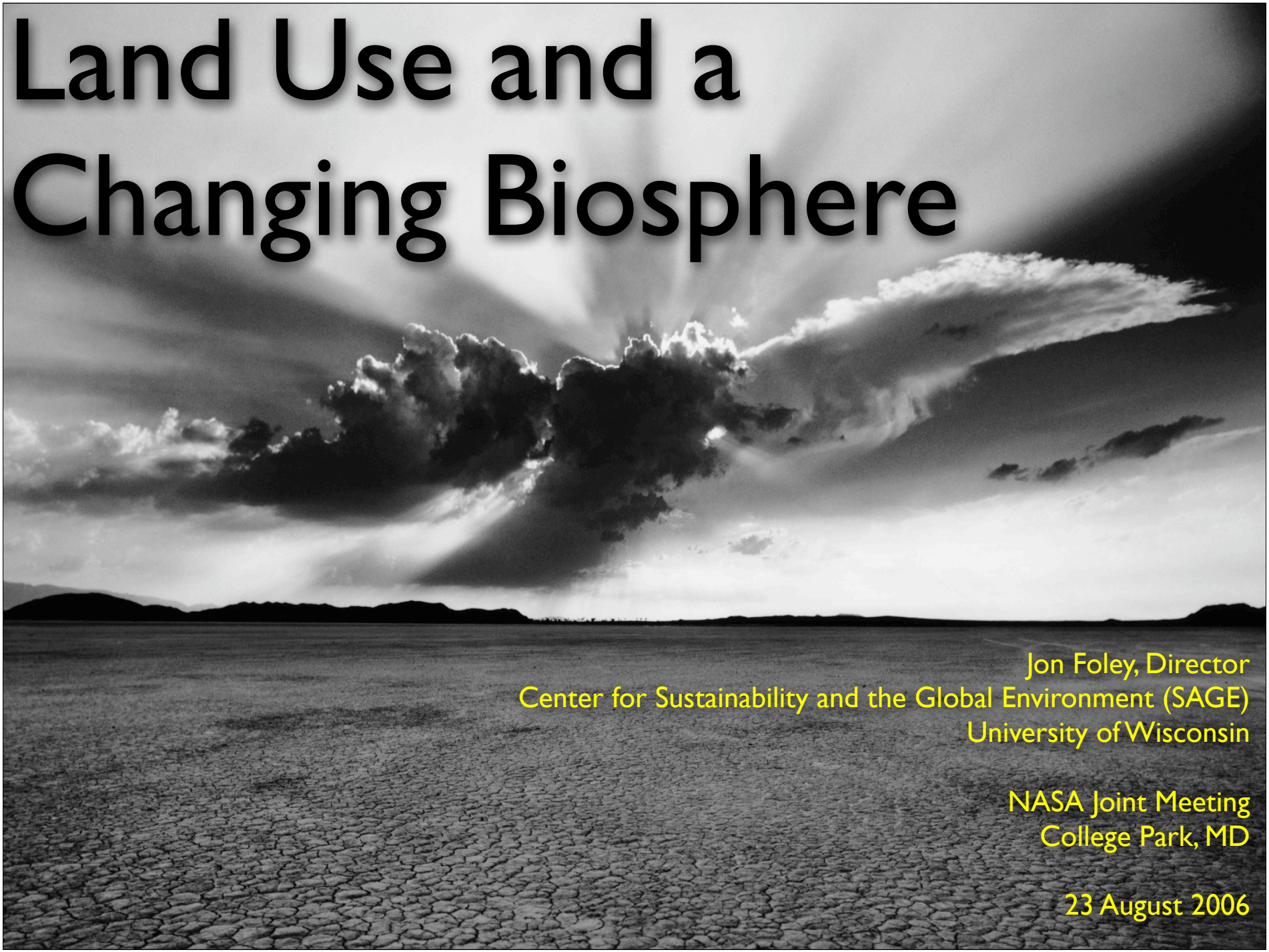
Land Use and a Changing Biosphere

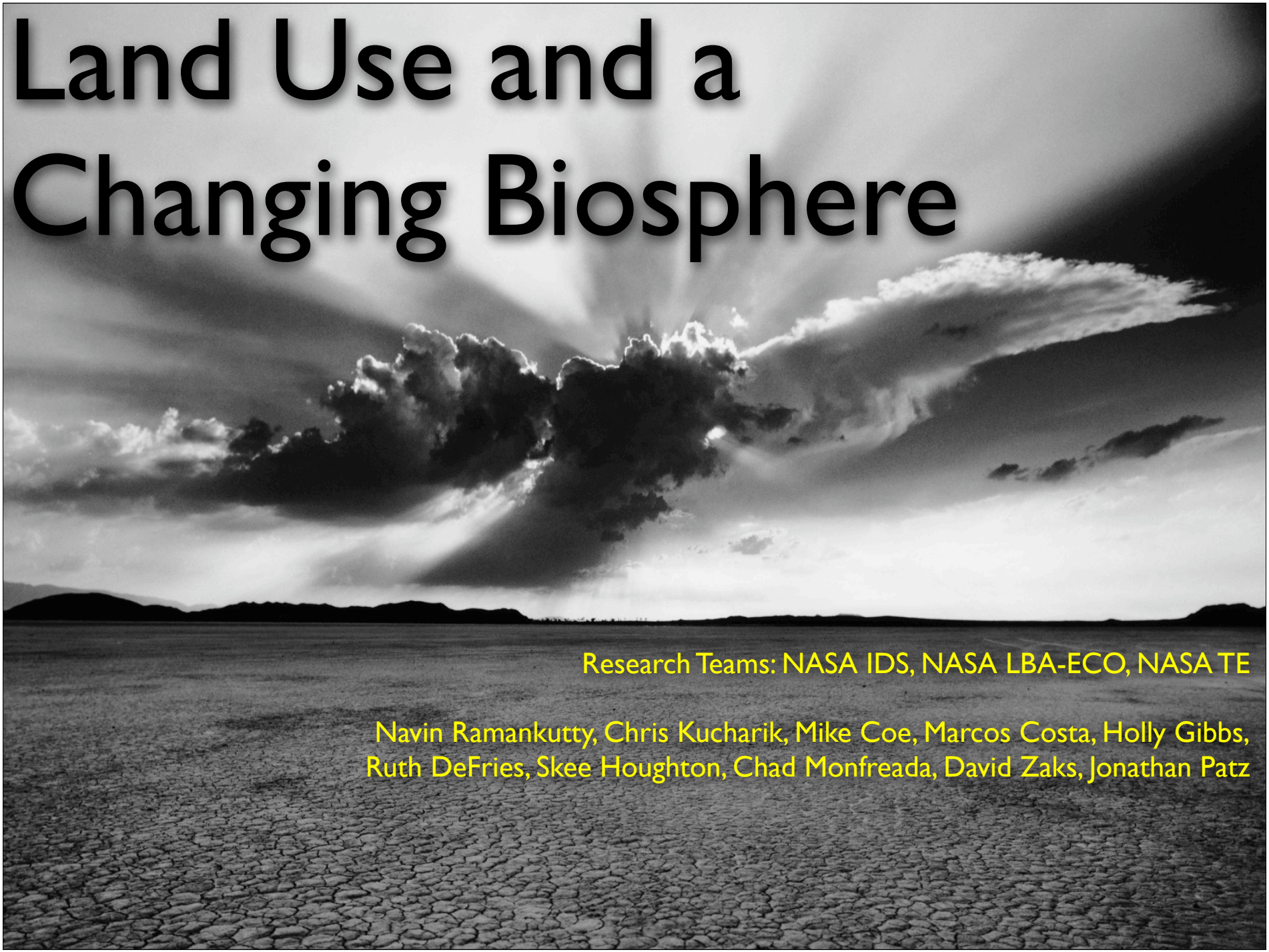


Jon Foley, Director
Center for Sustainability and the Global Environment (SAGE)
University of Wisconsin

NASA Joint Meeting
College Park, MD

23 August 2006

Land Use and a Changing Biosphere



Research Teams: NASA IDS, NASA LBA-ECO, NASA TE

Navin Ramankutty, Chris Kucharik, Mike Coe, Marcos Costa, Holly Gibbs,
Ruth DeFries, Skee Houghton, Chad Monfreada, David Zaks, Jonathan Patz

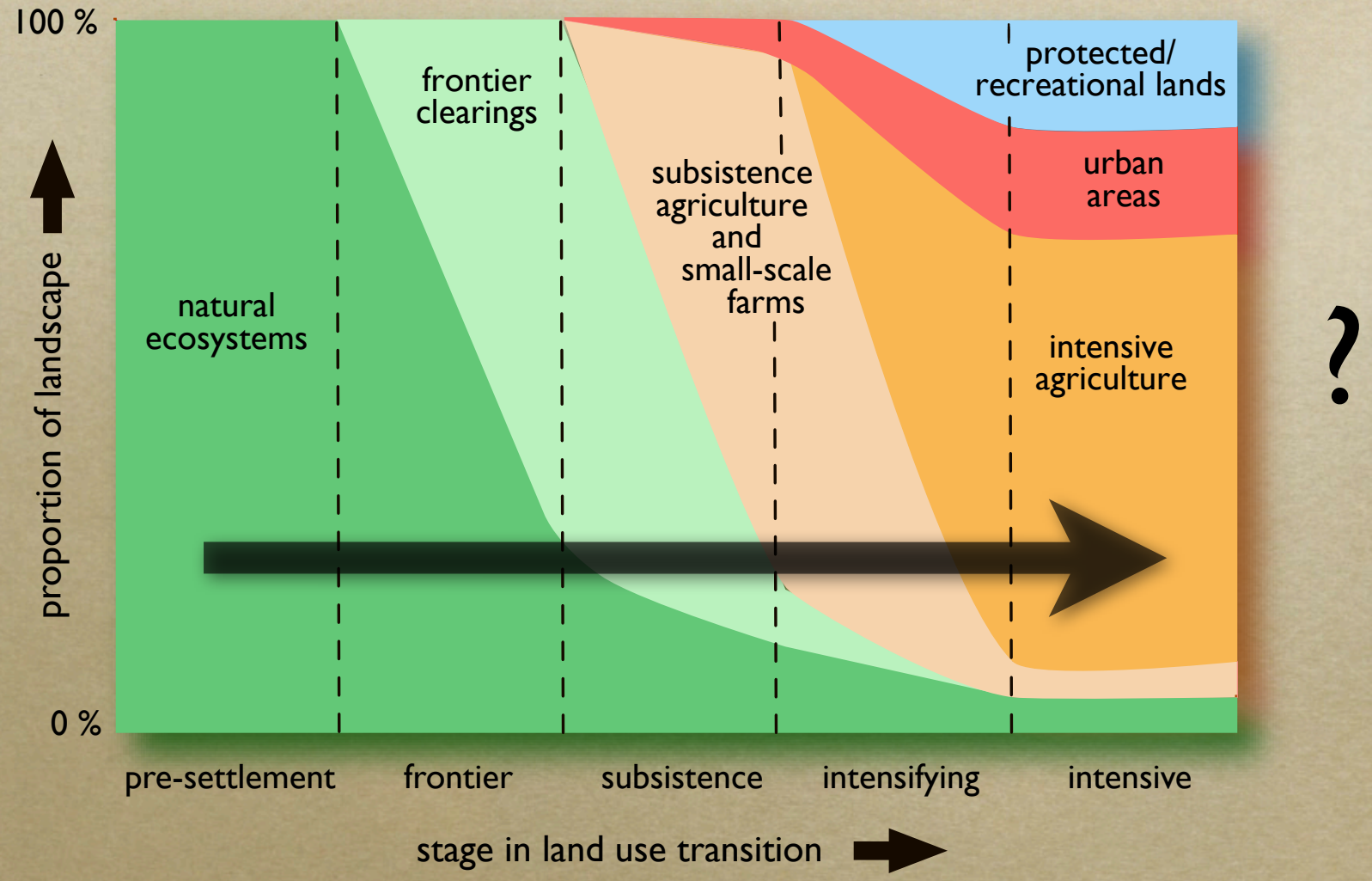
Global Change, So Far

Agriculture

Climate Change


Image: NASA, ASTER Science Team
Minnesota
Kansas
Germany
Bolivia
Thailand
Brazil

Repeating Pattern Across Globe



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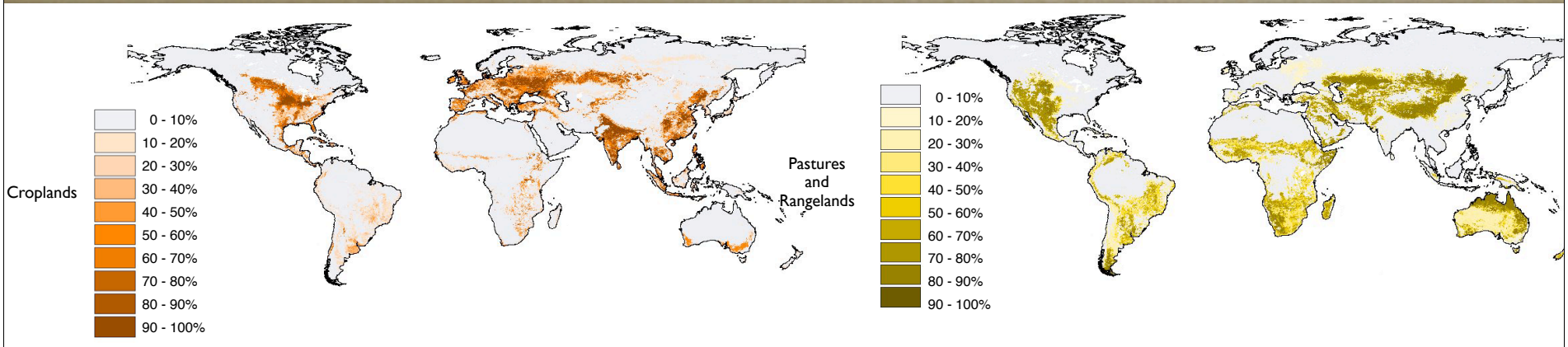
Adapted from: Foley et al., Science, 2005

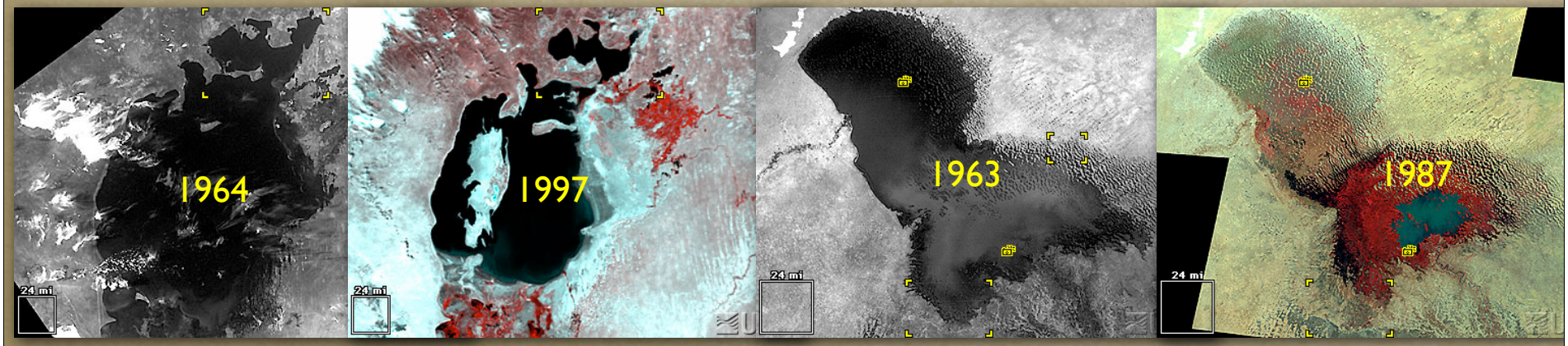
I) Land Clearing / Degradation

- *massive* changes to Earth's land
  - *~40% of land converted to agriculture*
    - *~18 million km² in crops*
    - *~30 million km² in pastures, rangeland*
  - *and ~80% of land has human disturbance*
  - *today, ~40% of global photosynthesis now in human hands*



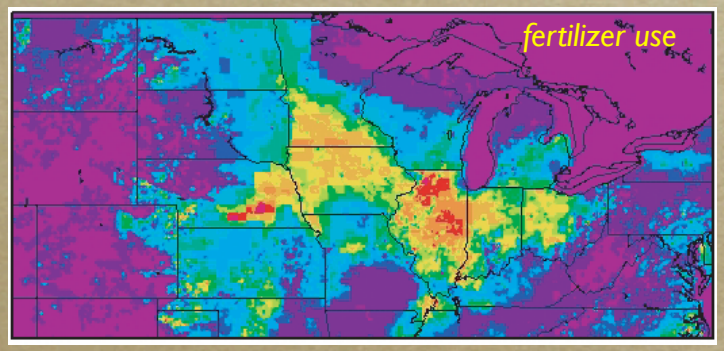
2) Water Degradation

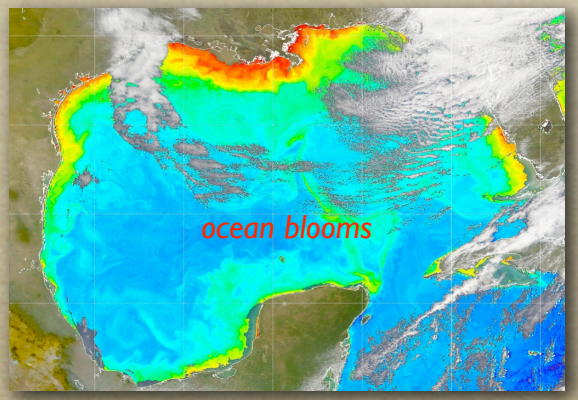
- *massive* increases in water use
  - *water use tripled in 50 years*
  - *mostly due to agriculture*
    - *70% irrigation, 20% industry, 10% domestic*
  - *~50% of available freshwater flow already co-opted*
    - *result: dry rivers, groundwater depletion*



3) Excess Nutrient Pollution

- *massive* release of excess nutrients
  - *doubling natural nitrogen, phosphorus flows*
  - *polluted lakes and rivers*
  - *coastal "dead zones"*





Hypoxic zone, mid-July, 1999

Source: N. Rabalais (LUMC)

And So On...

- *greenhouse gas emissions*
- *soil degradation*
- *reduced biodiversity*
- *novel biological threats*
- *agriculture, already, has altered the biosphere as much as we expect from future climate change...*
- *combined impacts in the future?*

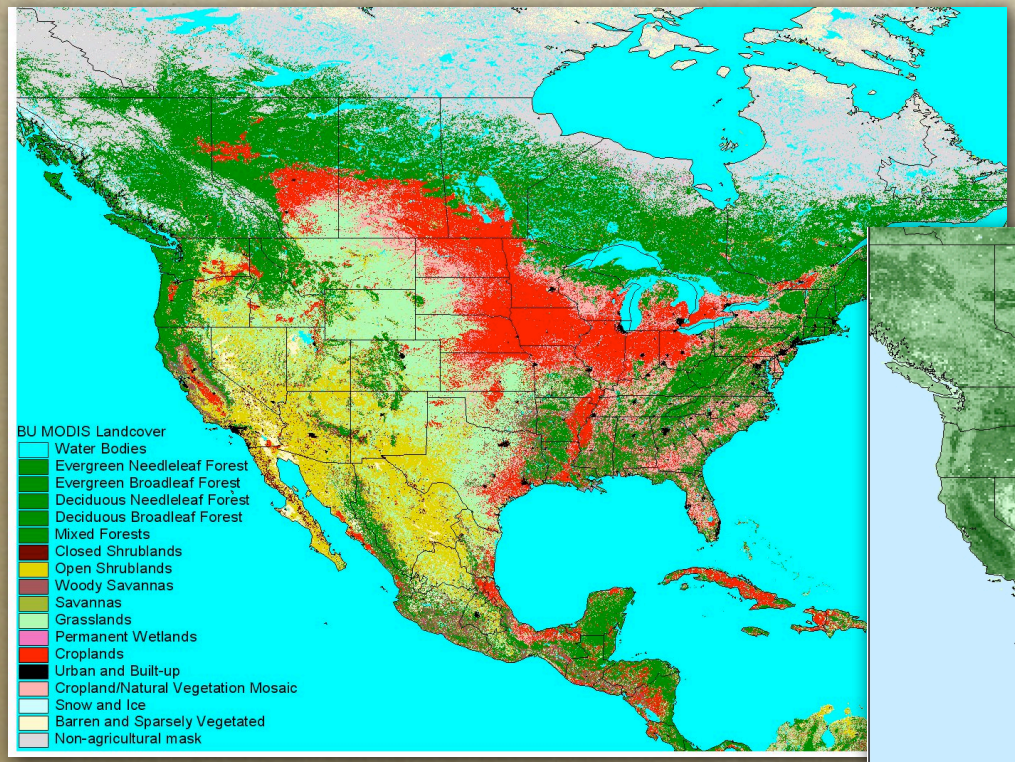
Characterizing Agricultural Land Use

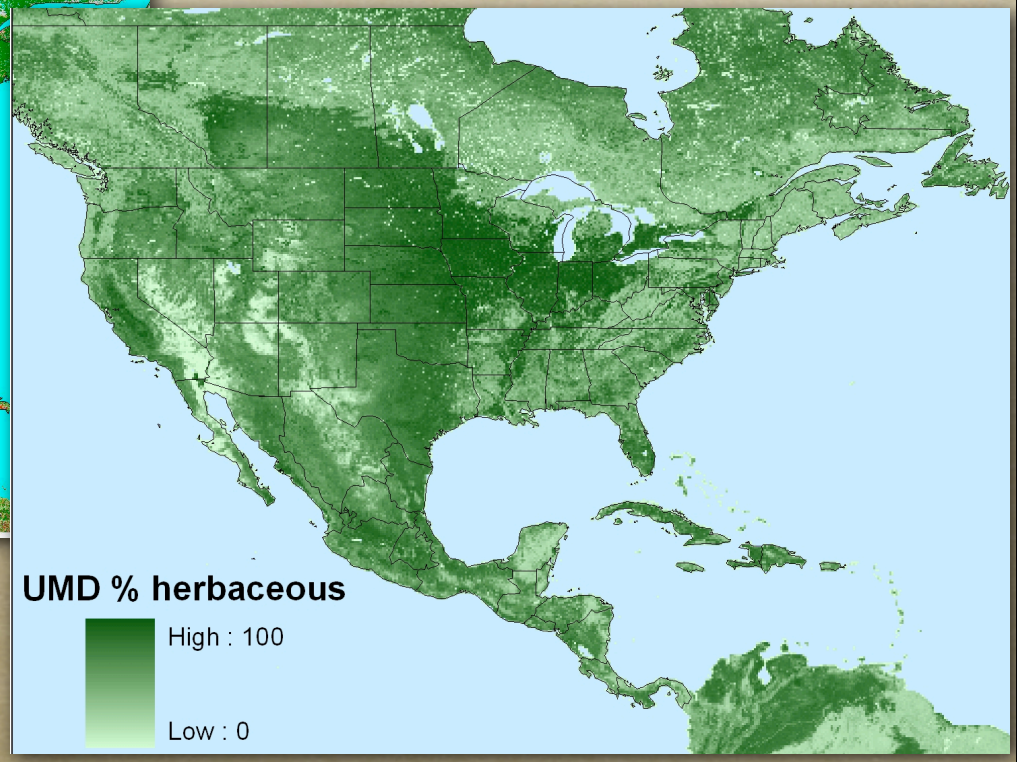
We Know Global Patterns of Agricultural Practices, Right?

Not as well as we like...

Global Satellite Data

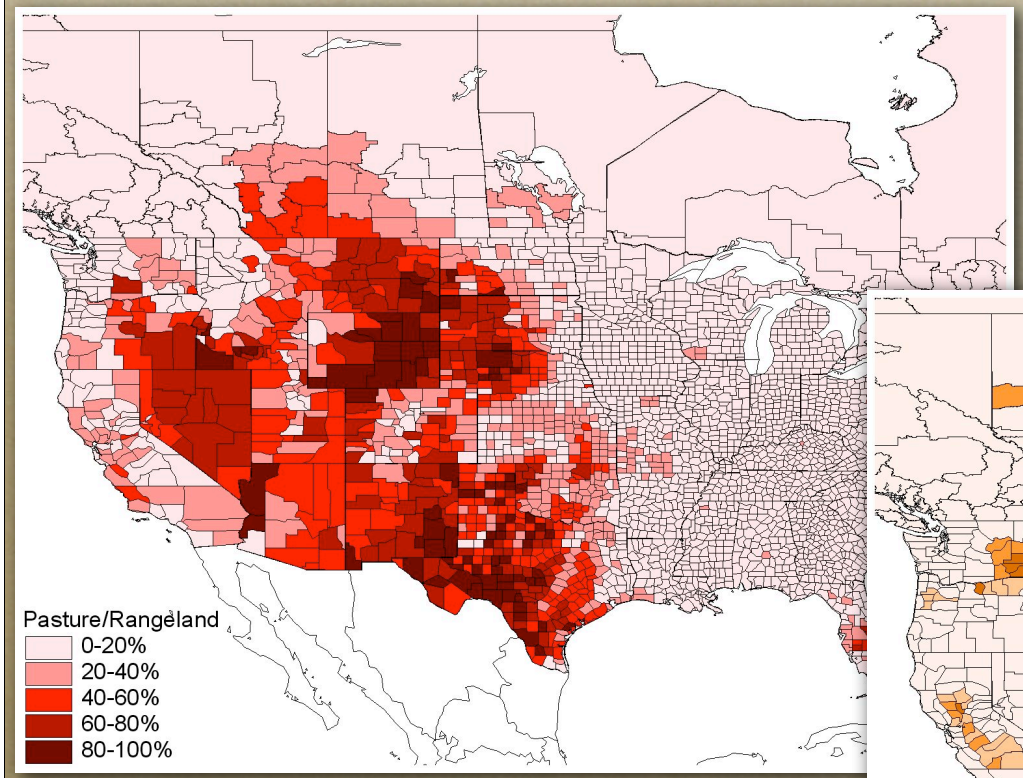
Helpful, but Not Yet Enough...



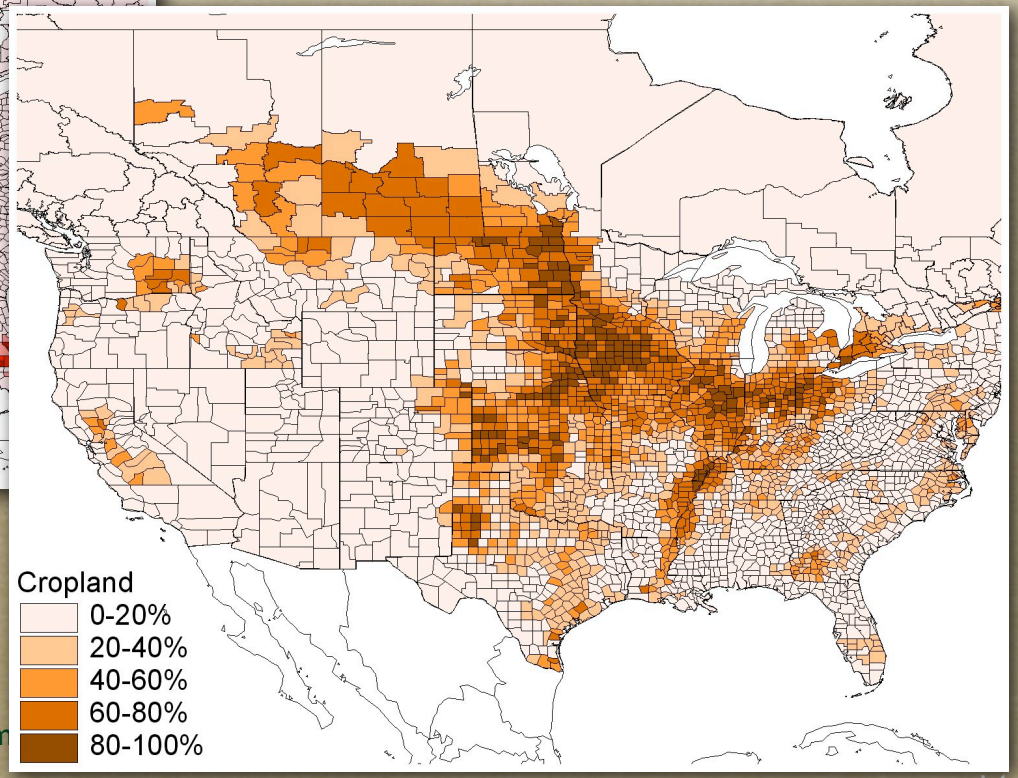


Possible to Add More?

Blending Biophysical & Social Data



statistically "fuse" census and satellite datasets



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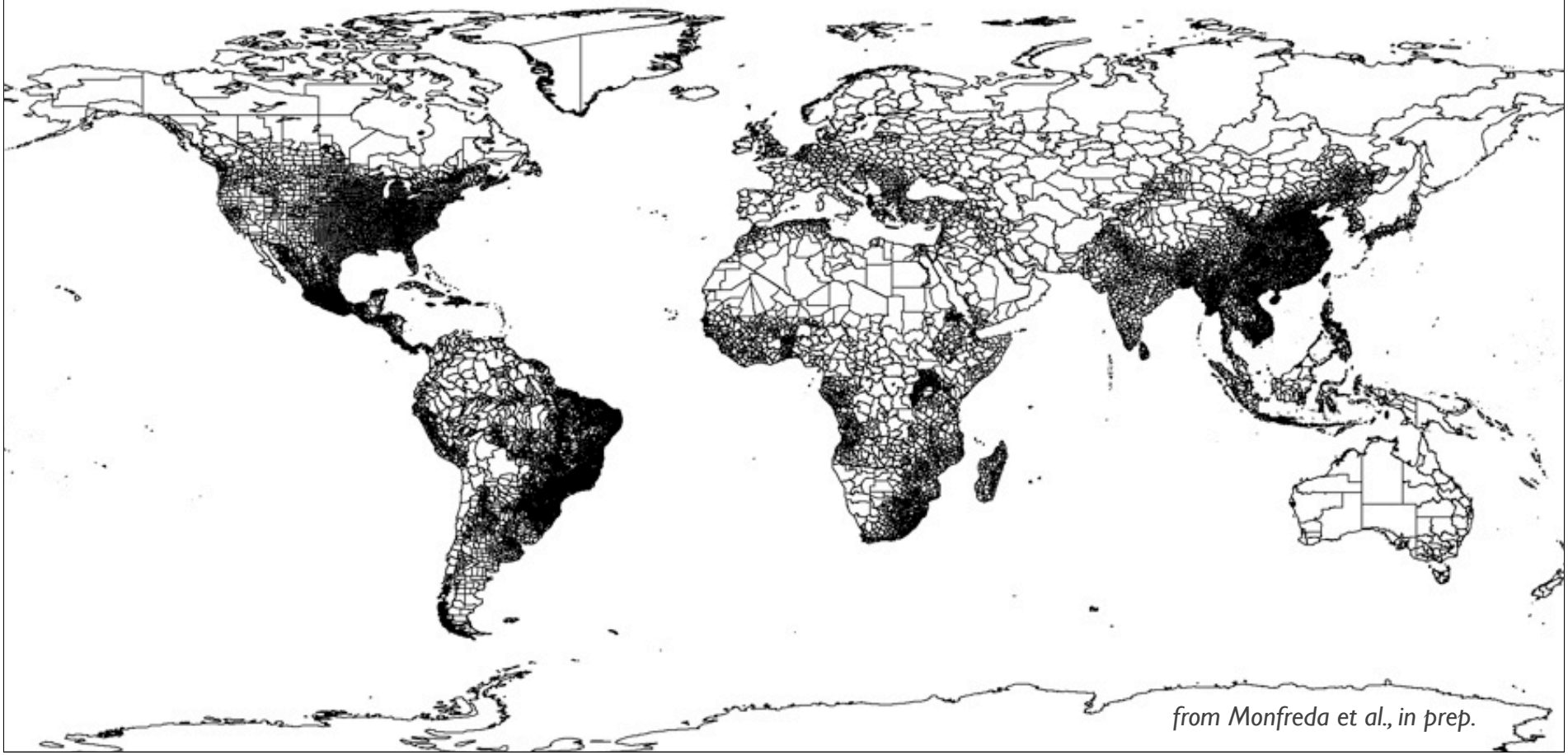
Global Census Data

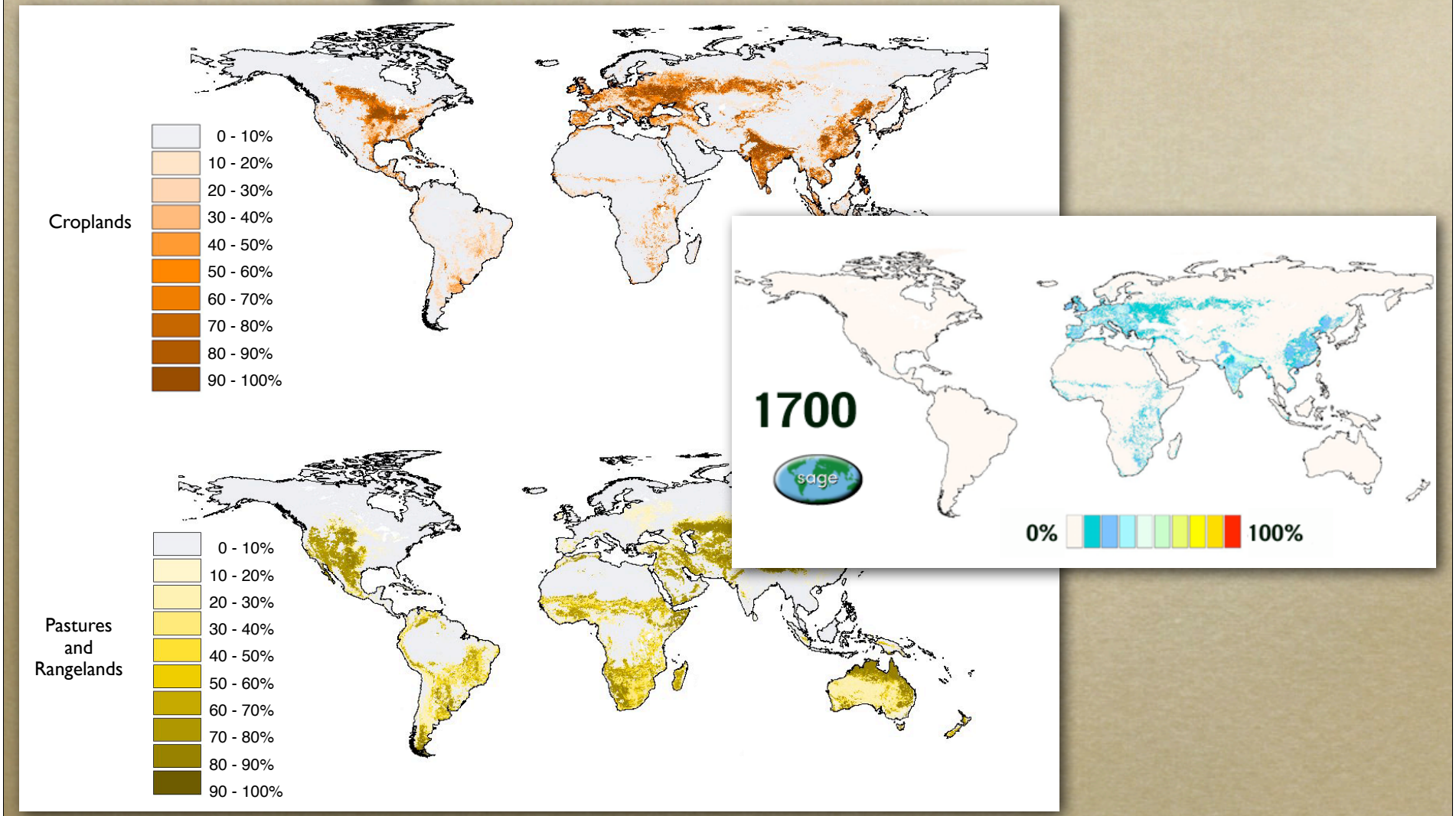
2,299 state / provincial units
and 19,751 county / district units

total of **22,050** census units



from Monfreda et al., in prep.

Global Agricultural Land Use



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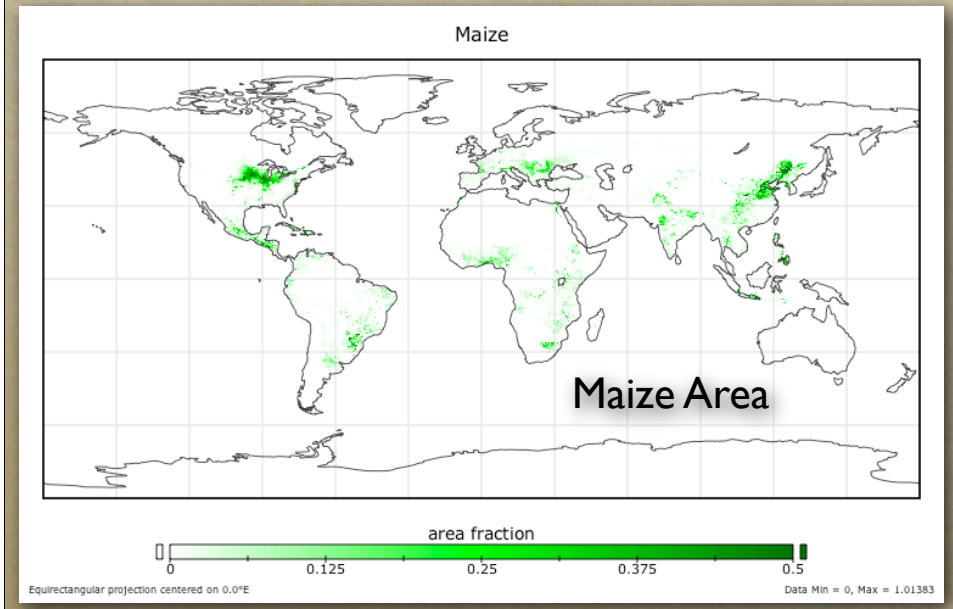
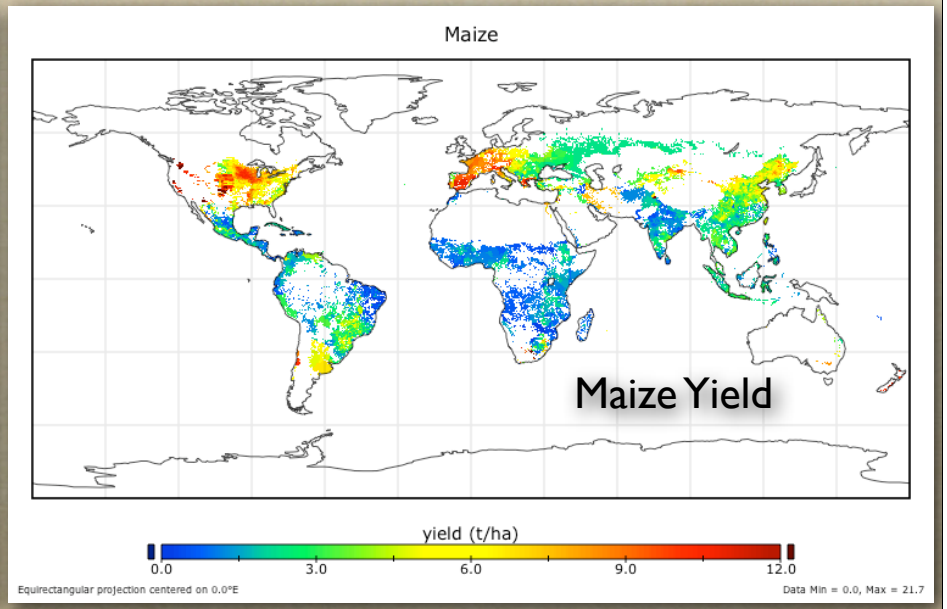
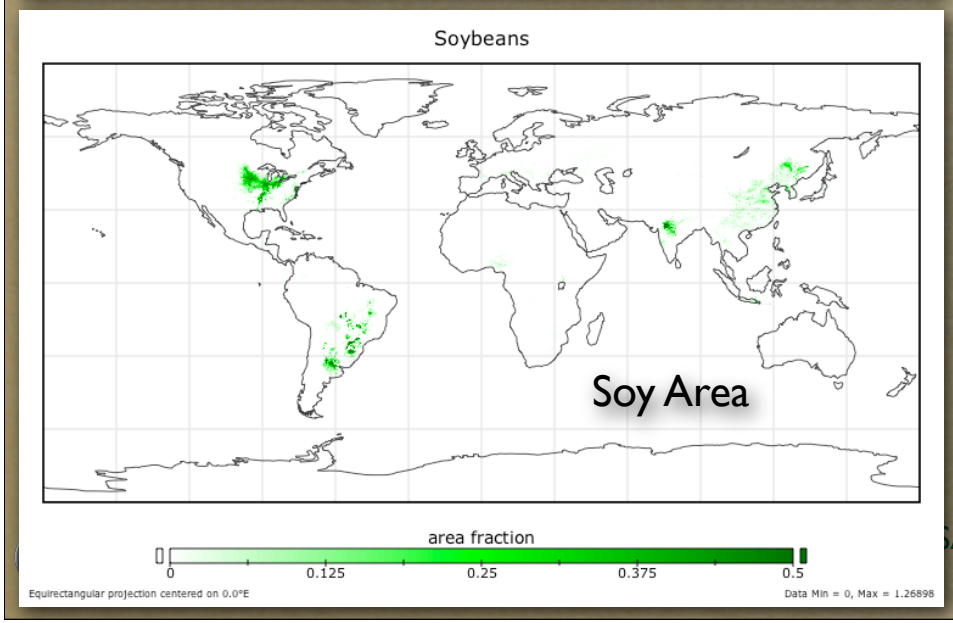
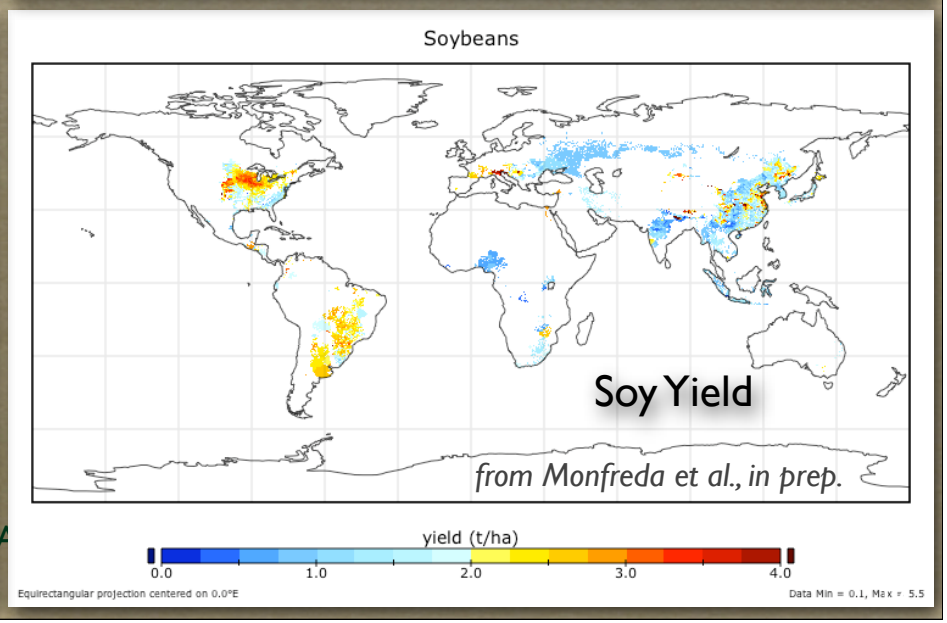
from Foley et al., Science, 2005
movie from www.sage.wisc.edu

Individual Crop Types

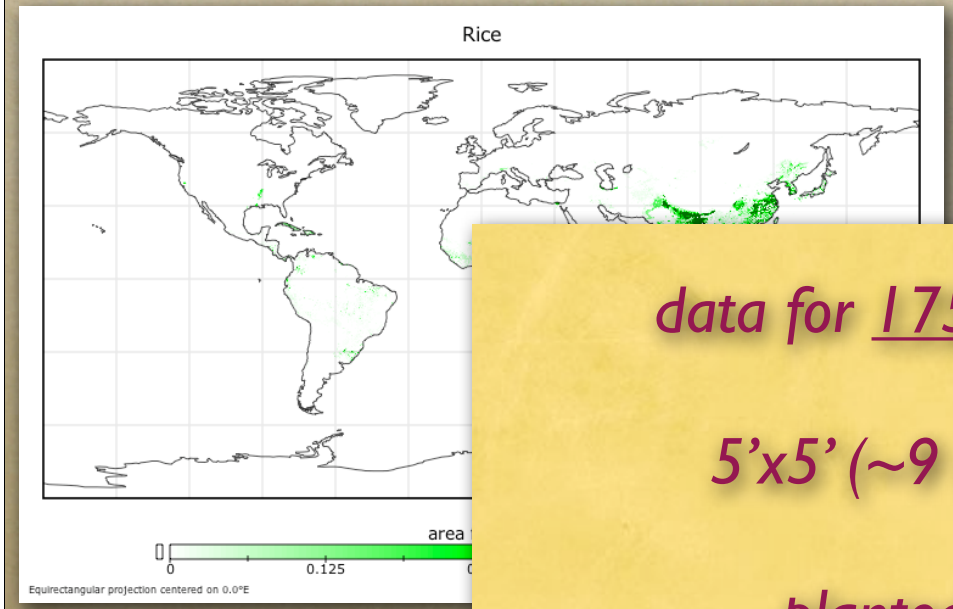


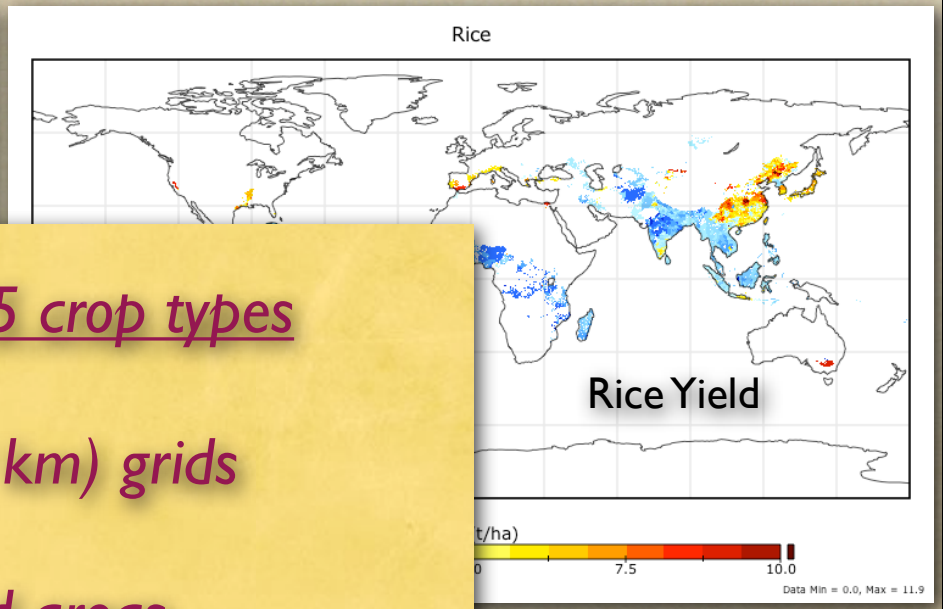






Individual Crop Types

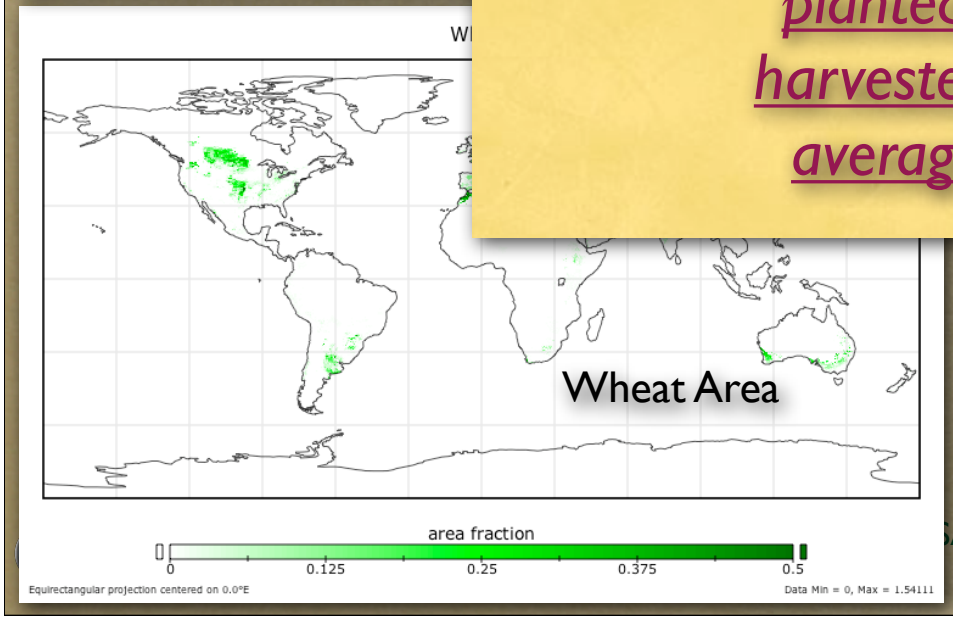


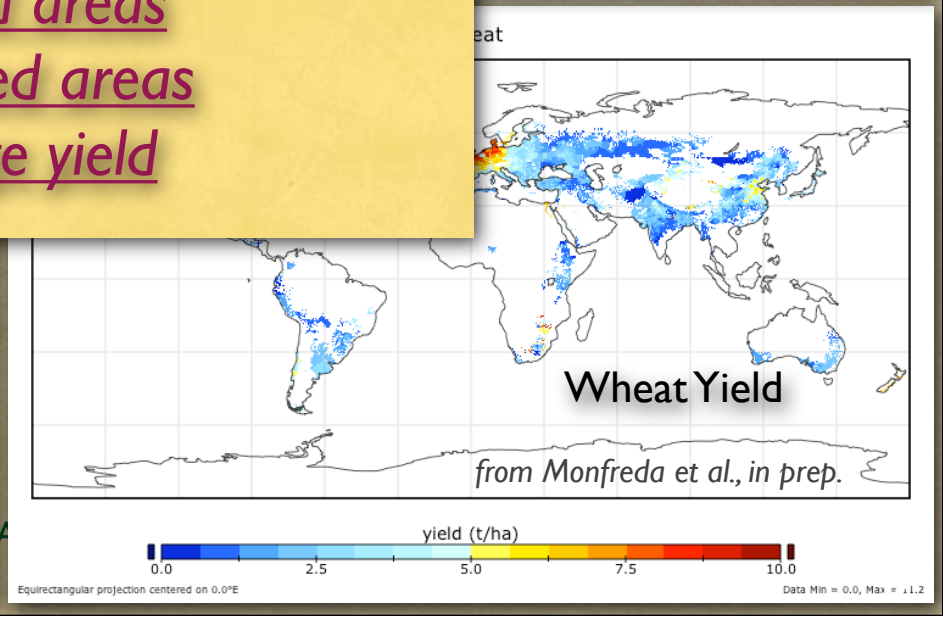


data for 175 crop types

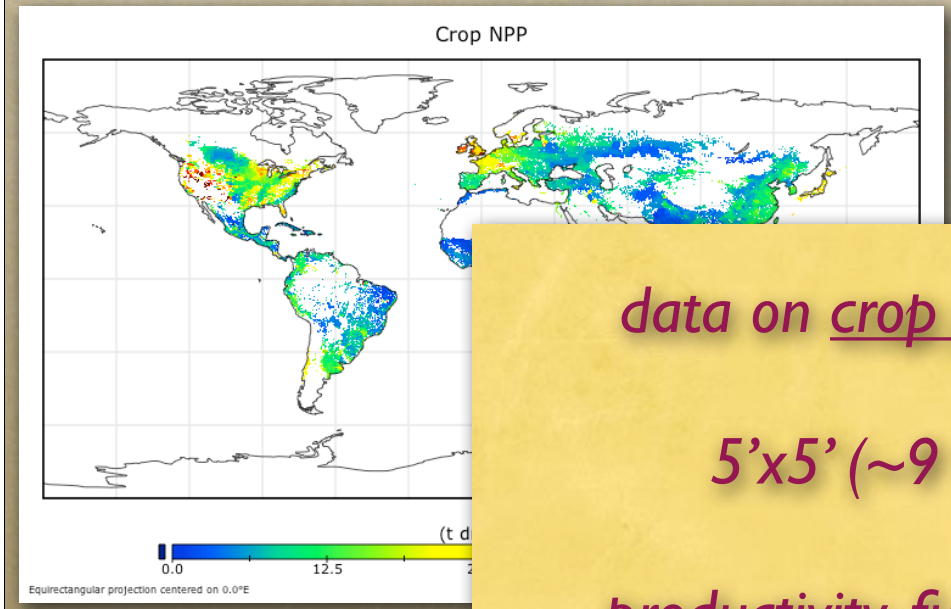
5'x5' (~9 km) grids

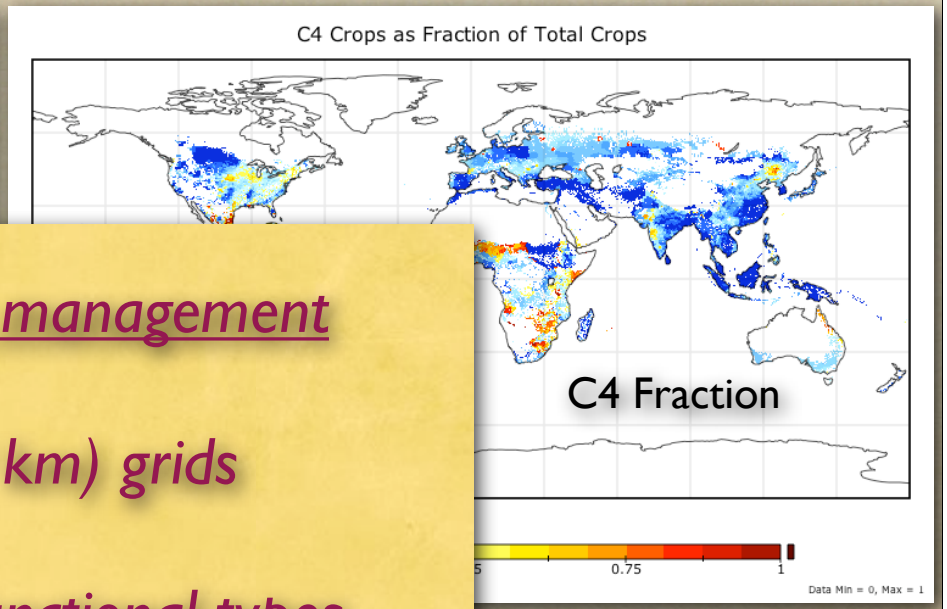
planted areas
harvested areas
average yield





Data on Agricultural Practices

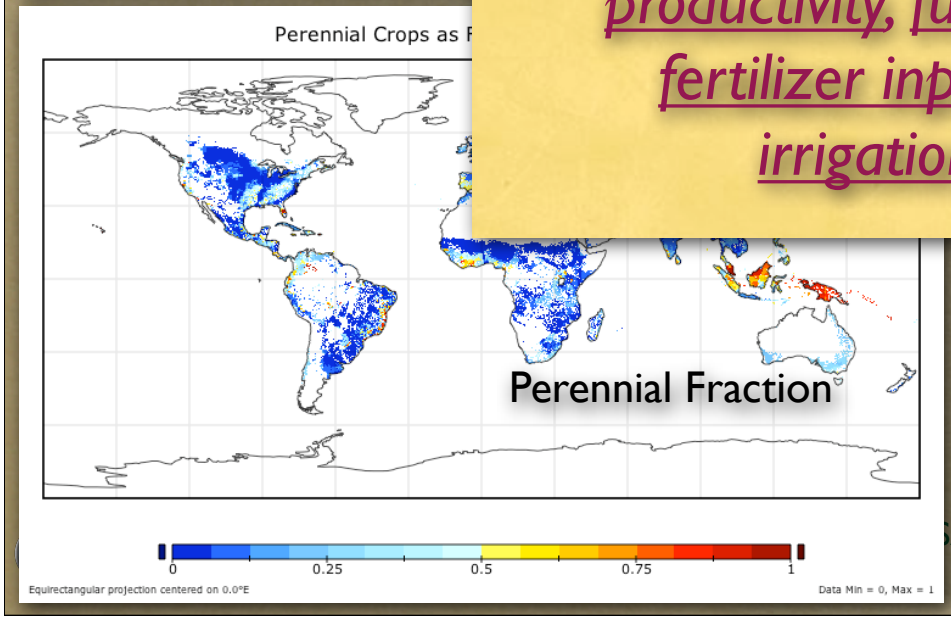


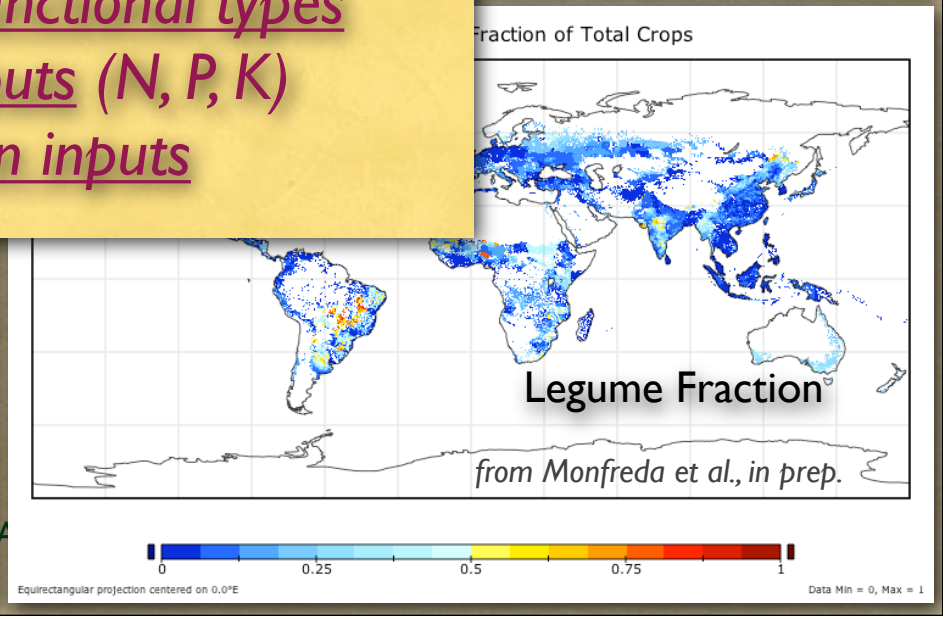


data on crop management

5'x5' (~9 km) grids

productivity, functional types
fertilizer inputs (N, P, K)
irrigation inputs



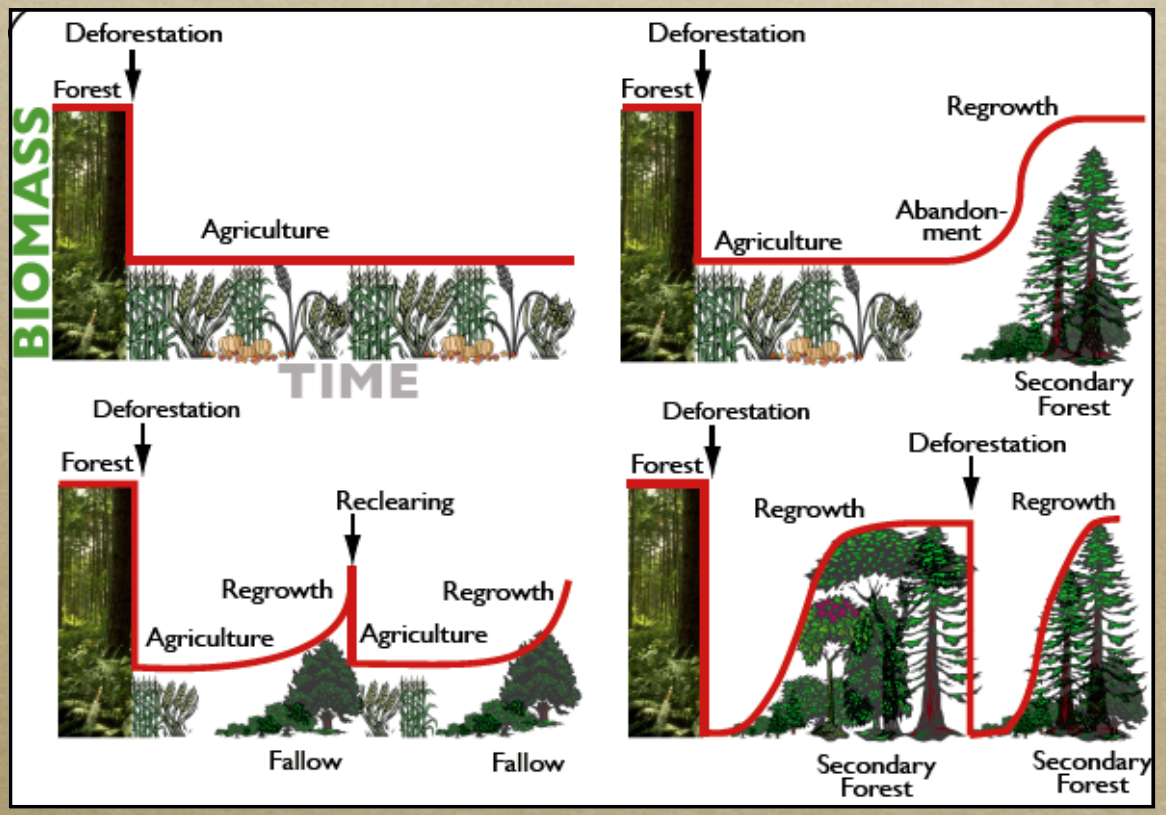


We Know Deforestation Rates, Right?

Sure, but...

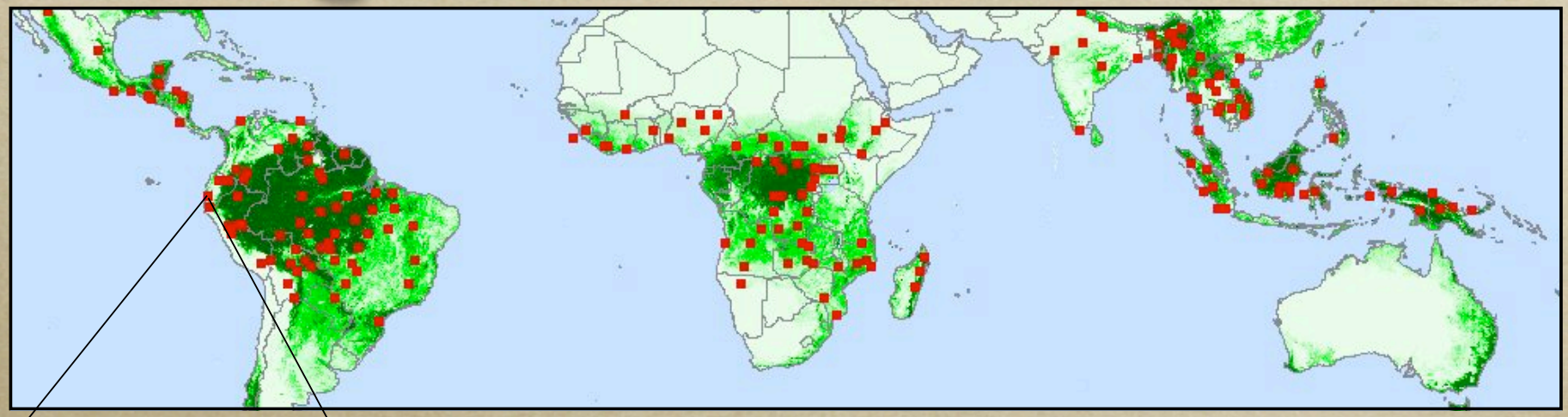
What Happens *Next*?

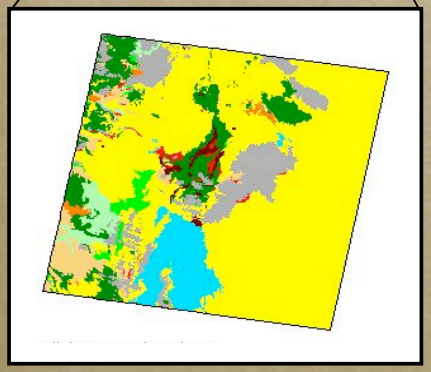
- balance of clearing, management, regrowth
- critical to many questions
  - *carbon release, uptake*
  - *forest management*
  - *food systems*
  - *biodiversity*



Ramankutty et al., submitted

Tracking Fate of Deforested Land





need high-resolution, richly classified data

(so probably not MODIS, not wall-to-wall Landsat)

~600 targeted, manually-classified, validated Landsat scenes from FAO, TREES, etc.

aiming to build library of 1000-2000 scenes

and *local knowledge!*

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University of Wisconsin, Madison

Gibbs et al., in prep.

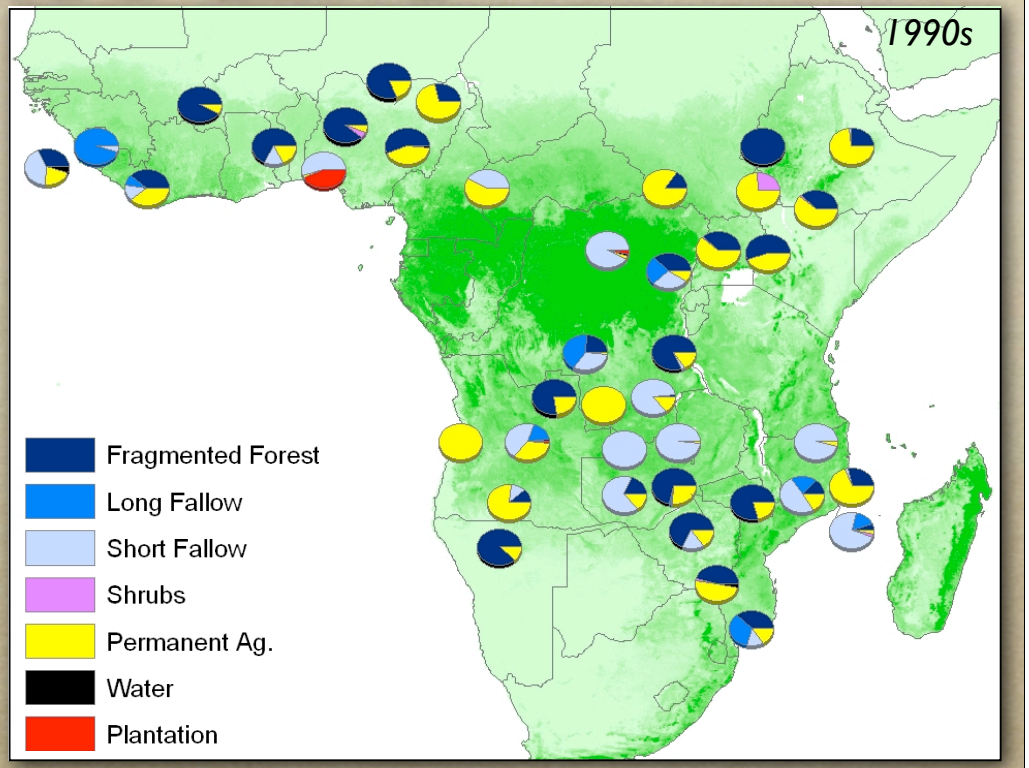
Fate of Deforested Land

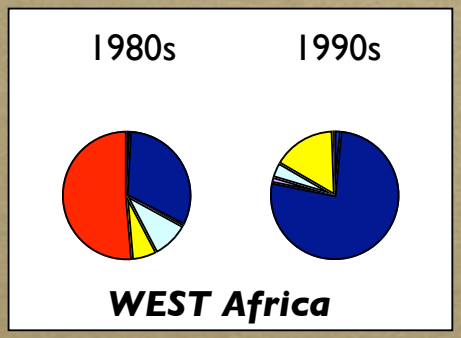
All Regions → Fragmented forest increased {p ~0.06}

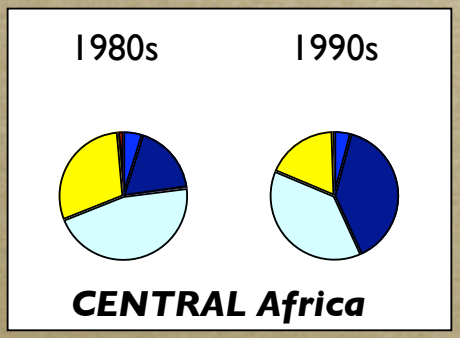
West Africa → Permanent agriculture increased {p ~0.02} while plantations decreased

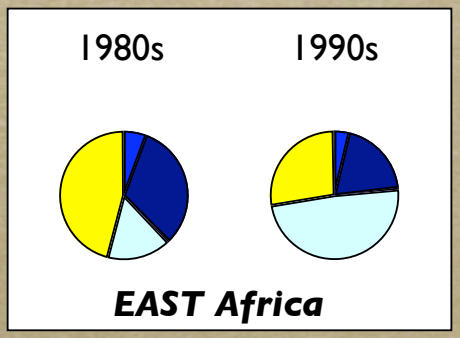
East Africa → Permanent agriculture decreased {p ~0.02} while short fallow increased

Central Africa → remained stable









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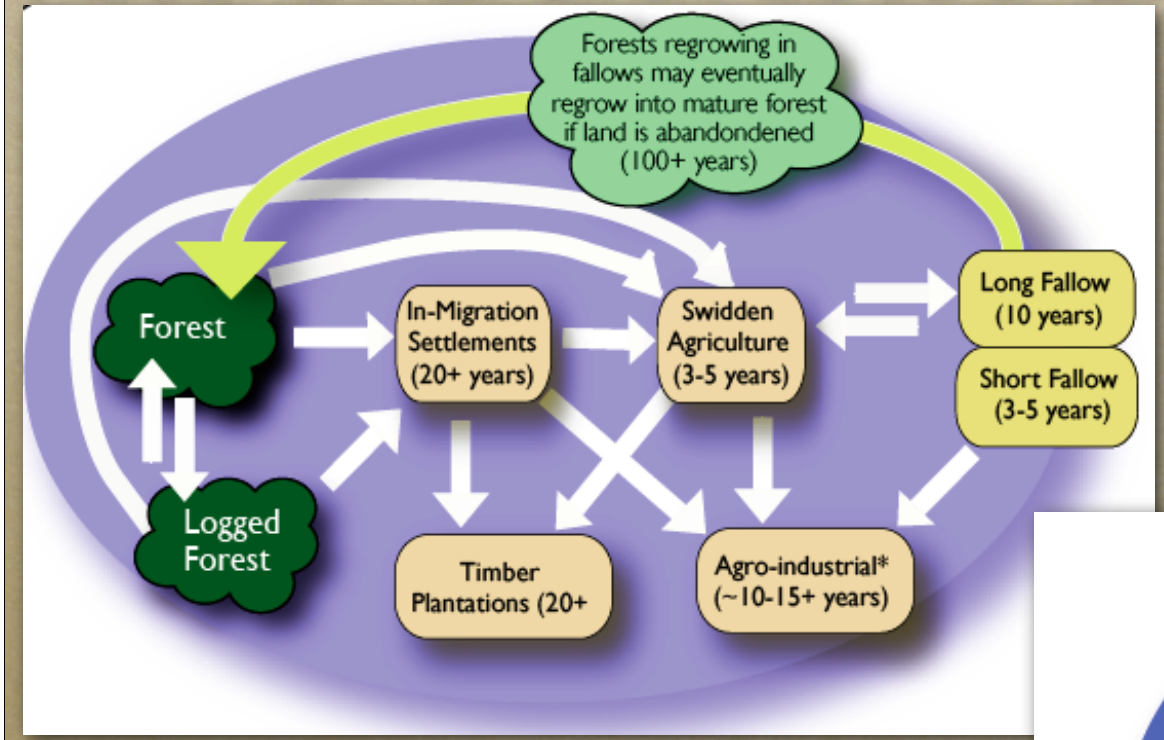
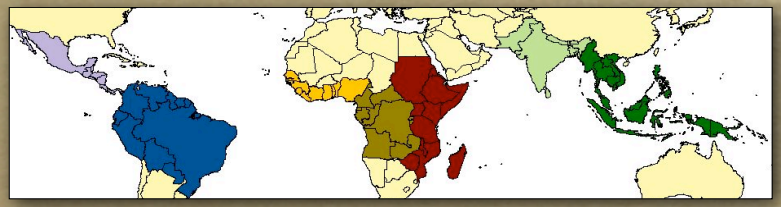
Gibbs et al., in prep.

Fate of Deforested Land

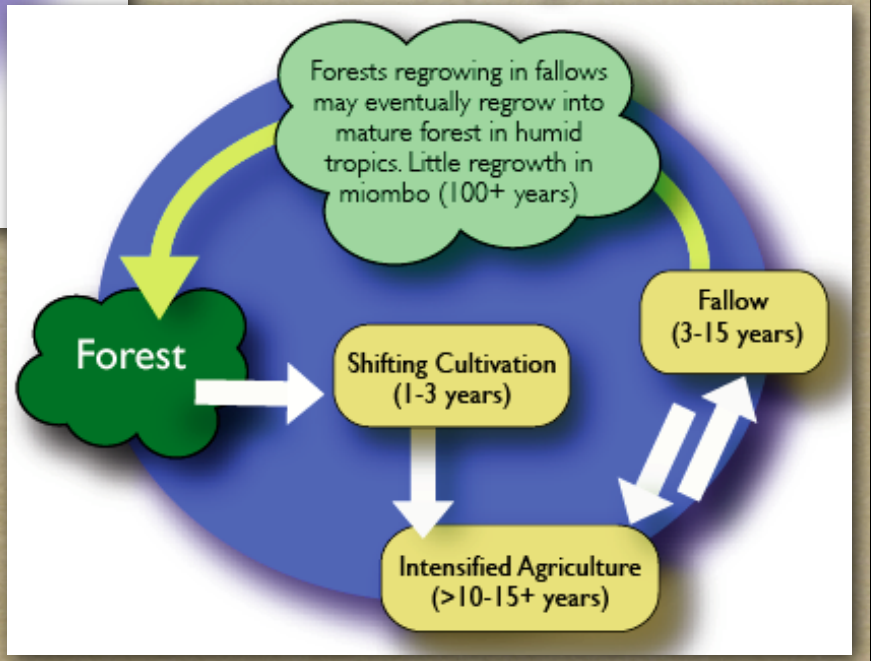


Southeast Asia during the 1990s



now being incorporated in climate / carbon cycle models

West Africa during the 1990s



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Gibbs et al., in prep.


Exploring
Consequences
of Land Use

Carbon Cycle, Physical Climate System

Natural Resources, Human Health

Carbon Cycle, Physical Climate System

Natural Resources, Human Health

Deforestation & Water Resources

Tocantins River upstream of Porto Nacional
~175,000 km^2 watershed

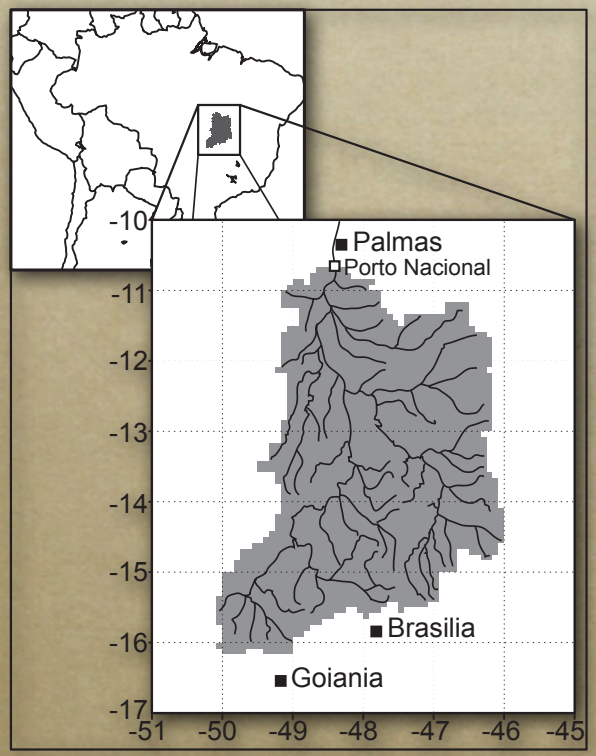
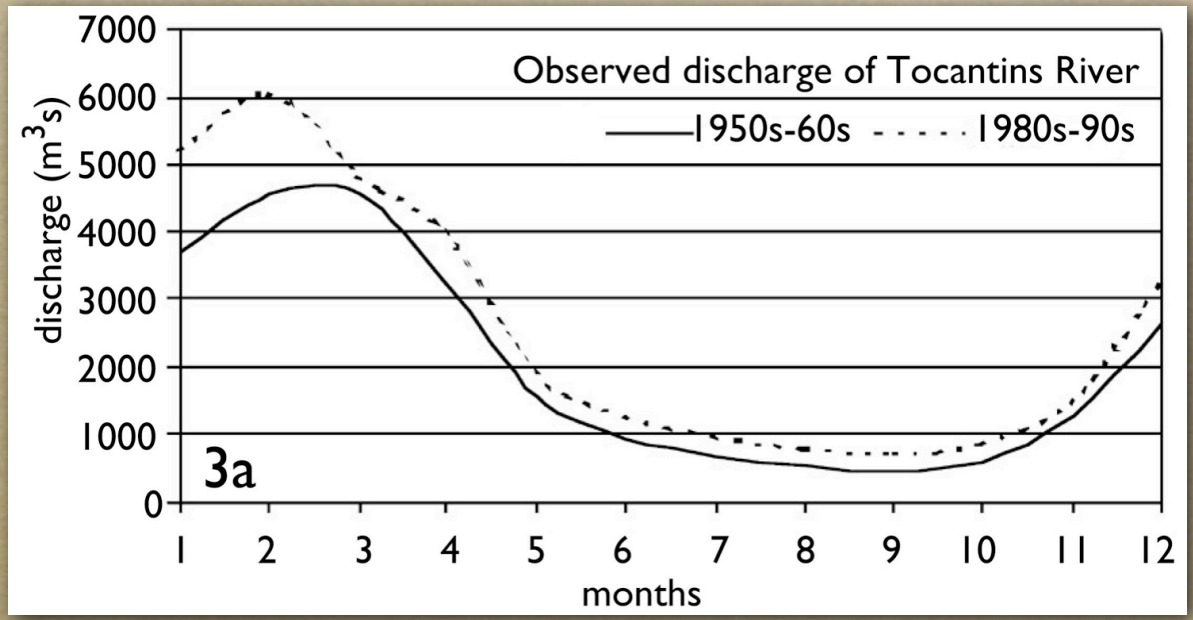


Figure 1

- precipitation did not change

- discharge increased by 24-28%



Source: Costa et al. (2003)

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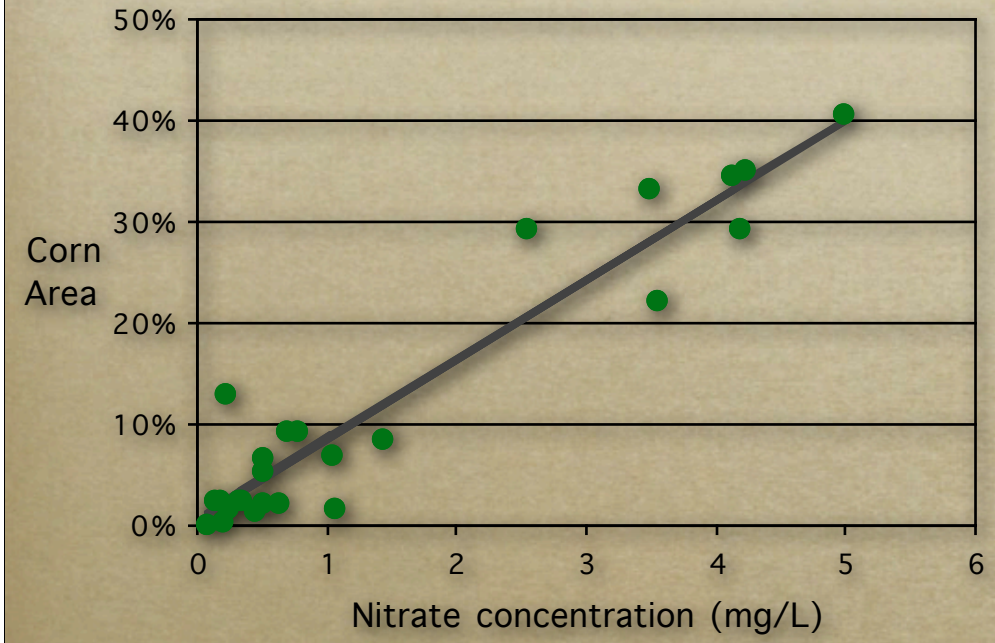
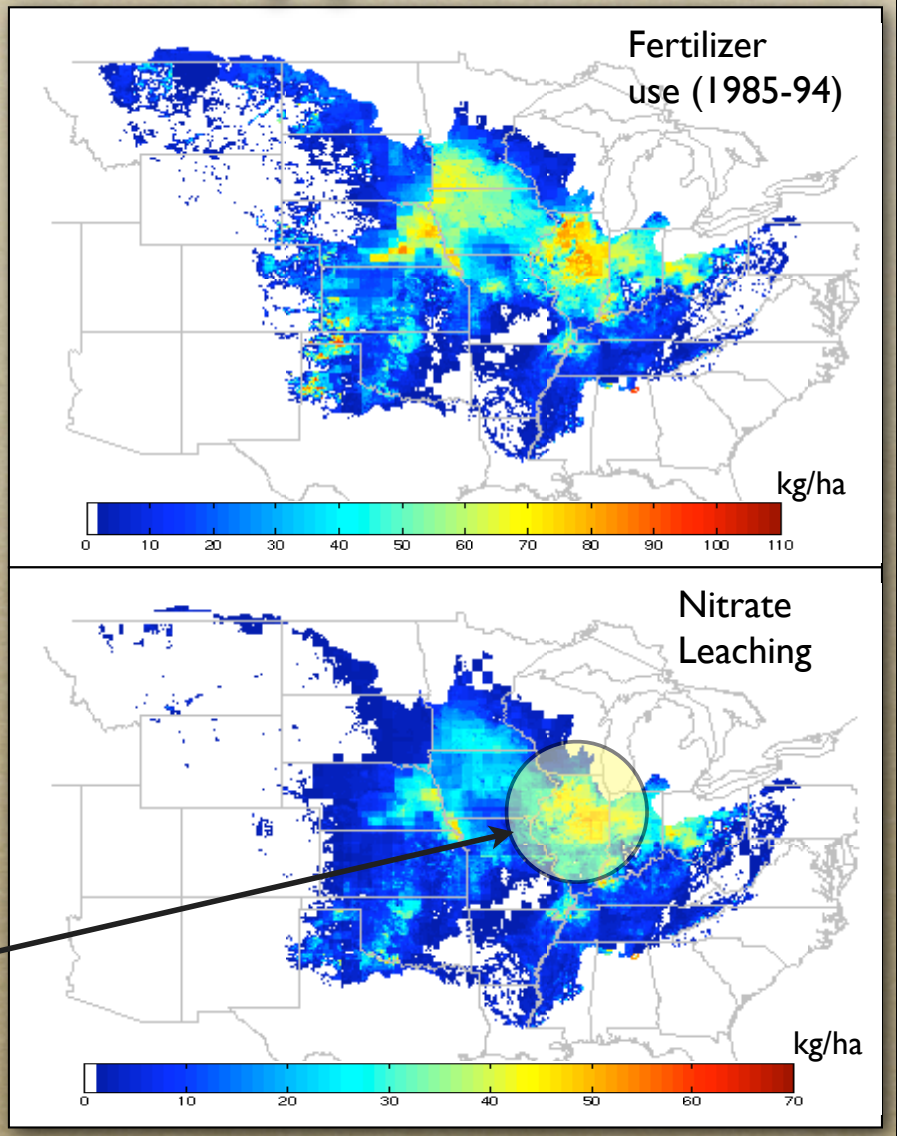
Fertilizer Use & Gulf Hypoxia





high fertilizer inputs
and wet, highly variable climate

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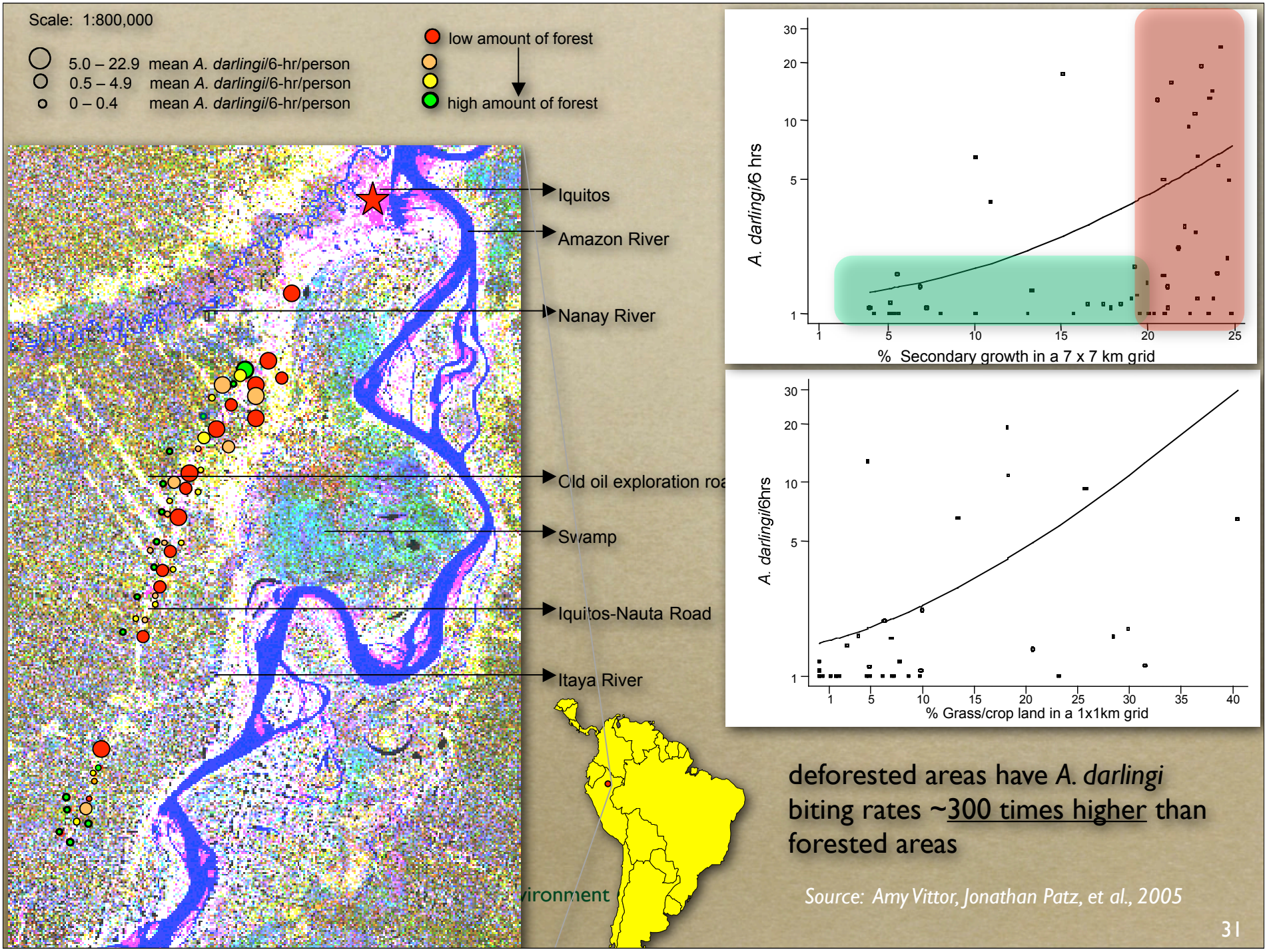
Donner, Kucharik and Foley, GBC, 2005

Deforestation & Disease

most efficient vector of New World malaria
infected by *Plasmodium vivax* and *Plasmodium falciparum*

widely distributed across Latin America
highly anthropophilic

Image Source: http://cb.usp.br/~marcelcp



deforested areas have *A. darlingi* biting rates ~300 times higher than forested areas

Source: Amy Vittor, Jonathan Patz, et al., 2005

Modeling Framework for Biosphere Management

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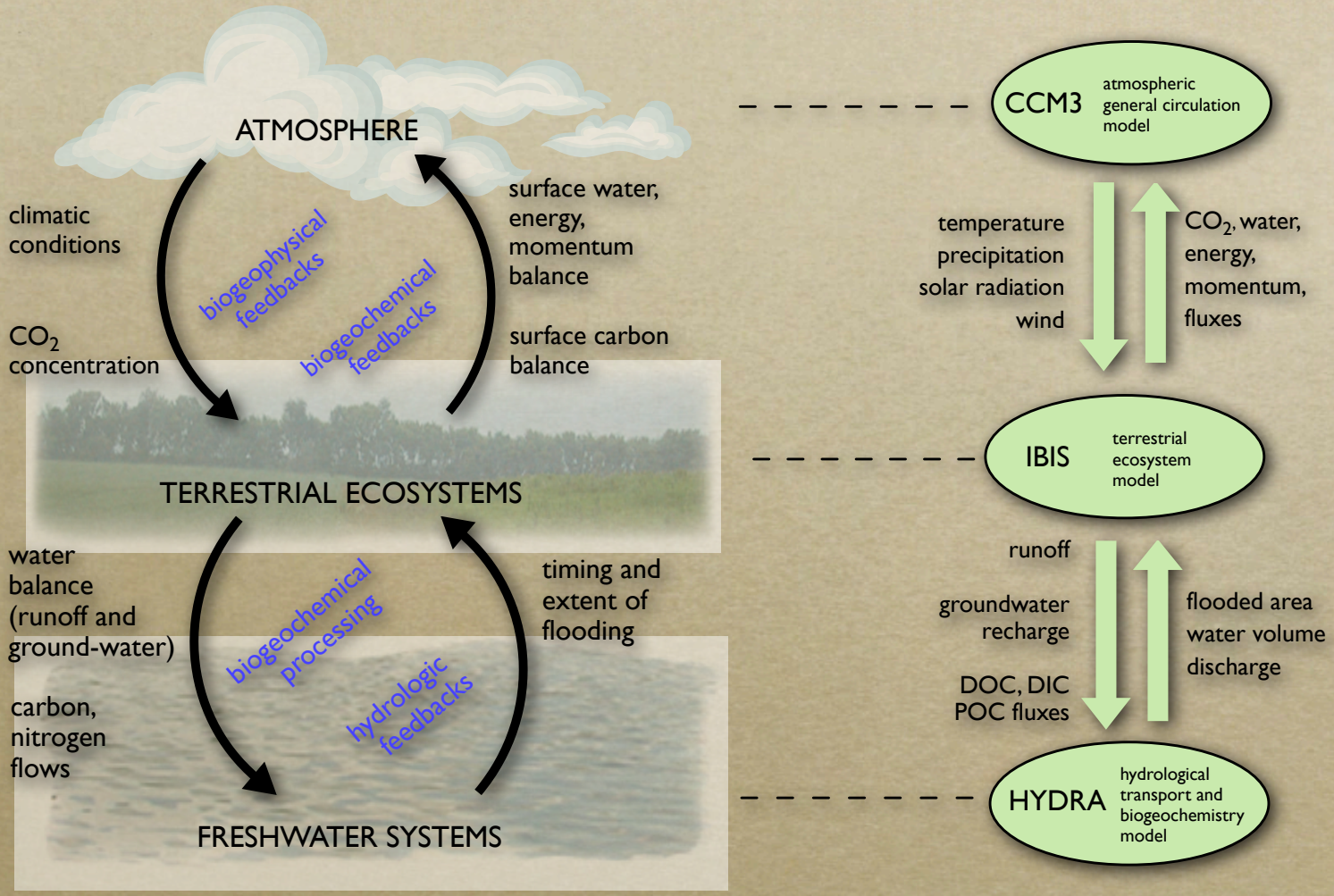
e.g., Coupled Earth System Model

from *Climate Change* to *Land Use Change*...



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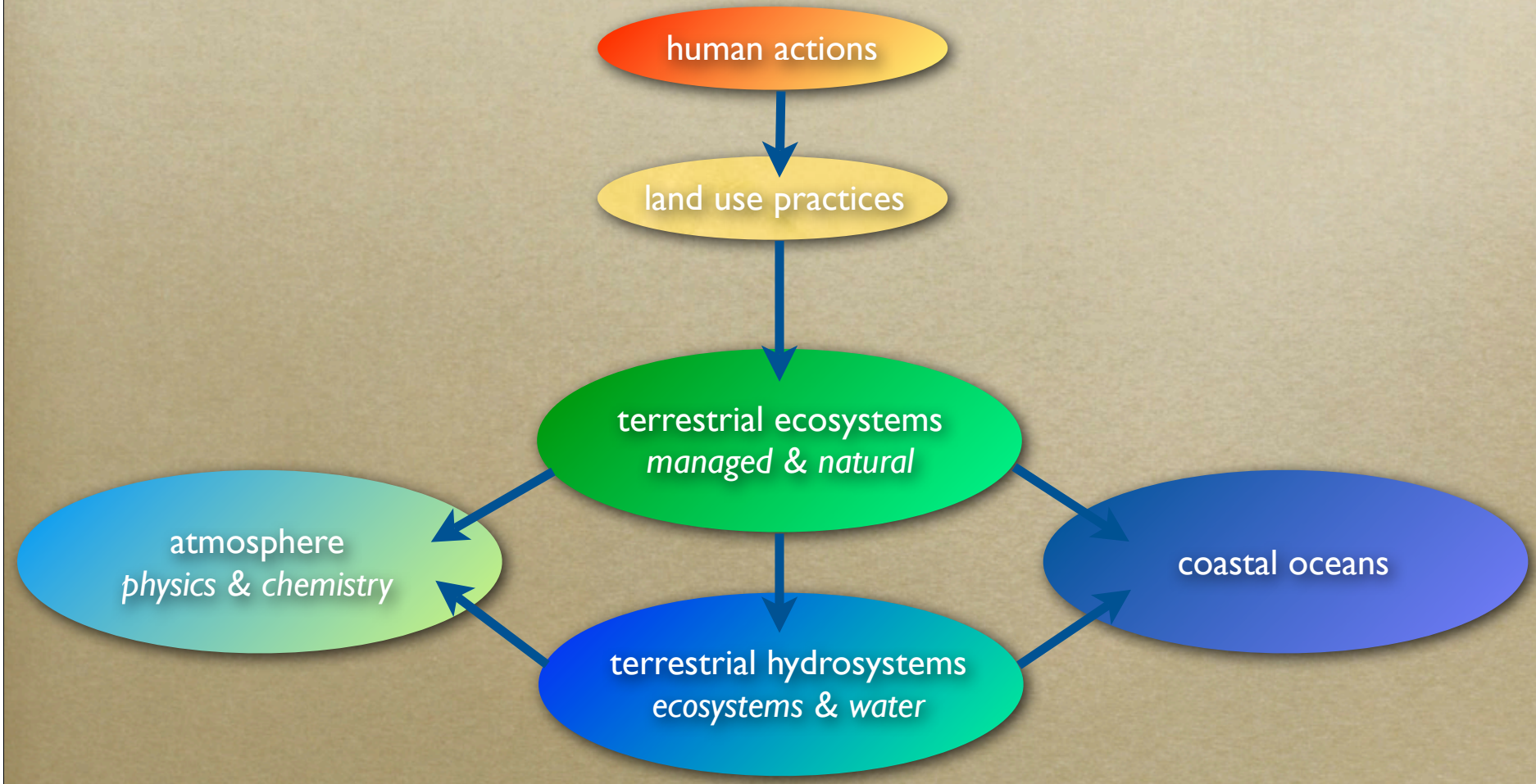
Different Conceptual Framework



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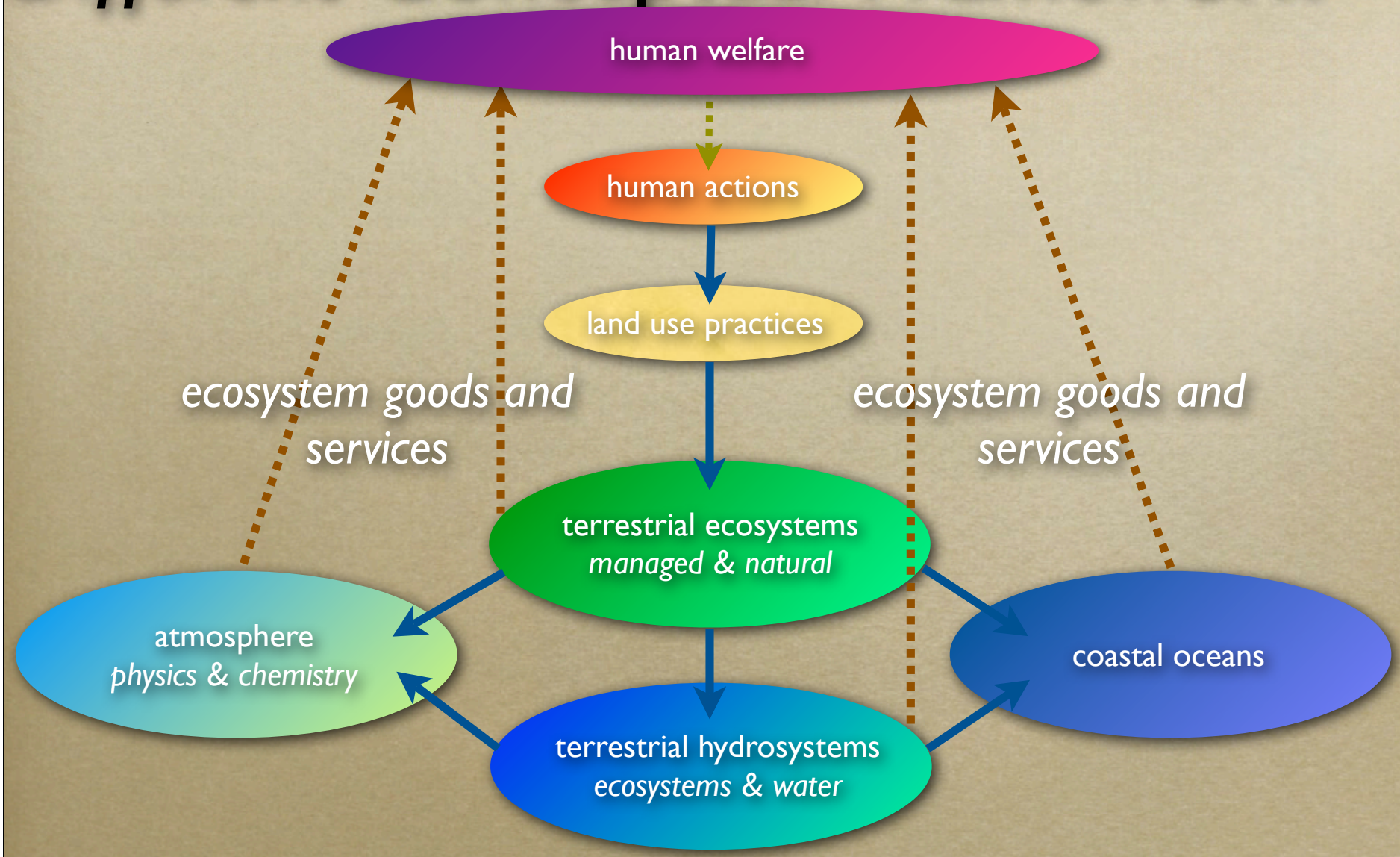
Different Conceptual Framework



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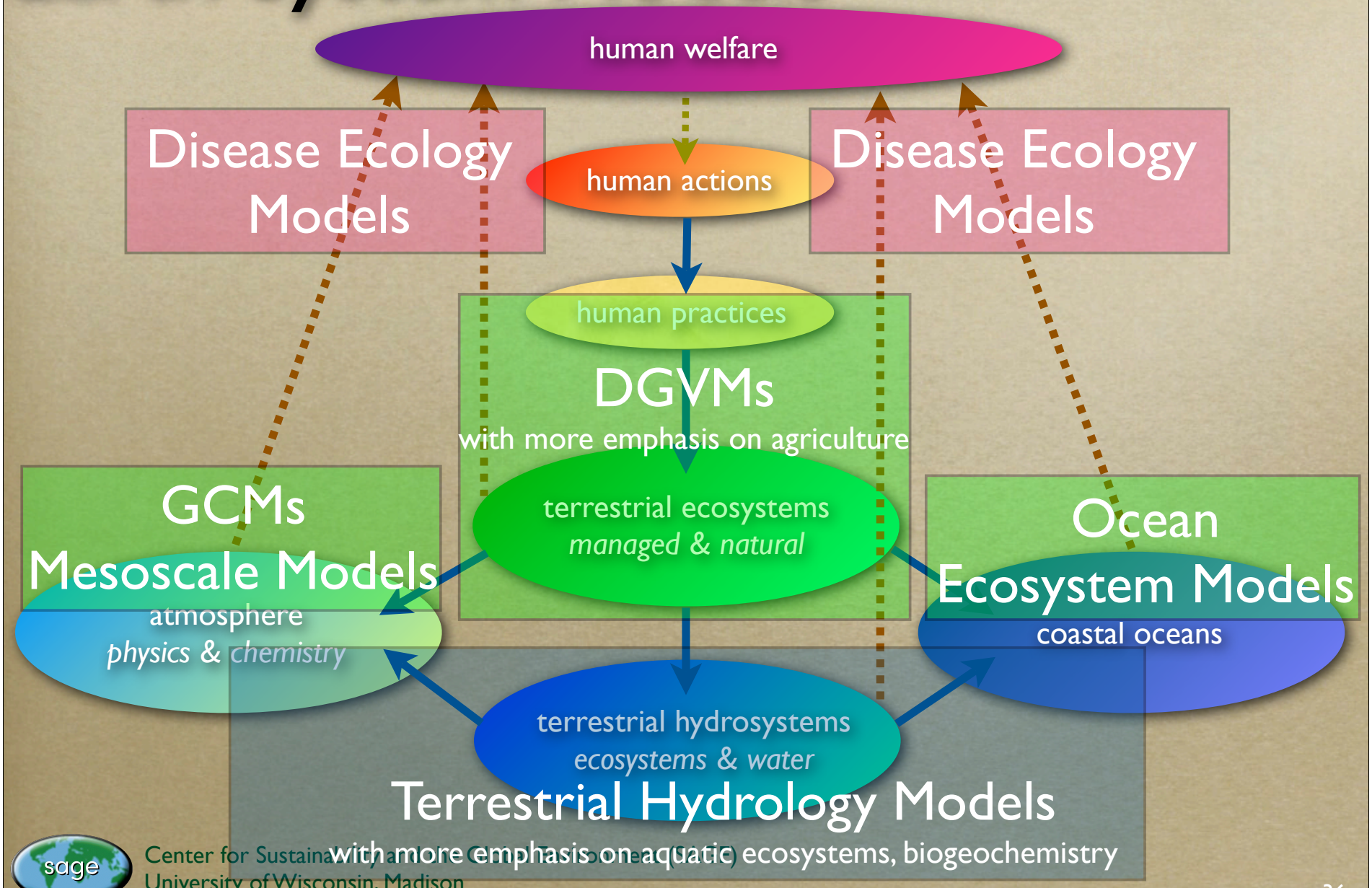
Earth System Models



3 Things to Remember

Agriculture is a Major Planetary Force

It's Critical to Bridge Local to Global Scales, Natural & Social Data

Useful to Refocus Earth System Models on Ecosystem Services and Human Needs


Thank You!