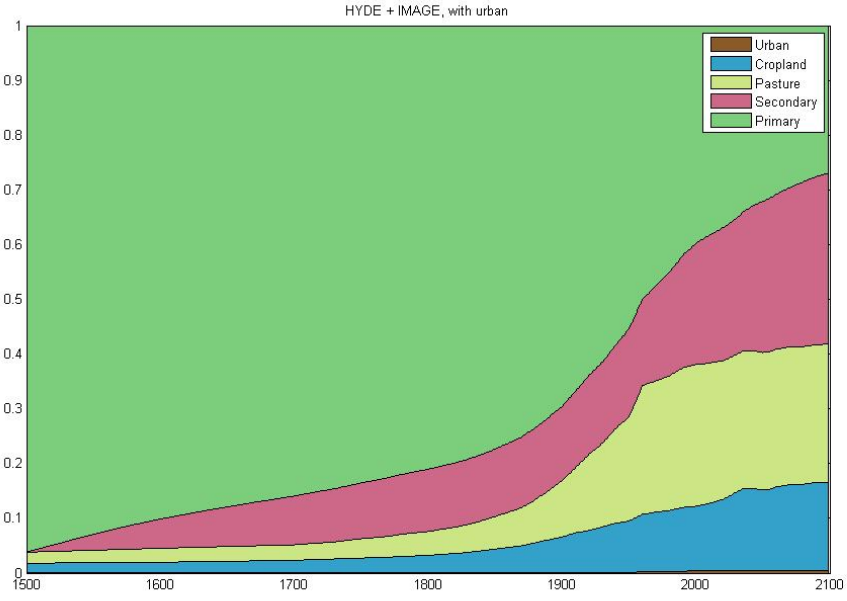
LUH-GCAM



LUH-AIM



LUH-IMAGE



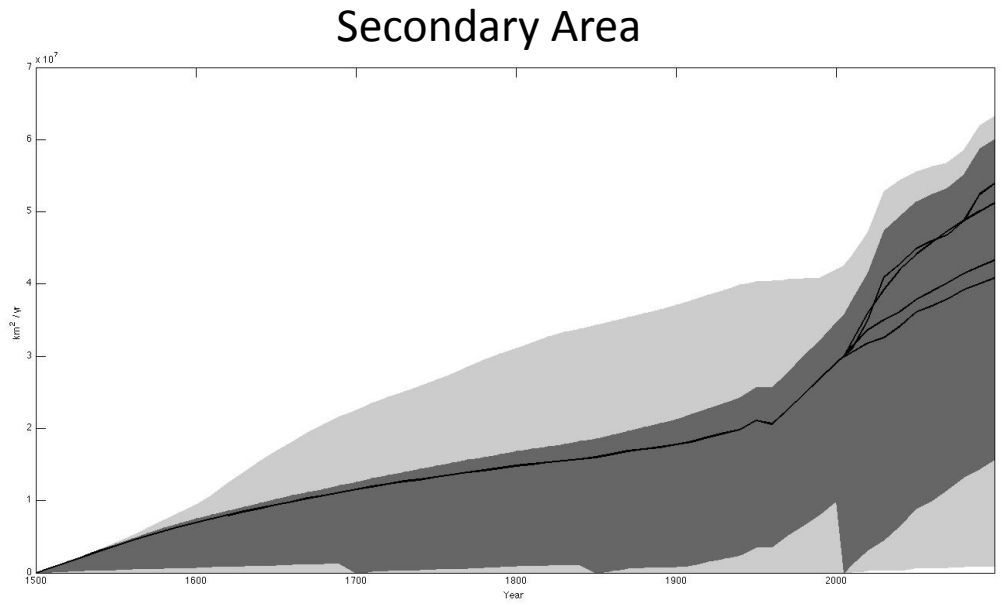
Model Sensitivity

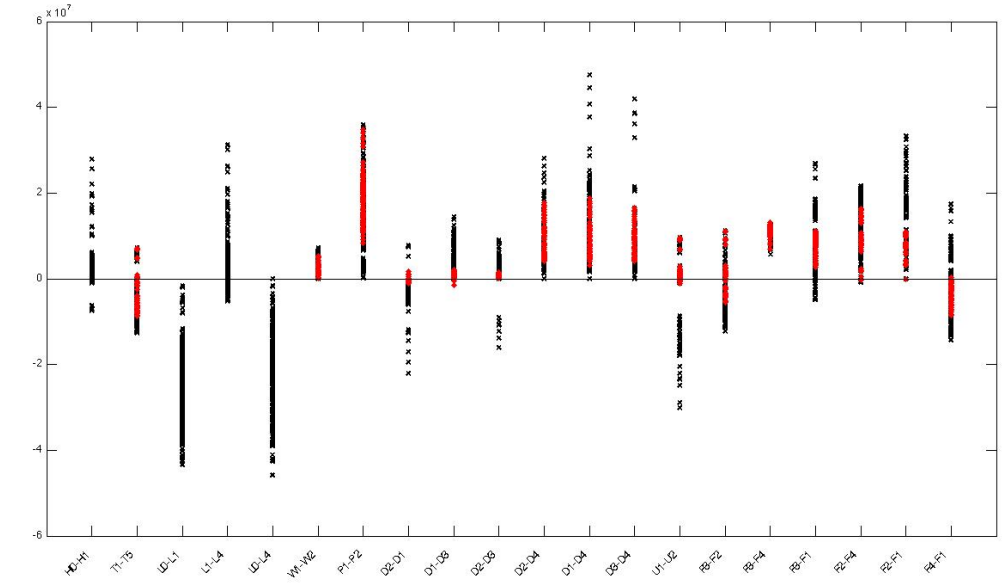
Model factor	Number of Cases: Description
Historical land-use reconstruction (*H*)	3: HYDE 3.0, "No Data", None
Residence time of agricultural land (*T*)	2: Shifting cultivation, no shifting cultivation
Wood harvest history reconstruction (*L*)	3: No wood harvest, FAO wood harvest reconstruction, "No Data"
Land-conversion wood clearing tallied as harvest to satisfy annual wood harvesting (*W*)	2: Included 100%, not included
Priority for land-use transitions (*P*)	2: Primary, secondary
Historical start date (*D*)	4: 1500, 1700, 1850, 2005
Urban land use included (*U*)	2: Included, not included
Future land-use projections (*F*)	4: AIM, GCAM, IMAGE, MESSAGE

Total number of simulations: 1664

Key model factors:

- Inclusion of wood harvest
- Early simulation start date
- Primary vs. secondary priority
- Shifting cultivation





New Work

- Working with ESM groups to help guide the use of our products in their models
- Fully coupled IAM-GLM-ESM simulations (iESM)
- New development upon our existing framework:
  - Remote sensing data
  - Multiple crop and pasture types
  - What happens to land surface during transitions
  - Changing climate
  - Biofuels
  - Management layers, etc

Thank you

Louise Parsons Chini

lchini@umd.edu

http://luh.unh.edu