Planet Against the Grain

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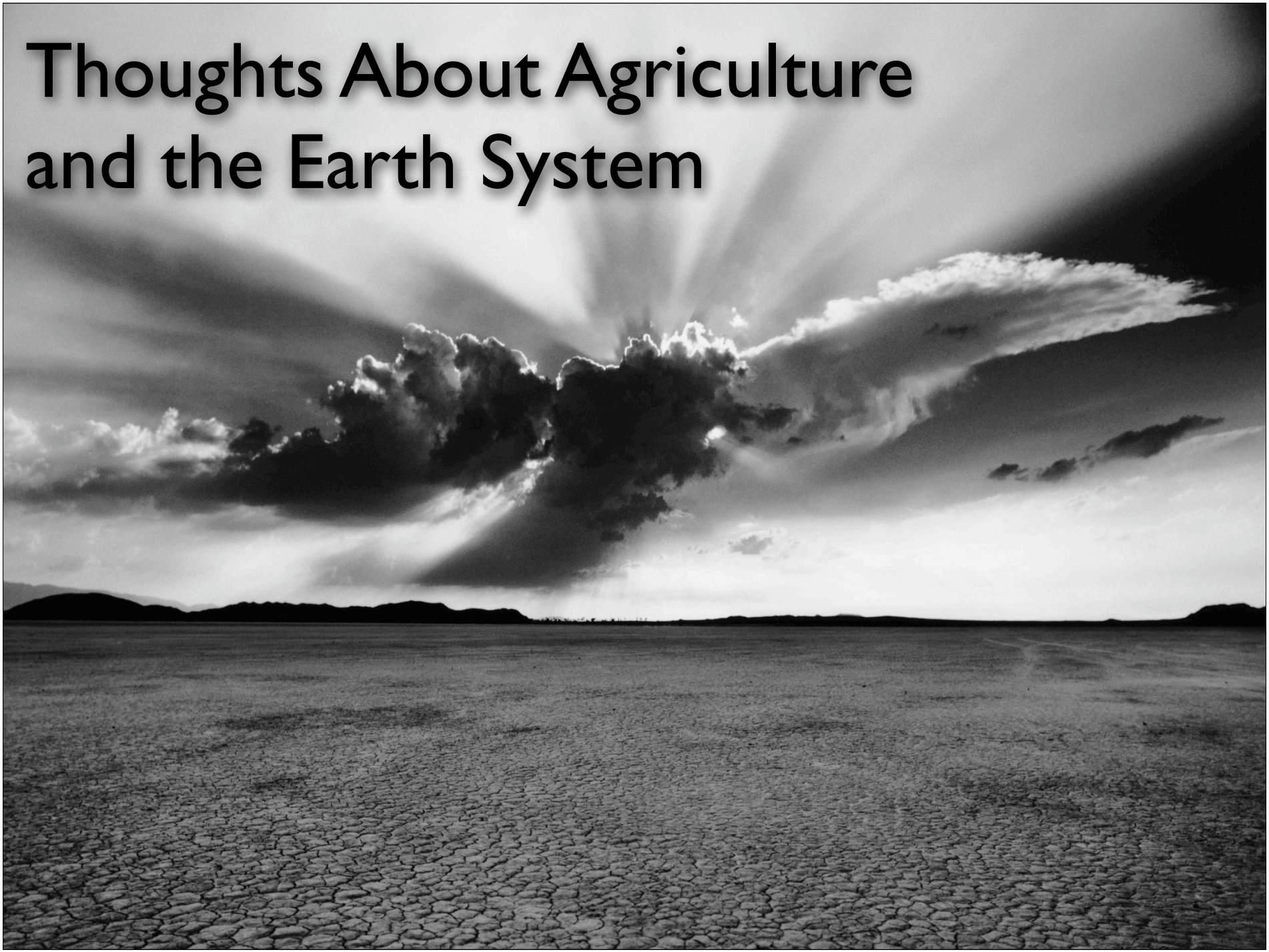
Center for Sustainability and the Global Environment (SAGE)
University of Wisconsin

NASA LCLUC Meeting
April 2007

Thoughts About Agriculture and the Earth System



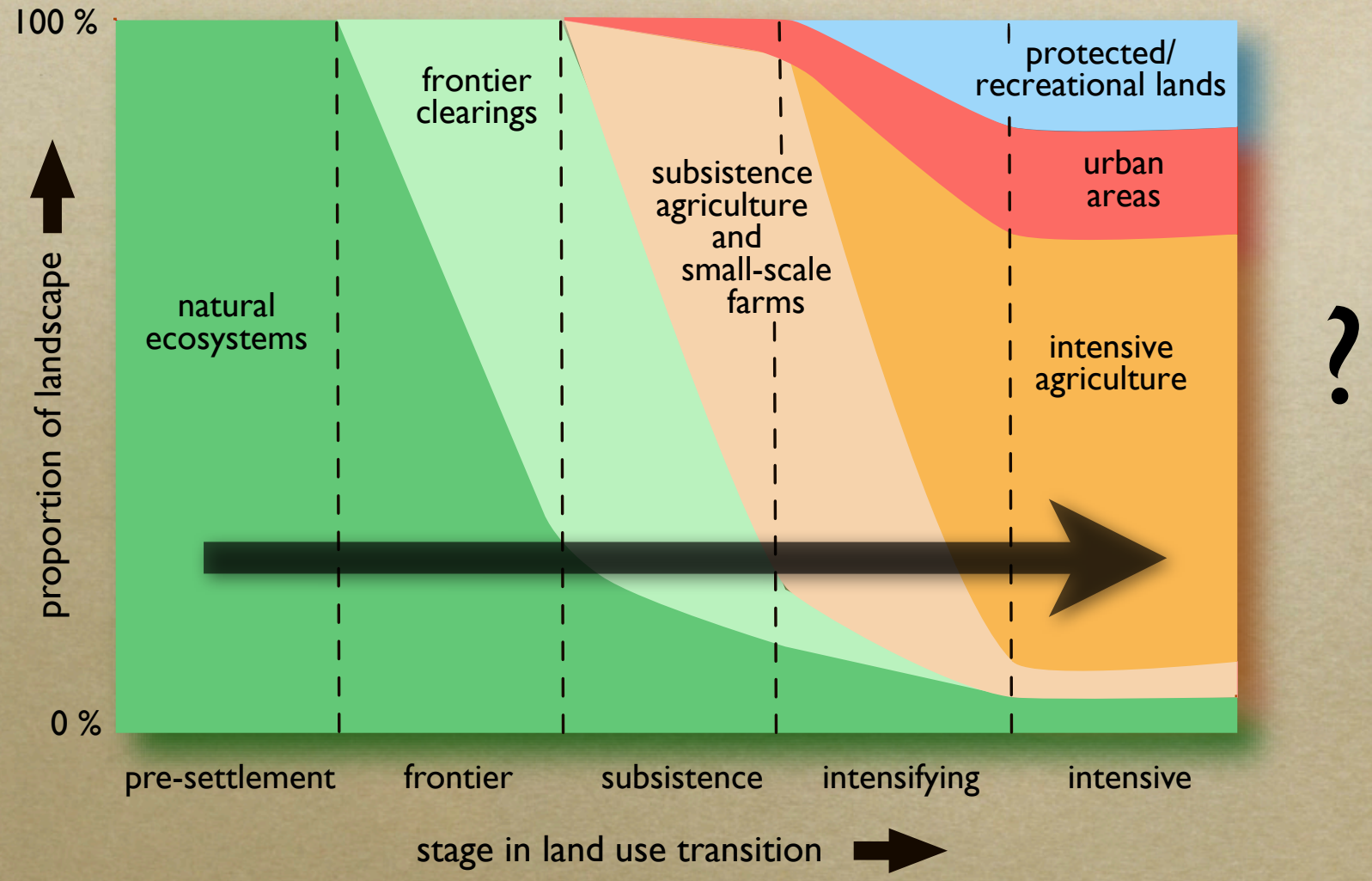
Global Change, So Far

Agriculture

Climate Change


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

Repeating Pattern Across Globe



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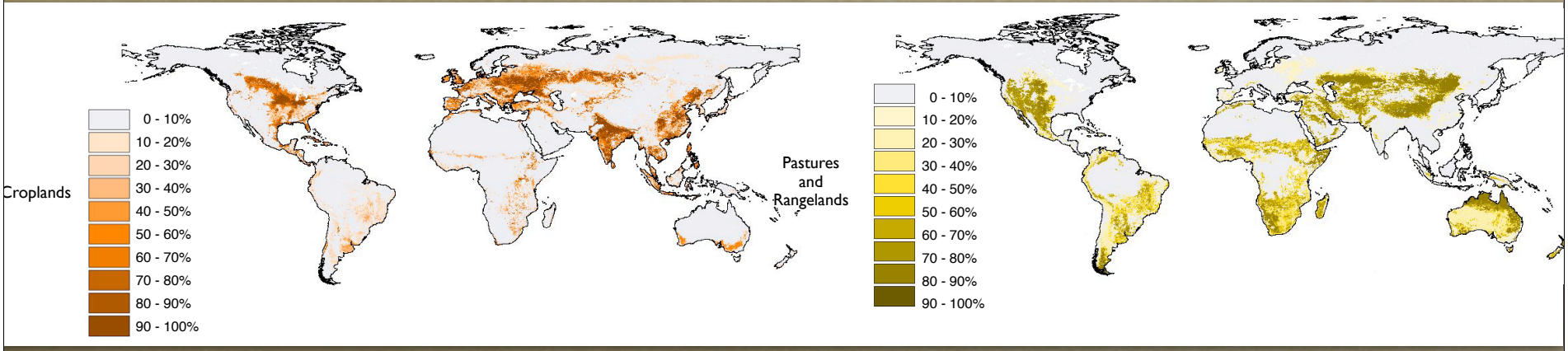
Adapted from: Foley et al., Science, 2005

I) Land Clearing / Degradation

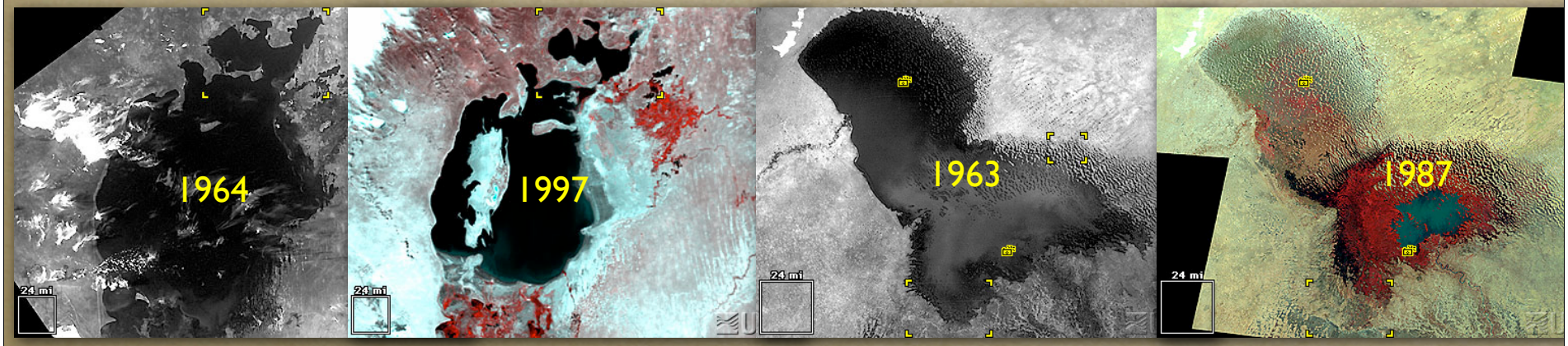
- *massive* changes to Earth's land
  - *~40% of land converted to agriculture*
    - *~18 million km^2 in crops*
    - *~30 million km^2 in pastures, rangeland*
  - *today, ~40% of global photosynthesis now in human hands*



Foley et al., Science, 2005; Ramankutty et al., in prep

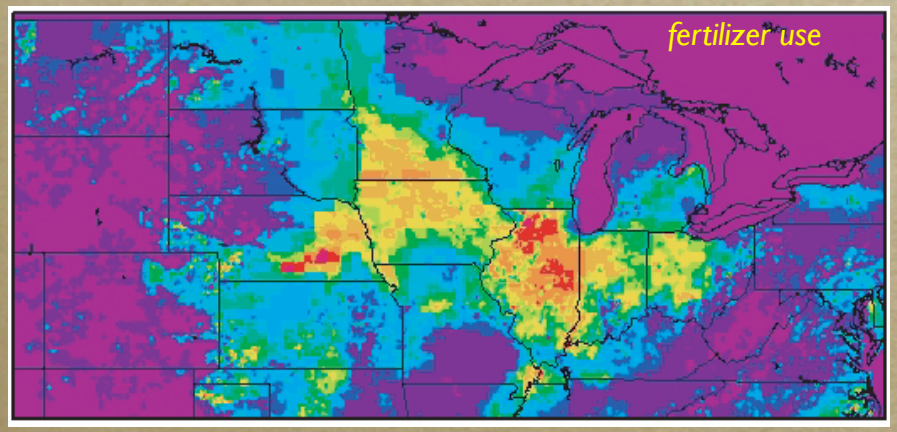
2) Water Degradation

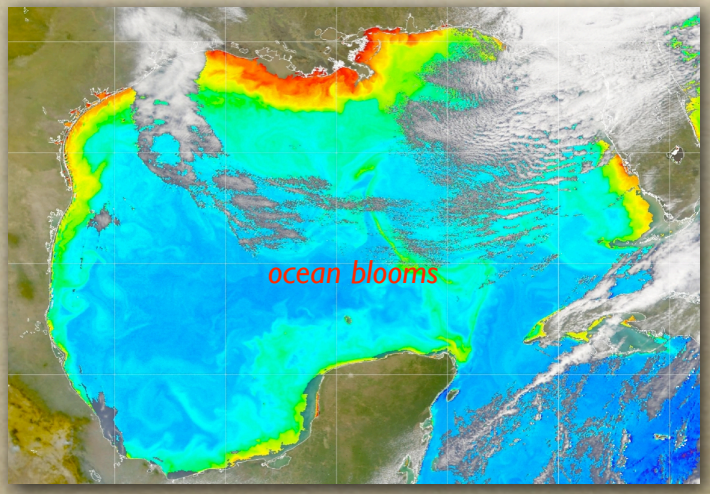
- *massive* increases in water use
  - *water use tripled in 50 years*
  - *mostly due to agriculture*
    - *70% irrigation, 20% industry, 10% domestic*
  - *~50% of available freshwater flow already co-opted*
    - *result: dry rivers, groundwater depletion*



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...

Important Point

- agriculture has already altered the biosphere as much as projections of future climate change...

- but now they're happening together...

Describing Global Agriculture

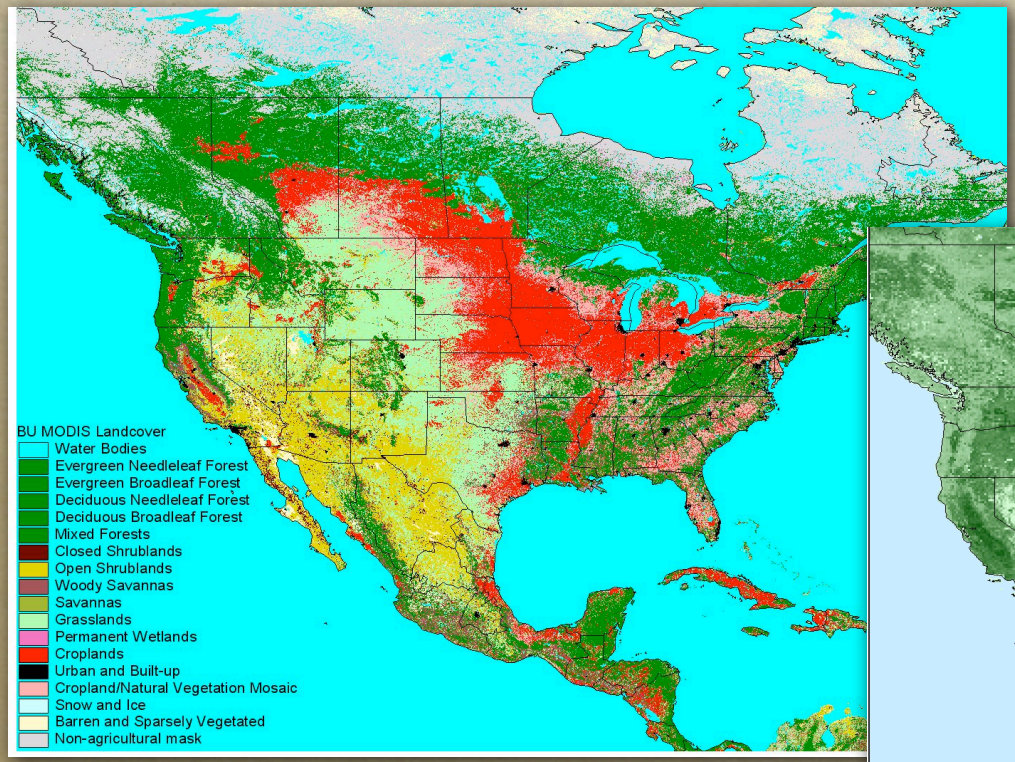
We Know the Global Patterns of Agriculture

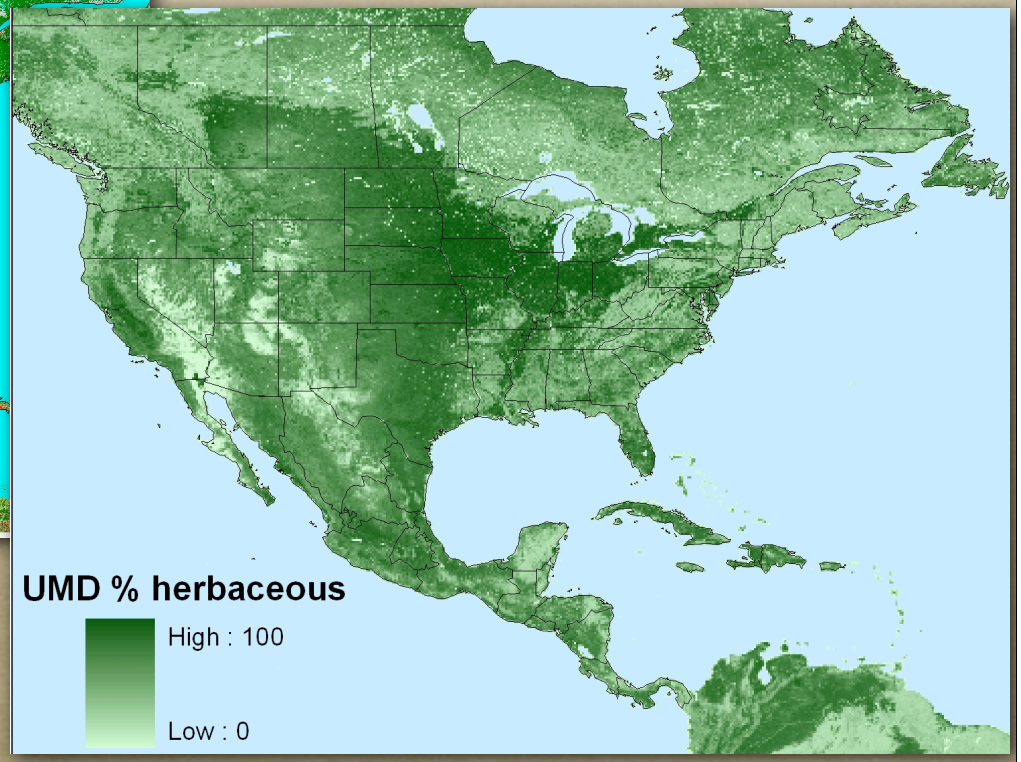
Right?

Well, Not Really...

Global Satellite Data

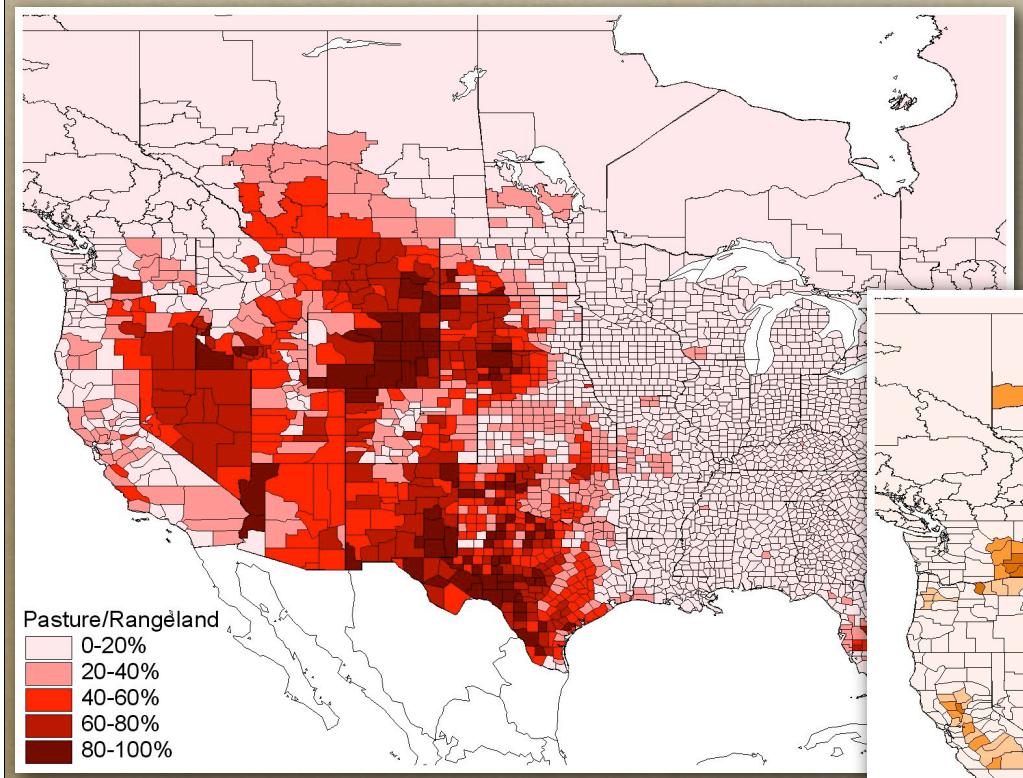
describes agricultural extent, but not much else...



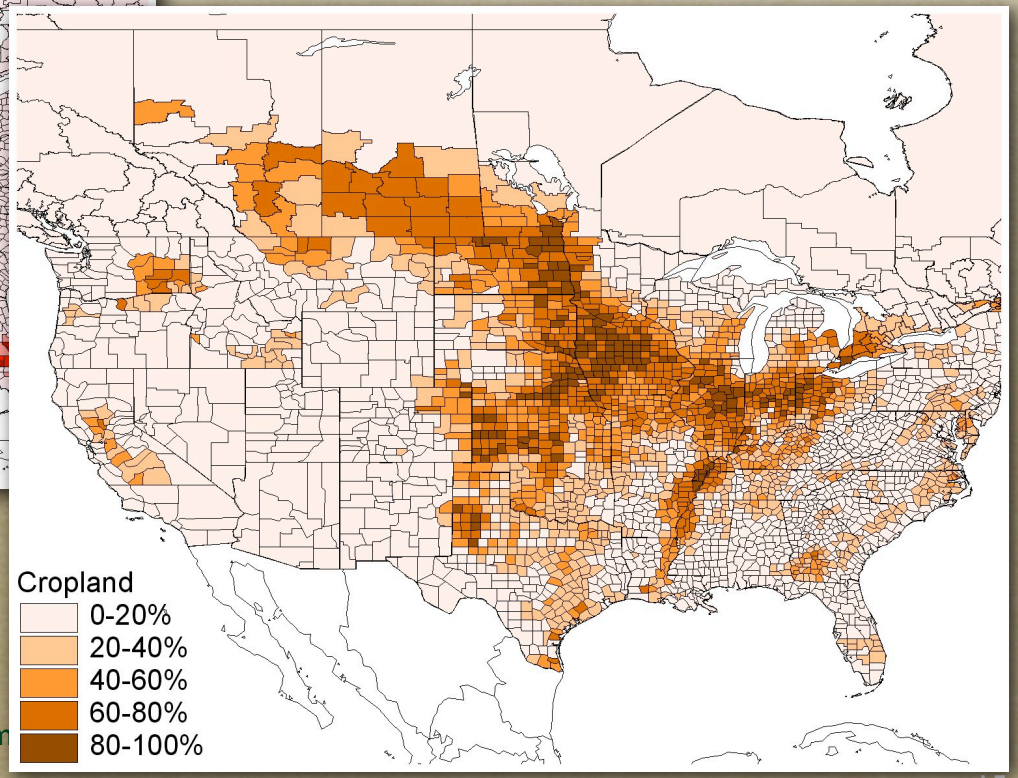


Possible to Learn More?

blending biophysical & social data



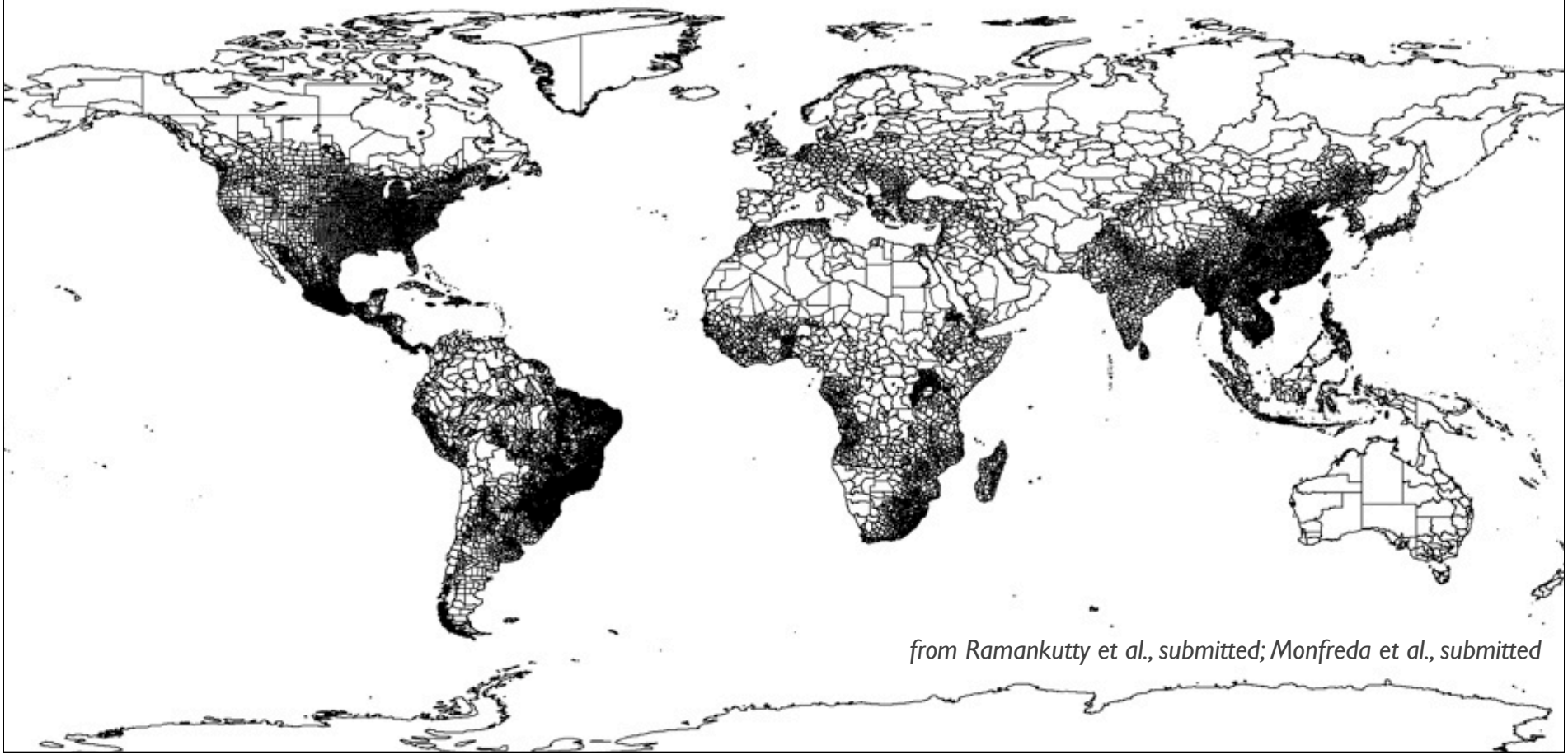
follow Ramankutty Method -- statistically "fuse" census and satellite datasets



Global Census Data

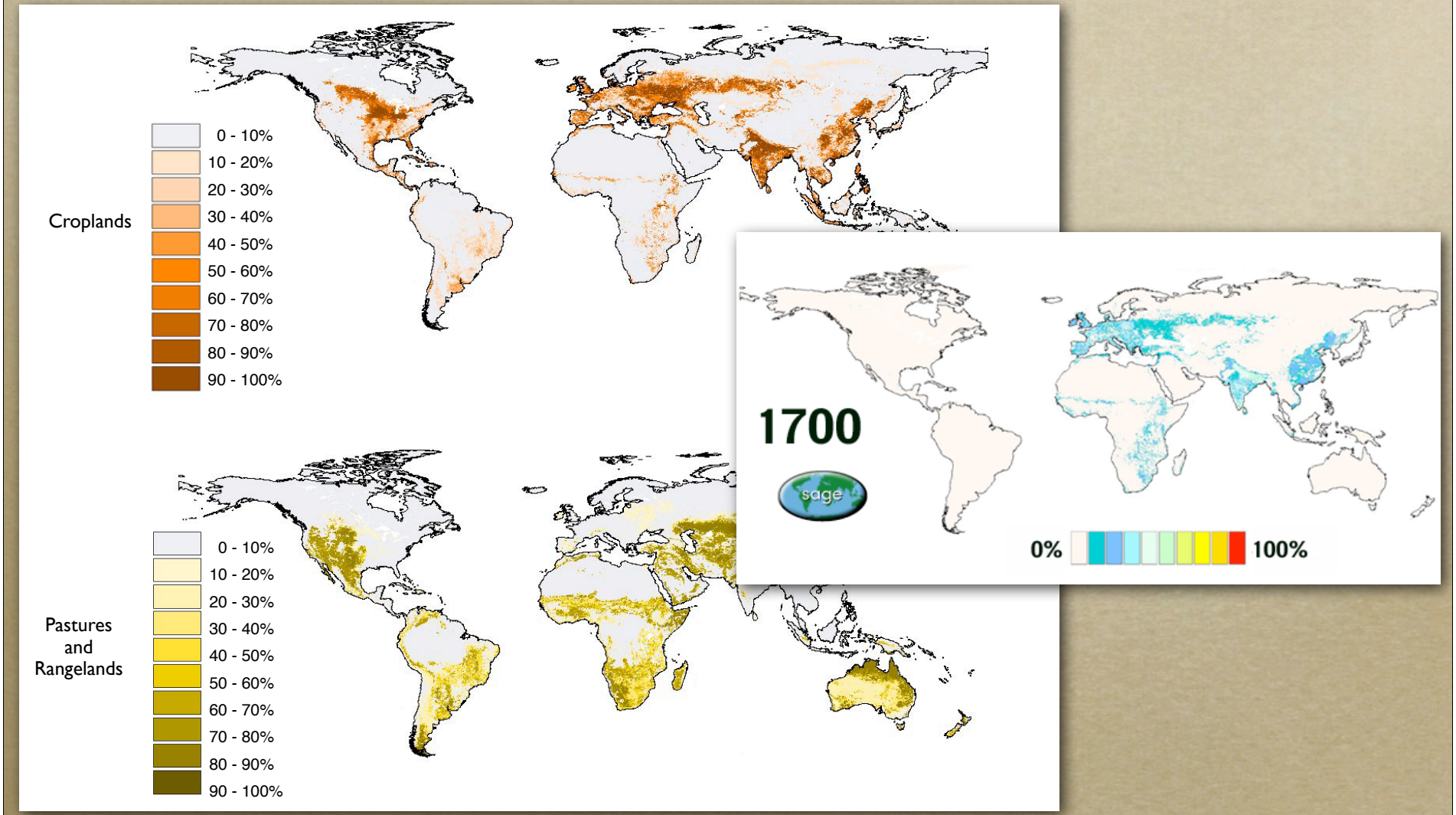
2,299 state / provincial units
and 19,751 county / district units

total of 22,050 census units



from Ramankutty et al., submitted; Monfreda et al., submitted

Global Agricultural Lands



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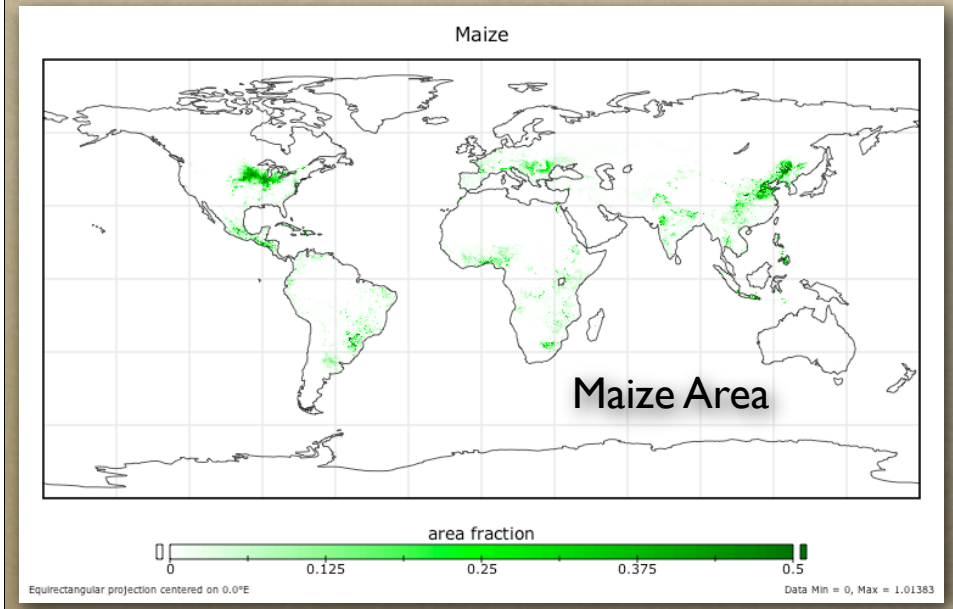
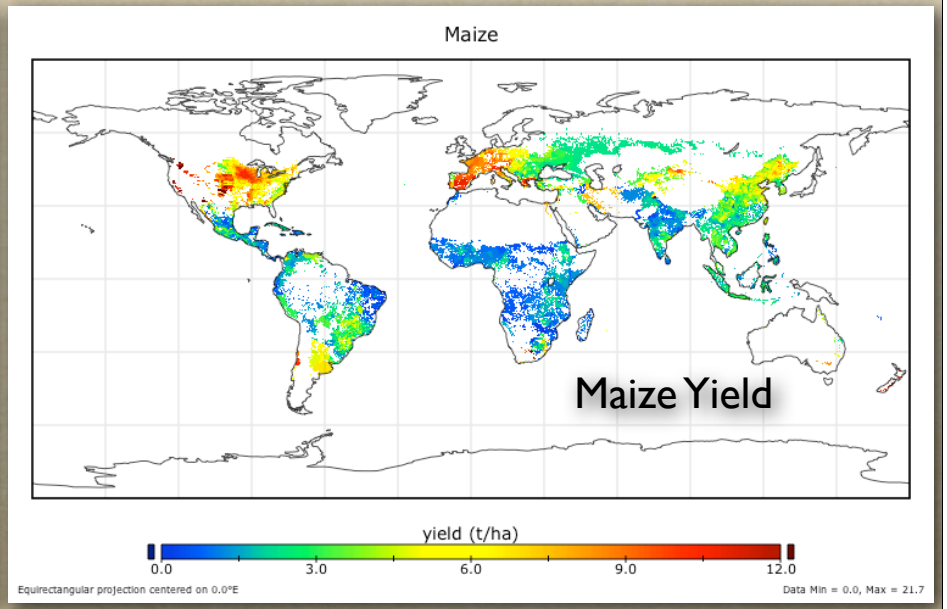
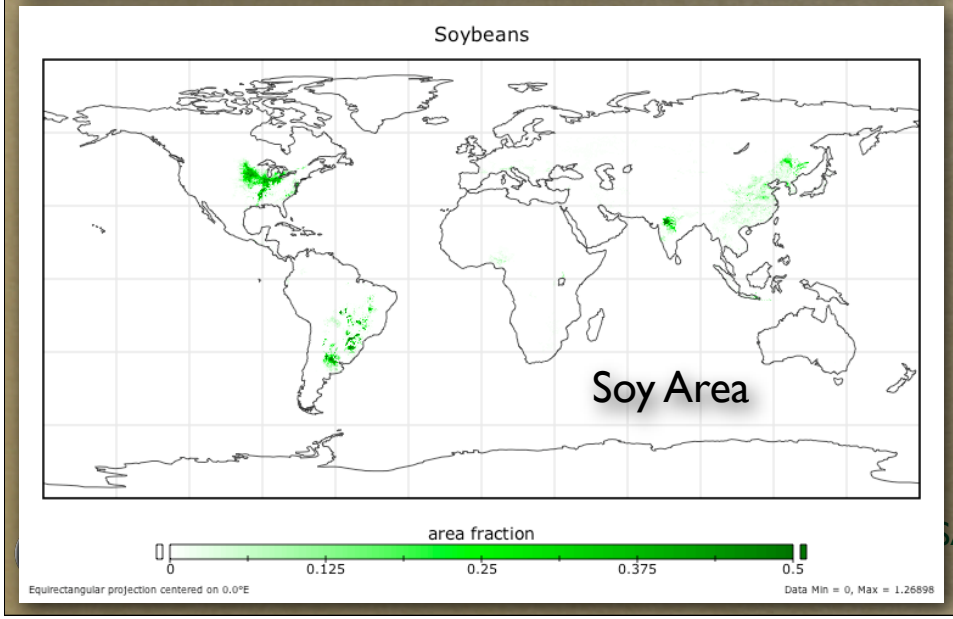
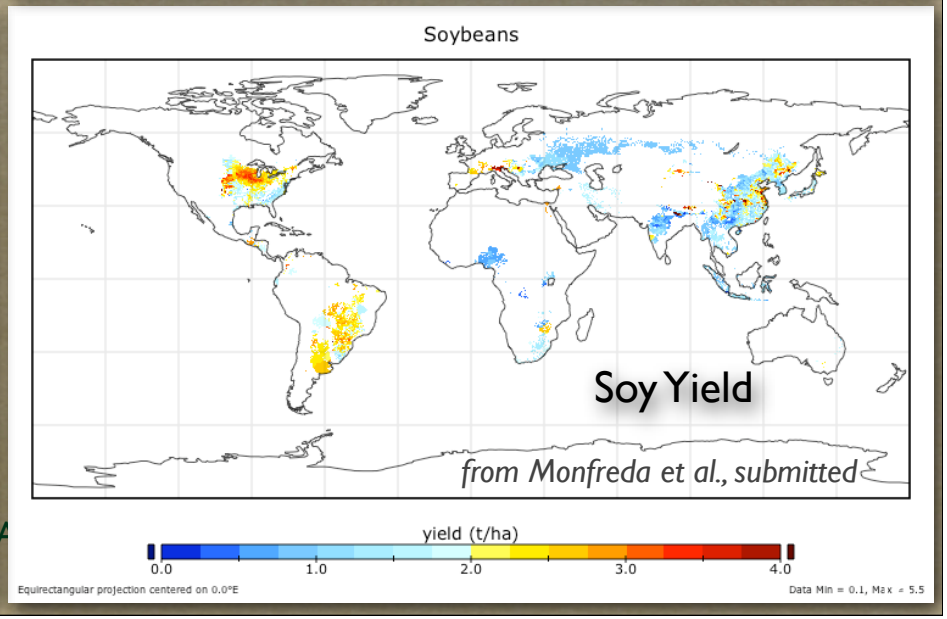
from Foley et al., Science, 2005; Ramankutty and Foley, 1999; movie from www.sage.wisc.edu

Individual Crops









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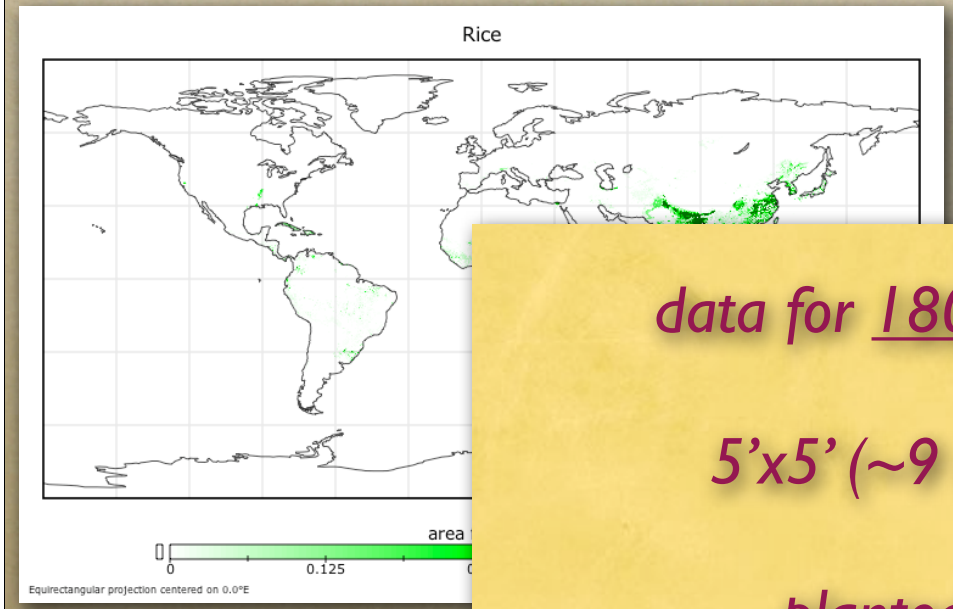
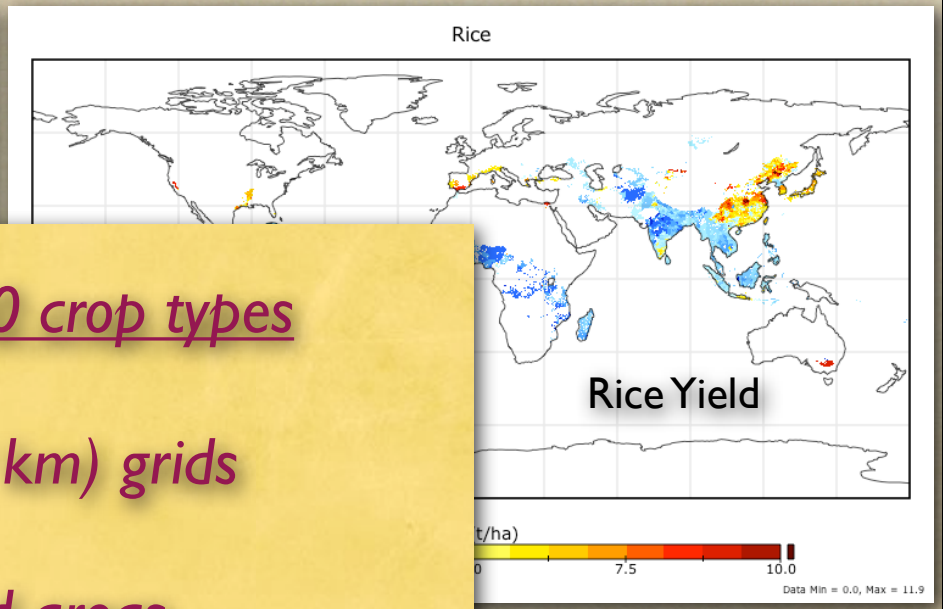
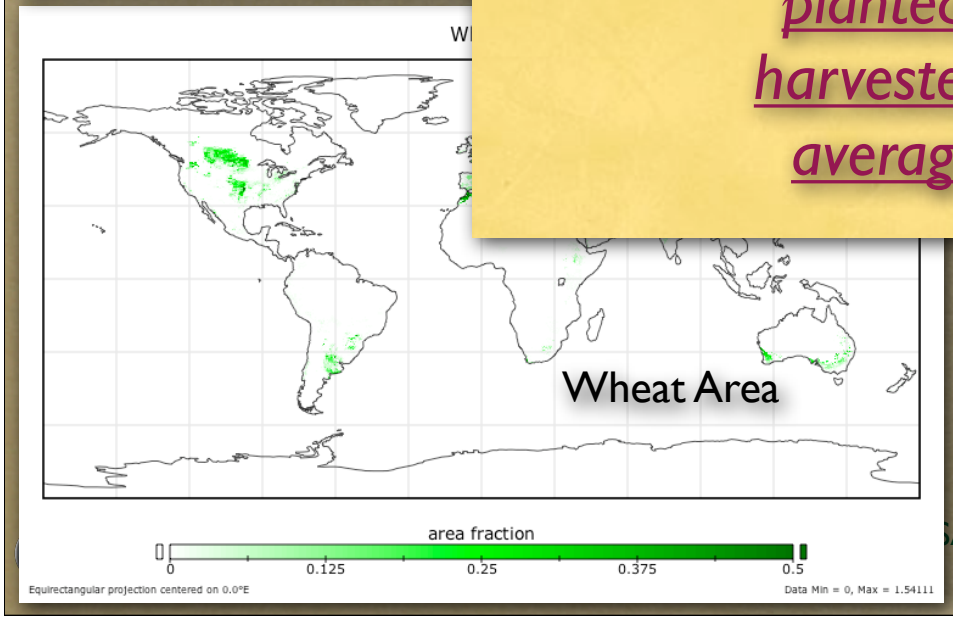


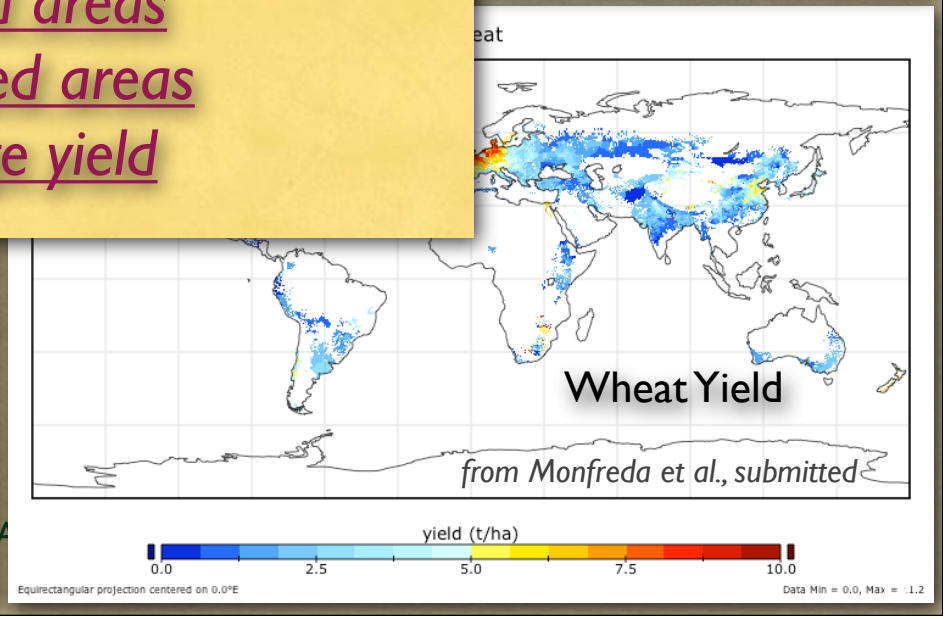


data for 180 crop types

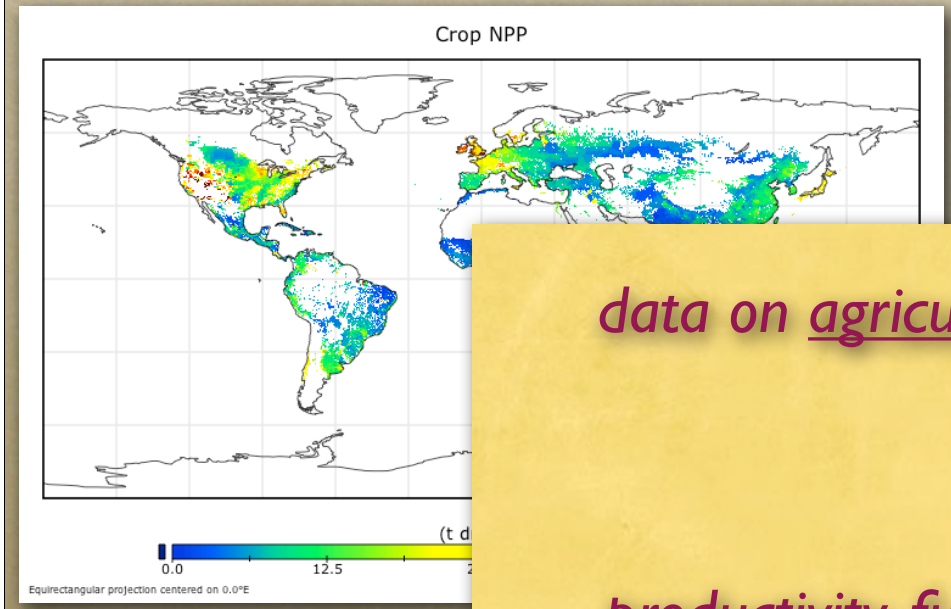
5'x5' (~9 km) grids

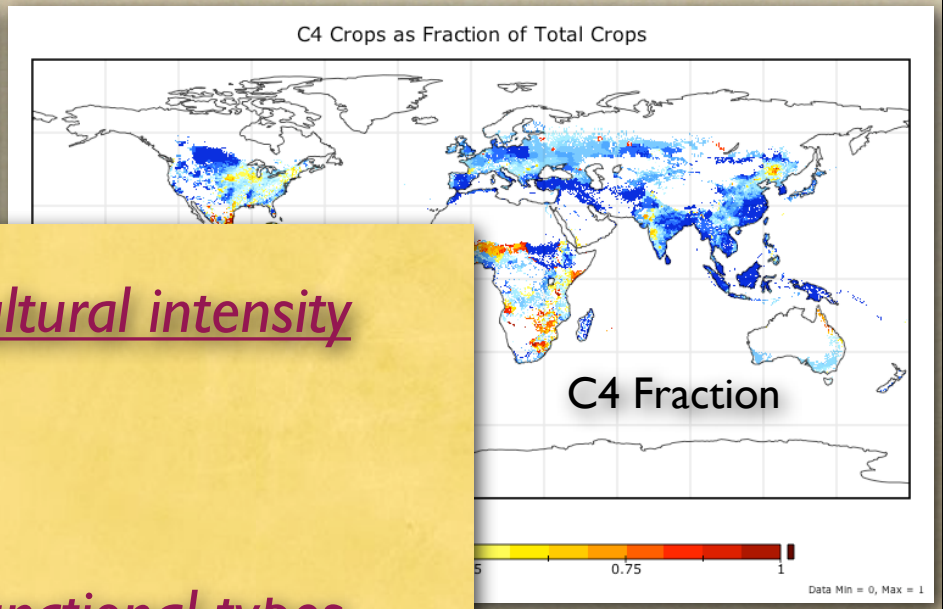
planted areas
harvested areas
average yield





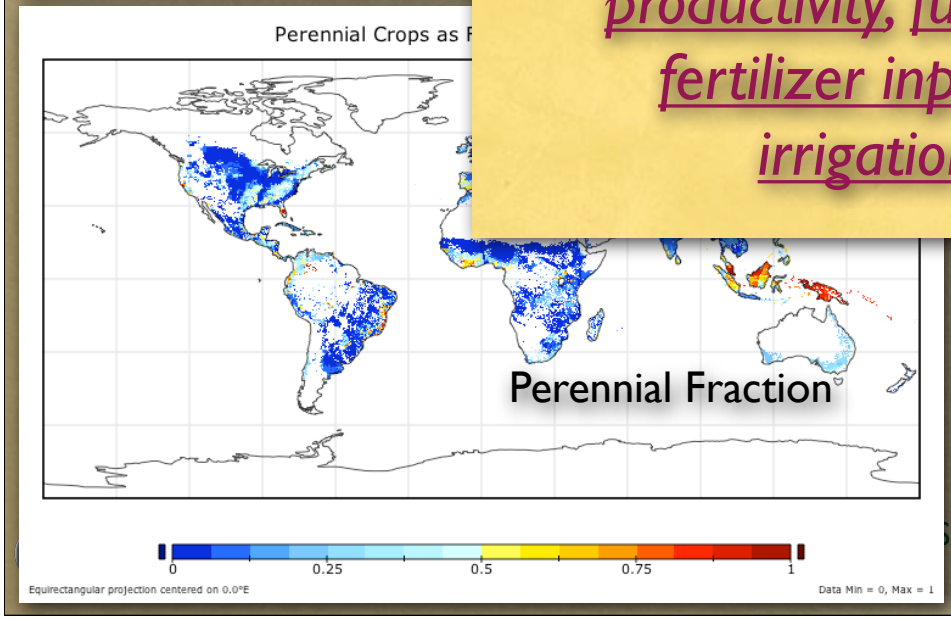
Agricultural *Intensity*

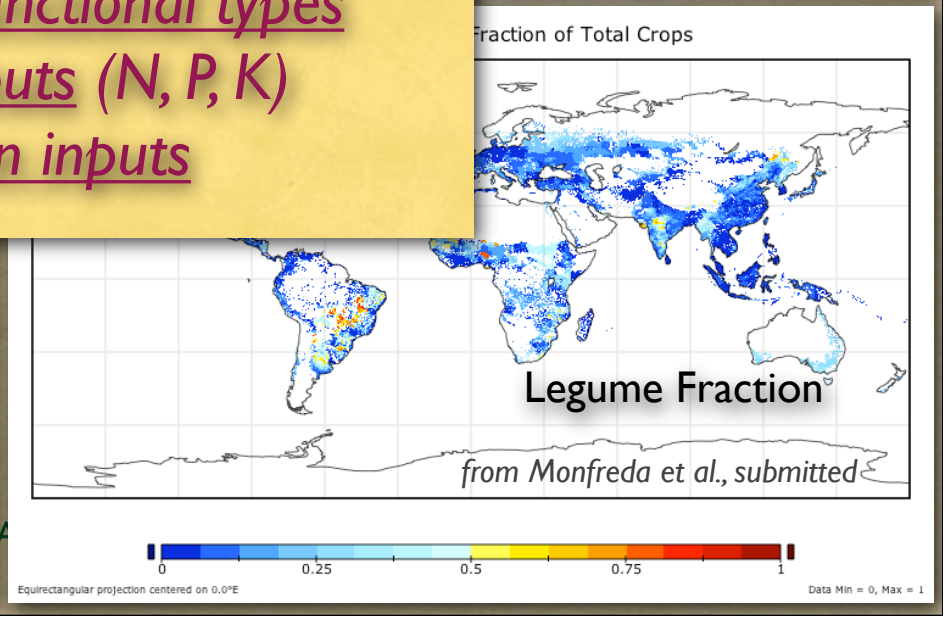




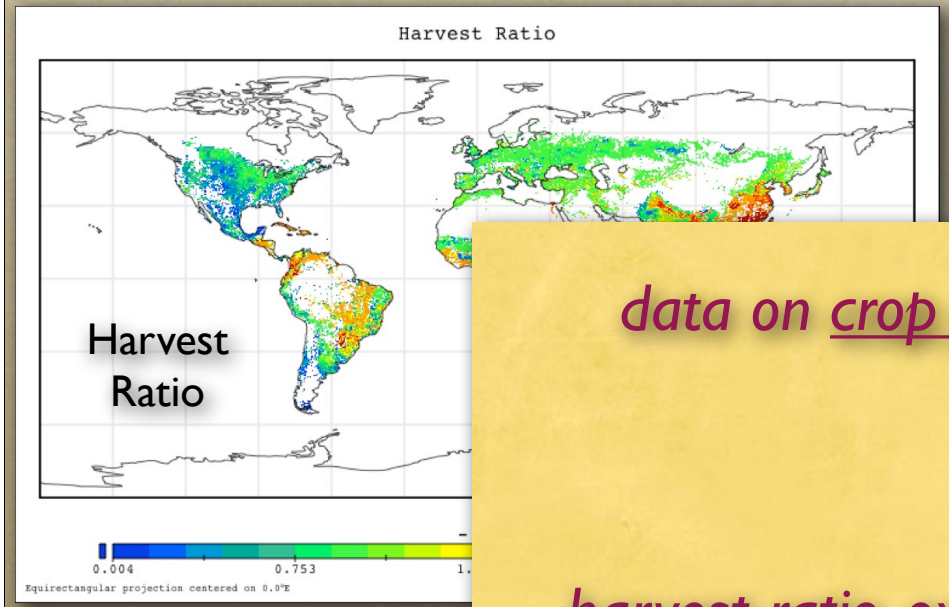
data on agricultural intensity

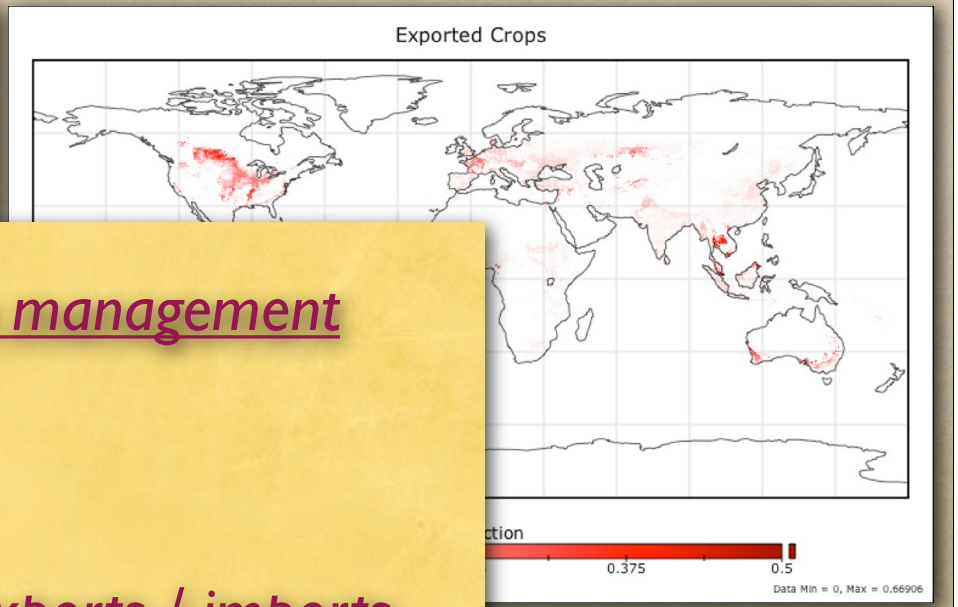
productivity, functional types
fertilizer inputs (N, P, K)
irrigation inputs





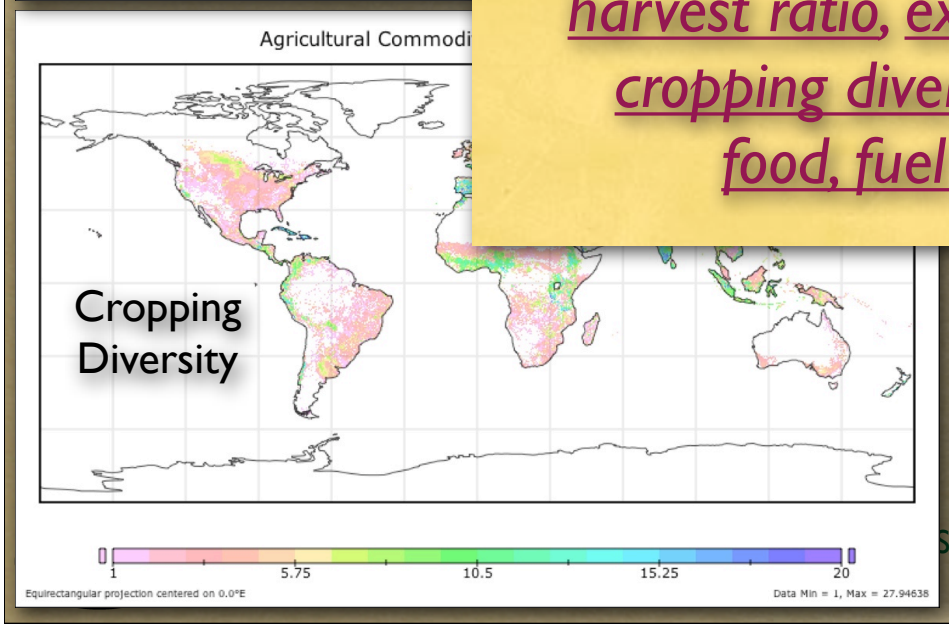
Agricultural *Management*

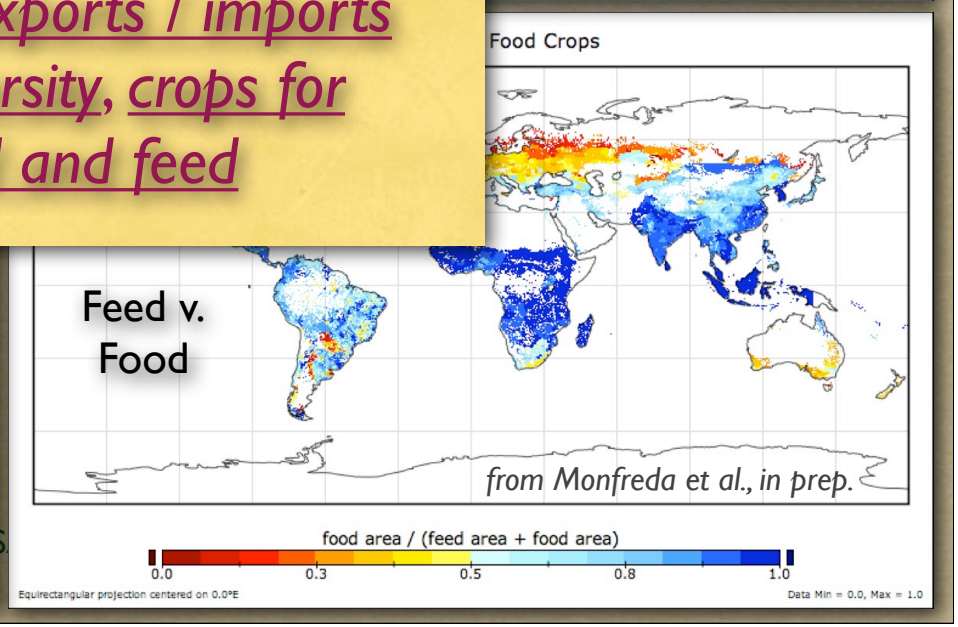




data on crop management

harvest ratio, exports / imports
cropping diversity, crops for food, fuel and feed





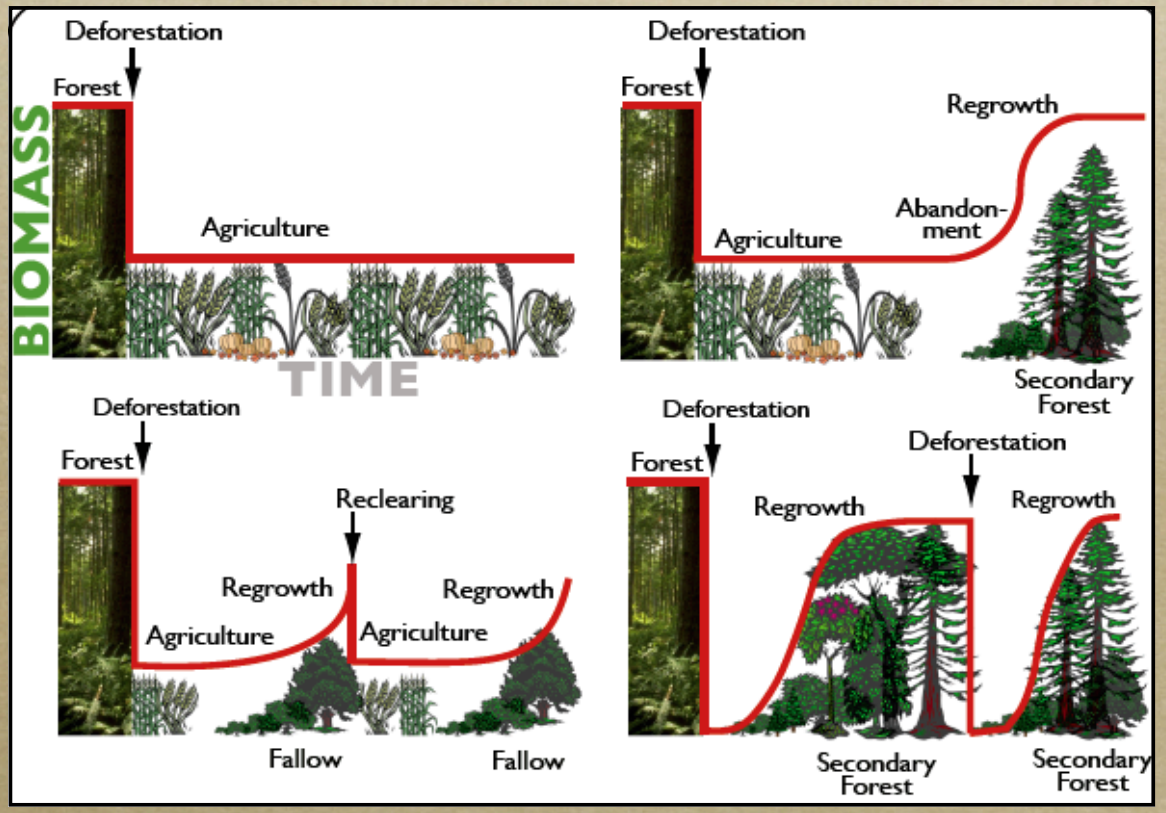
We Know the Global Patterns of Deforestation

Right?

Well, Not Really...

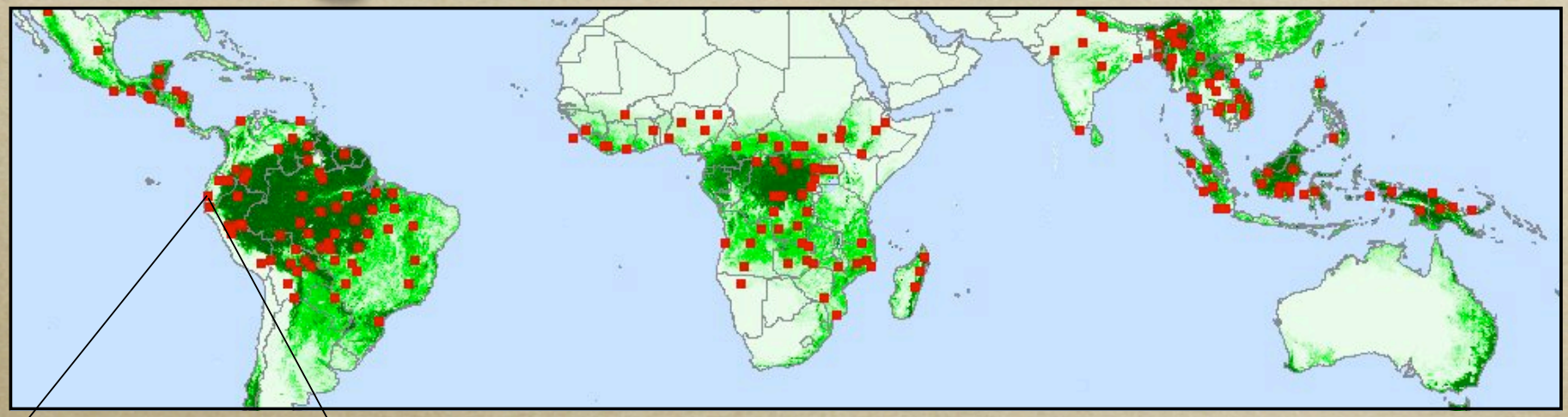
What Happens *Next*?

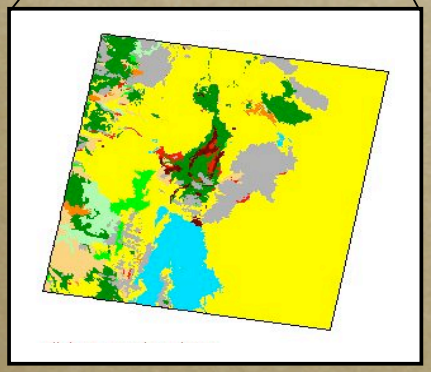
- fate of the cleared land?
- critical to many questions
  - *carbon release, uptake*
  - *forest management*
  - *food systems*
  - *biodiversity*



Ramankutty et al., 2007

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

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Gibbs et al., in prep.

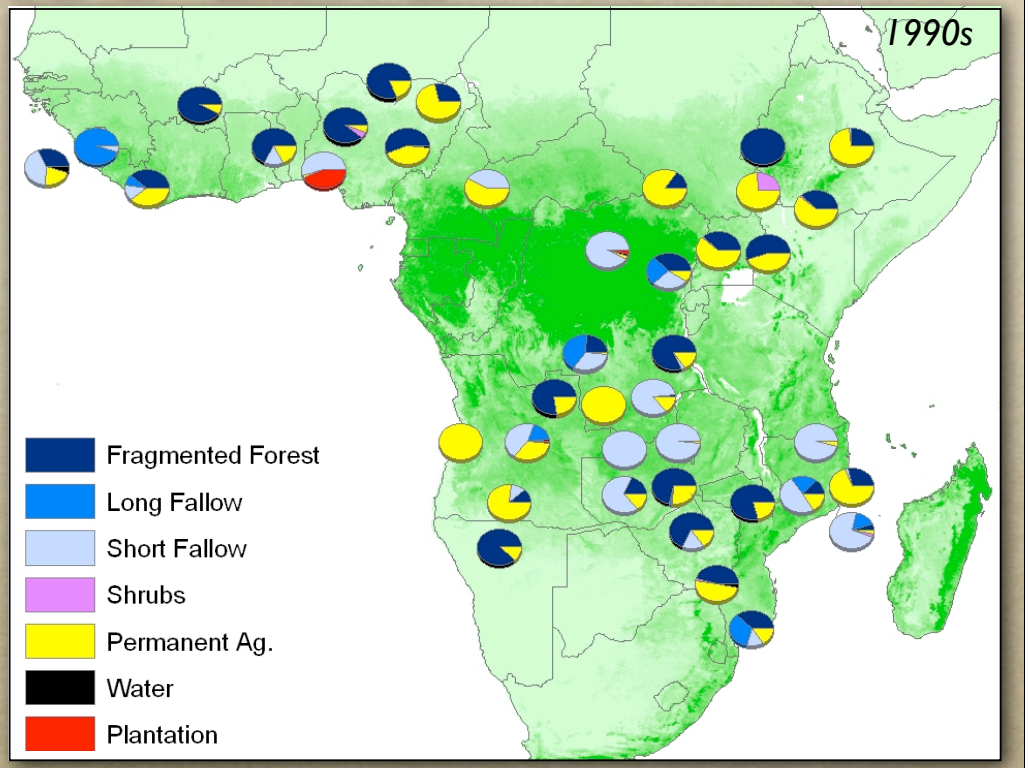
Fate of Deforested Land

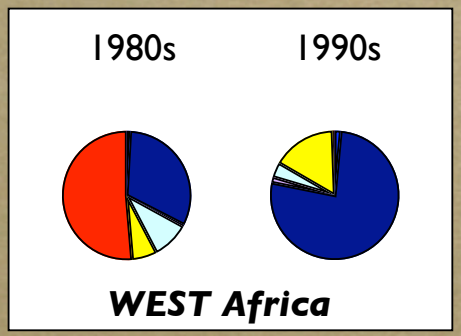
All Regions → Fragmented forest increased

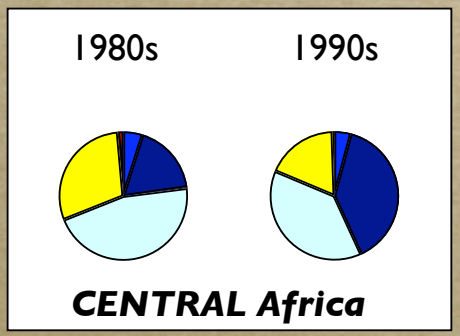
West Africa → Permanent agriculture increased while plantations decreased

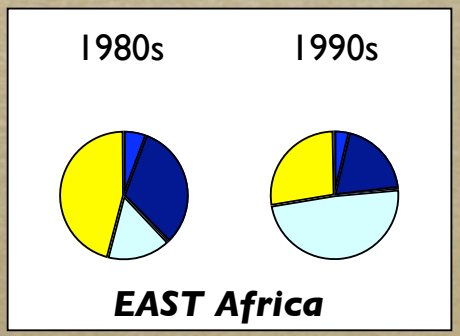
East Africa → Permanent agriculture decreased while short fallow increased

Central Africa → remained stable









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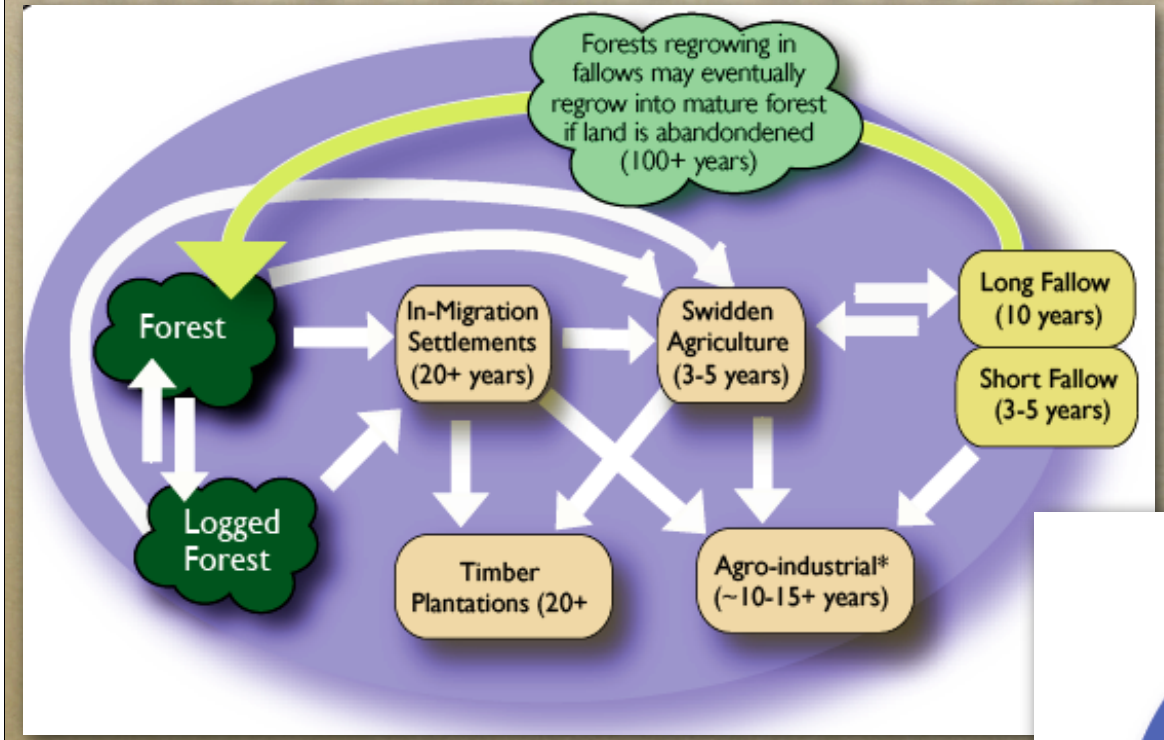
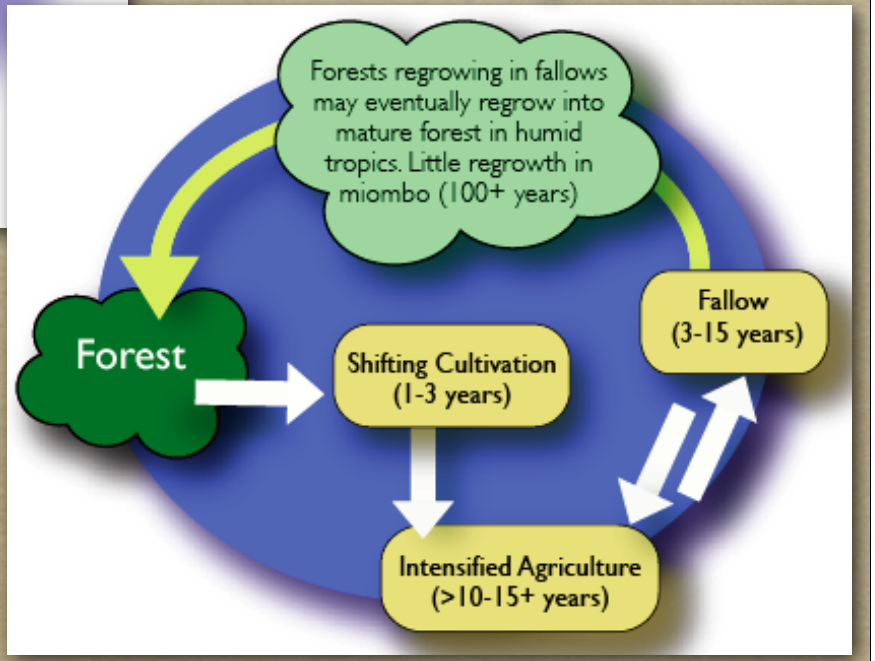
Fate of Deforested Land



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.

Lessons

Lesson #1

- fact: *agricultural areas* have expanded
  - *in past 40 years, area increased by ~12%*
- fact: *agricultural intensification* has been far larger
  - *in past 40 years, irrigated land increased by ~70%*
  - *fertilizer use increased ~700%*
  - *dramatic loss of cropping diversity*
- current approaches are inadequate
  - *global data products & models basically ignore this*
- need to focus on land use practices and agricultural management

Lesson #2

- fact: *forest area* has declined
- fact: *fate of deforested lands* is also changing
  - *shortening fallow cycles*
  - *more permanent clearings*
- current approaches are inadequate
  - *global data products & models basically ignore this*
- need to focus on fates of deforestation

Lesson #3

- key point: *land use practices are changing quickly; much more than changing land cover*
- massive shifts in the coming years...
  - *increasing biofuels (maize, sugarcane, oil palm, ...)*
  - *increasing demands for animal feed*
  - *increasing participation in global markets*
- **throw all of our old assumptions about land use / land cover change out the window...**

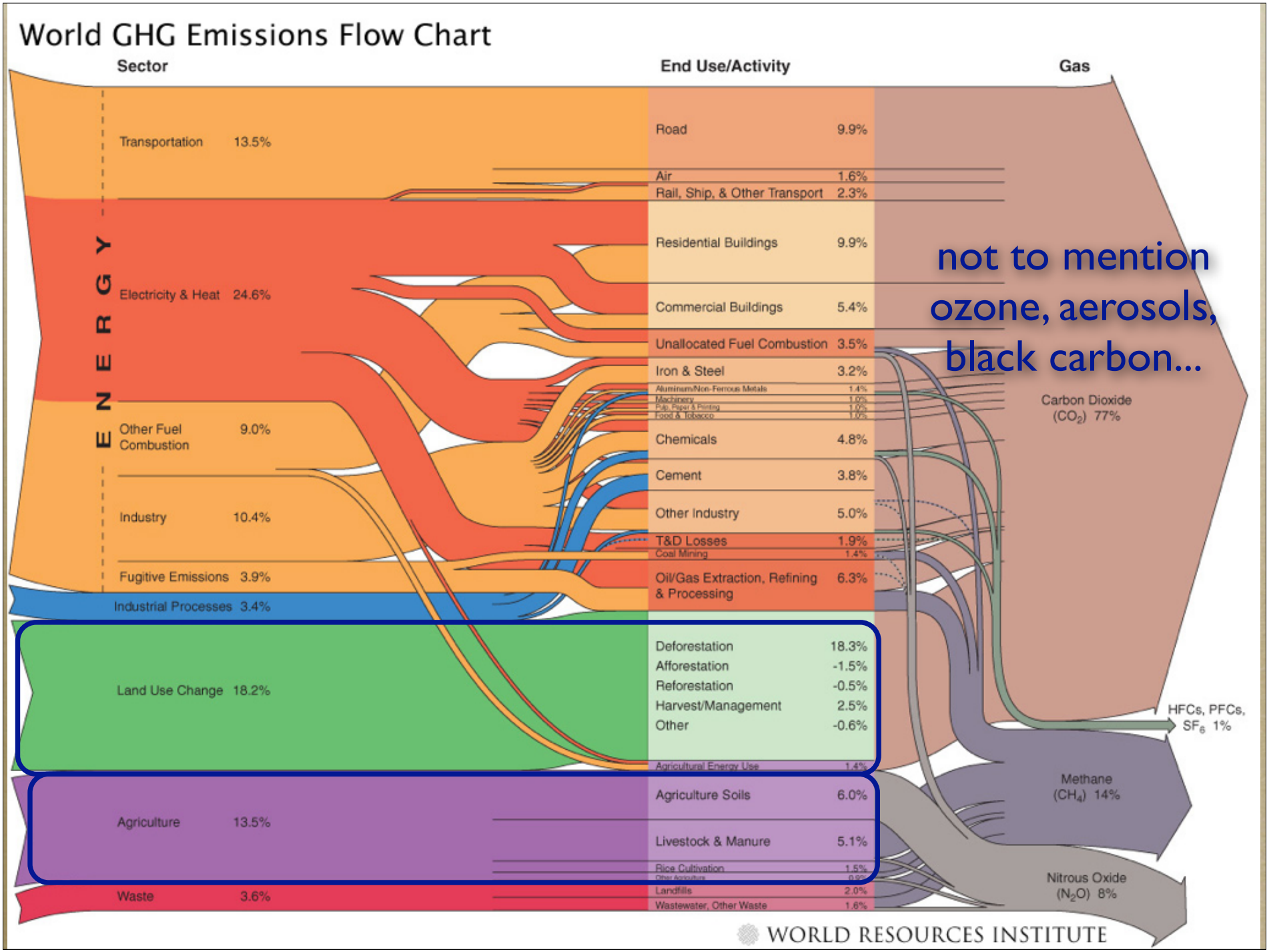
Exploring *Consequences* of Land Use

Land Use Consequences

Greenhouse Gases

"It's the *Emissions*, Stupid..."

sinks are important, but emissions are much larger, and more directly managed...


World GHG Emissions Flow Chart
Sector
End Use/Activity
Gas
ENERGY
Transportation 13.5%
Electricity & Heat 24.6%
Other Fuel Combustion 9.0%
Industry 10.4%
Fugitive Emissions 3.9%
Industrial Processes 3.4%
Land Use Change 18.2%
Agriculture 13.5%
Waste 3.6%
Road 9.9%
Air 1.6%
Rail, Ship, & Other Transport 2.3%
Residential Buildings 9.9%
Commercial Buildings 5.4%
Unallocated Fuel Combustion 3.5%
Iron & Steel 3.2%
Aluminum/Non-Ferrous Metals 1.4%
Machinery 1.0%
Pulp, Paper & Printing 1.0%
Food & Tobacco 1.0%
Chemicals 4.8%
Cement 3.8%
Other Industry 5.0%
T&D Losses 1.9%
Coal Mining 1.4%
Oil/Gas Extraction, Refining & Processing 6.3%
Deforestation 18.3%
Afforestation -1.5%
Reforestation -0.5%
Harvest/Management 2.5%
Other -0.6%
Agricultural Energy Use 1.4%
Agriculture Soils 6.0%
Livestock & Manure 5.1%
Rice Cultivation 1.5%
Other Agriculture 0.9%
Landfills 2.0%
Wastewater, Other Waste 1.6%
Carbon Dioxide (CO_2) 77%
HFCs, PFCs, SF_6 1%
Methane (CH_4) 14%
Nitrous Oxide (N_2O) 8%
not to mention ozone, aerosols, black carbon...
WORLD RESOURCES INSTITUTE

Points on Greenhouse Gases

- **wow!** global land use & agriculture, taken together, contribute more greenhouse gases than any single societal activity
  - *more than global transportation..*
  - *more than global electricity...*
  - *more than global heating...*
  - *more than global manufacturing...*
- altogether, agriculture and deforestation appear to contribute *at least* 1/3 of all GHG forcing

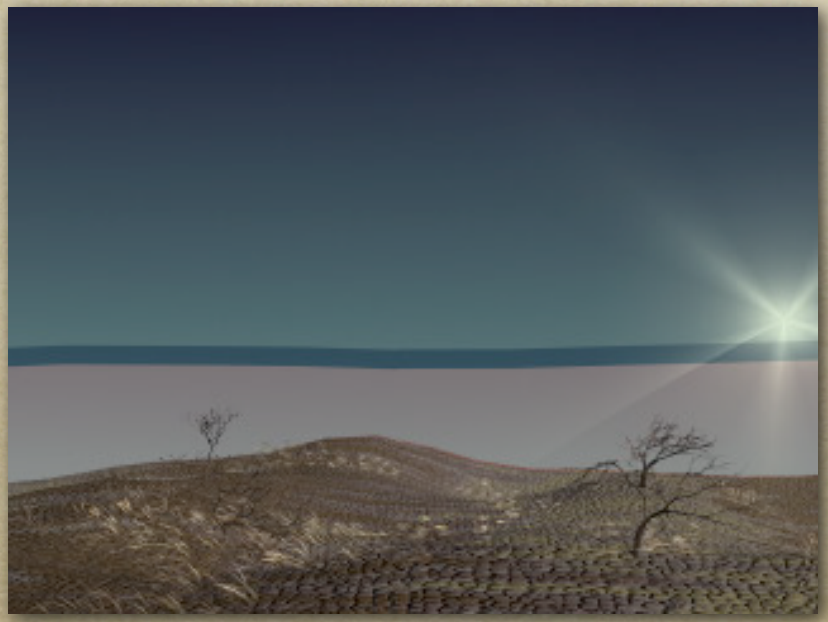
Points on Greenhouse Gases

- CO_2 from land use is important...
  - *but only about half the story*
- the other half...
  - *CH_4 from rice paddies, livestock*
  - *N_2O from agricultural lands*
- and that doesn't consider...
  - *fires: O_3, black carbon, aerosols*
  - *biogenic VOCs: O_3*
  - *linked chemistry of O_3, CH_4*

Land Use Consequences

Physical Climate

Land Use and Climate

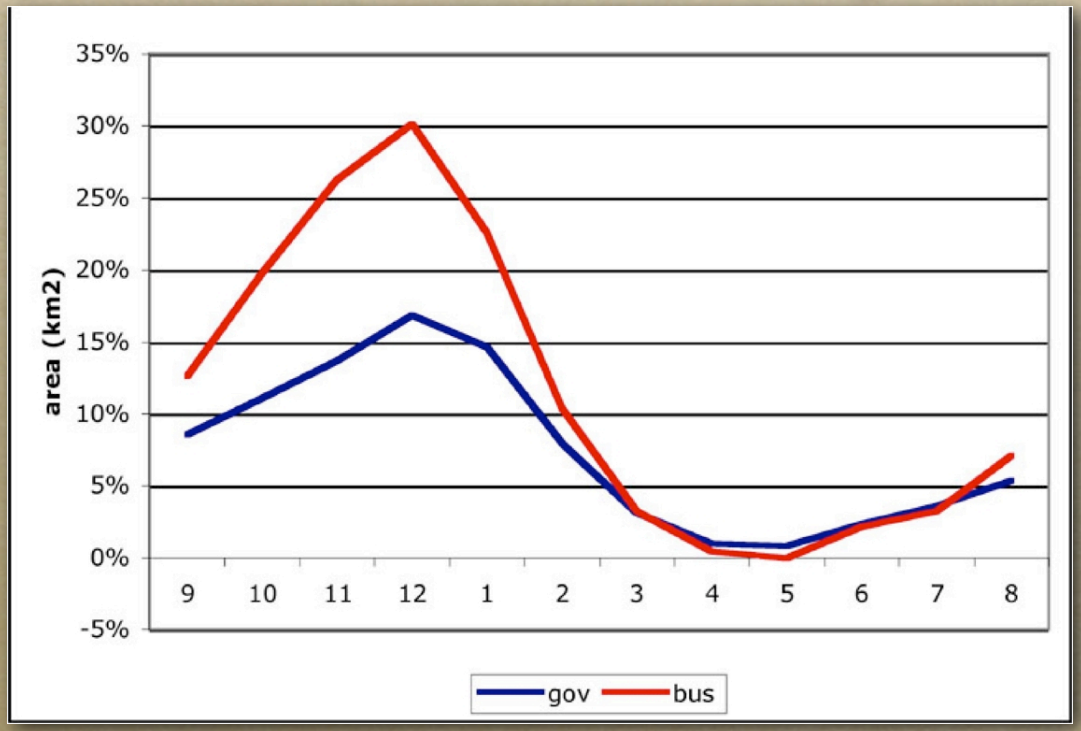


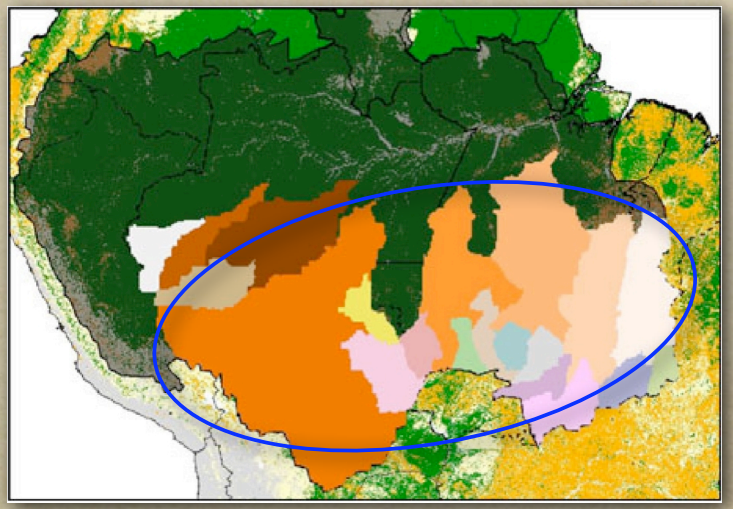
Source: NASA Earth Observatory

Land Use Consequences

Other Important Issues

Land Use and Hydrology





	2030 Governance Scenario	2030 Business-as-Usual Scenario
change in peak flooding	+17%	+30%

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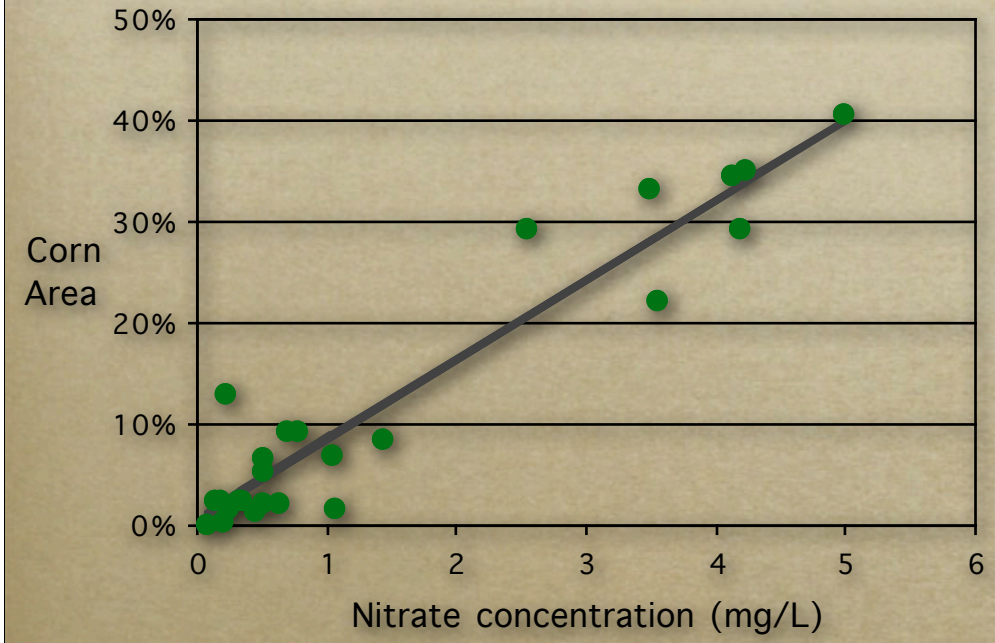
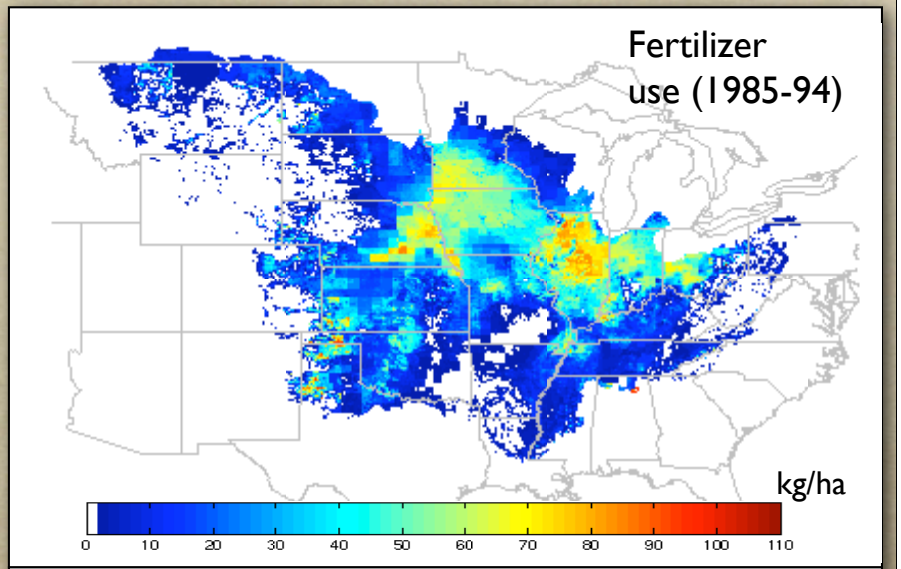
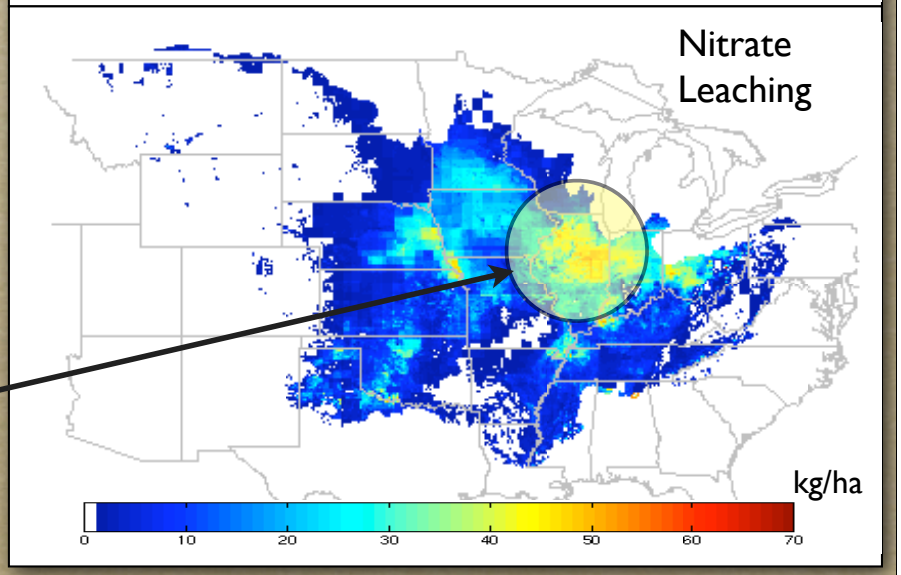
Souce: Preliminary Results from Coe (SAGE), Nepstad, Soares-Filho, and McGrath (WHRC)

Land Use and Pollution







high fertilizer inputs
and wet, highly variable climate

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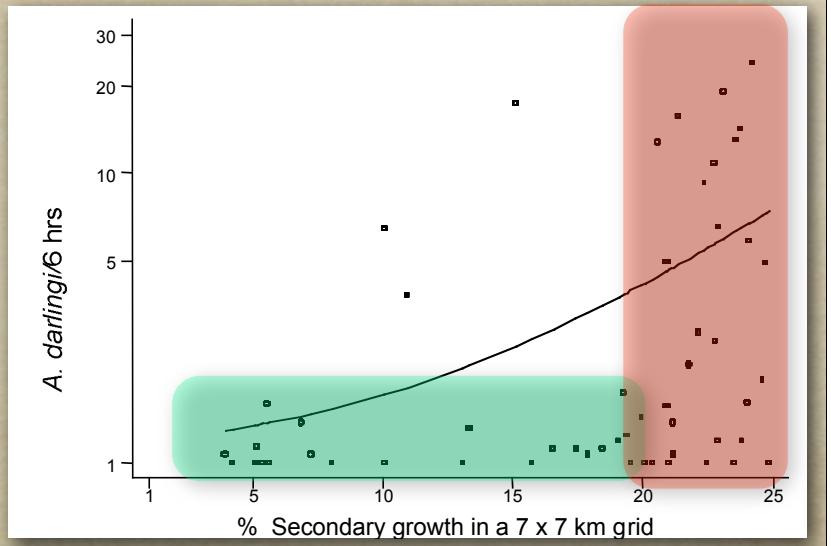
Donner, Kucharik and Foley, GBC, 2005

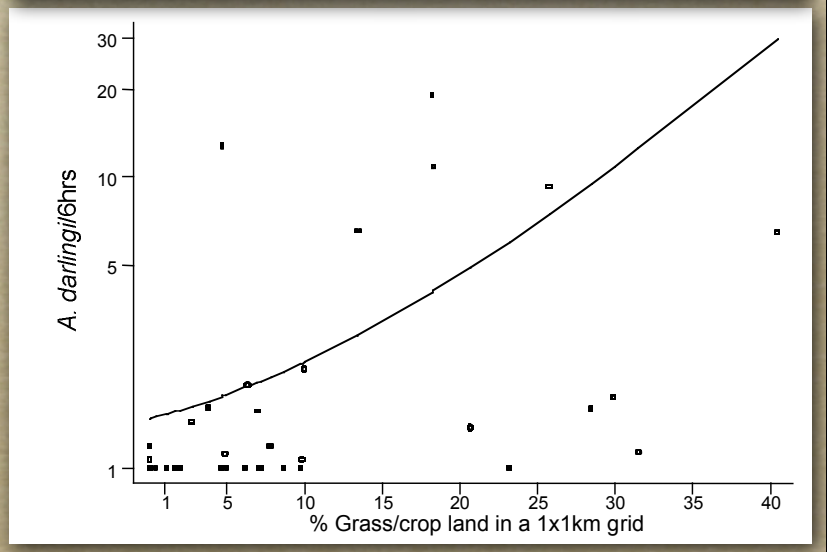
Land Use and Health

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

widely distributed across Latin America
highly anthropophilic

Figure 2 - Patz





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

Center for Sustainability and the Global Environment (SAGE)
University of Wisconsin, Madison

Lessons

Lesson #1

- agriculture & land use release more greenhouse gases than any other single human activity
- extends far beyond CO_2
  - *other greenhouse gases, especially CH_4, O_3, N_2O*
  - *also aerosols, black carbon*
- effects on physical climate also large
  - *regional in scale, but still important*
  - *often get "washed out" in outdated climate metrics of radiative forcing and global mean temperature*

Lesson #2

- changes in land use / land cover have many other, direct impacts on human societies

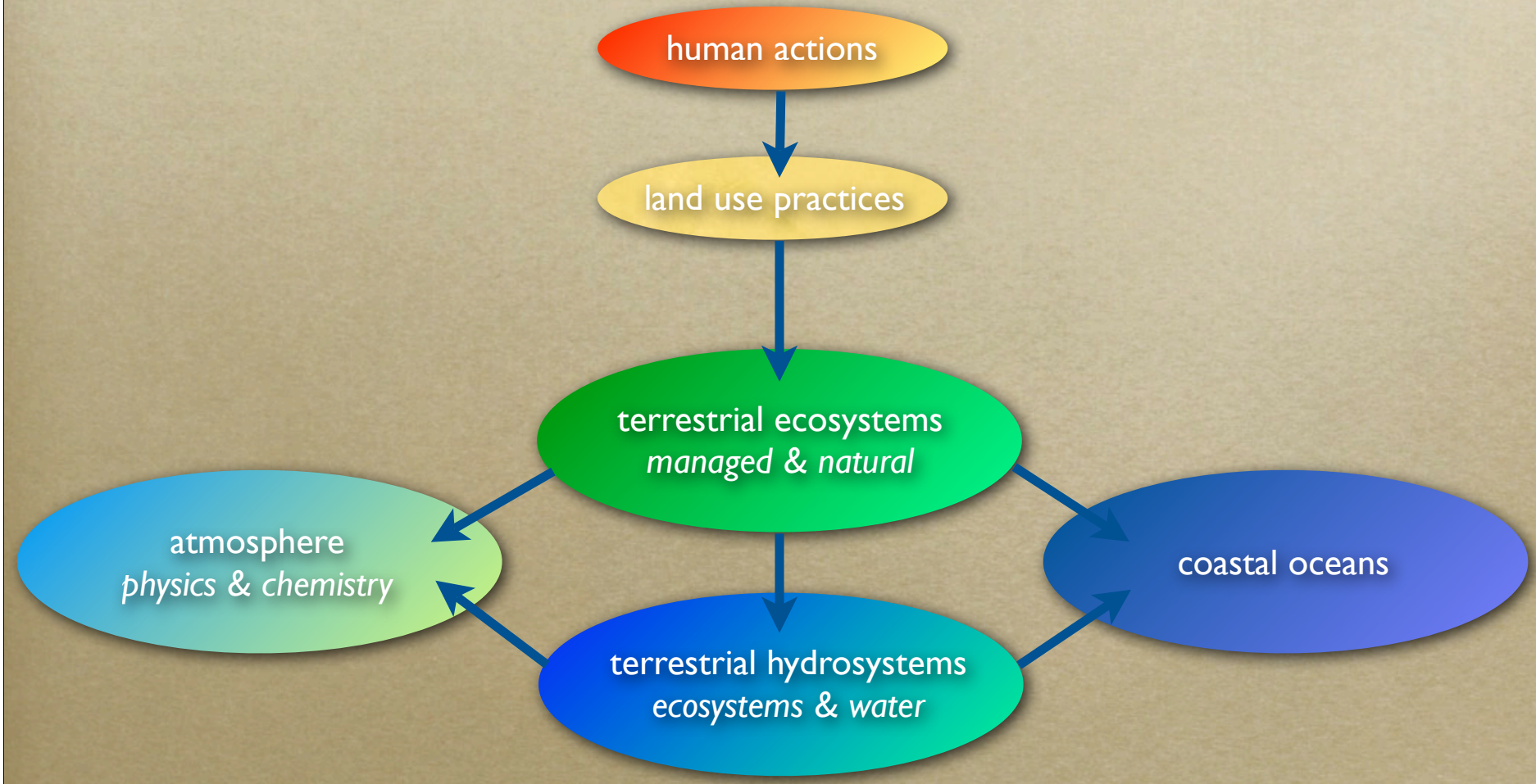
- direct effects...
  - *agricultural production (food, feed and fuels)*
  - *water quantity and water quality*
  - *vector-borne disease*
  - *etc...*

Bottom Line

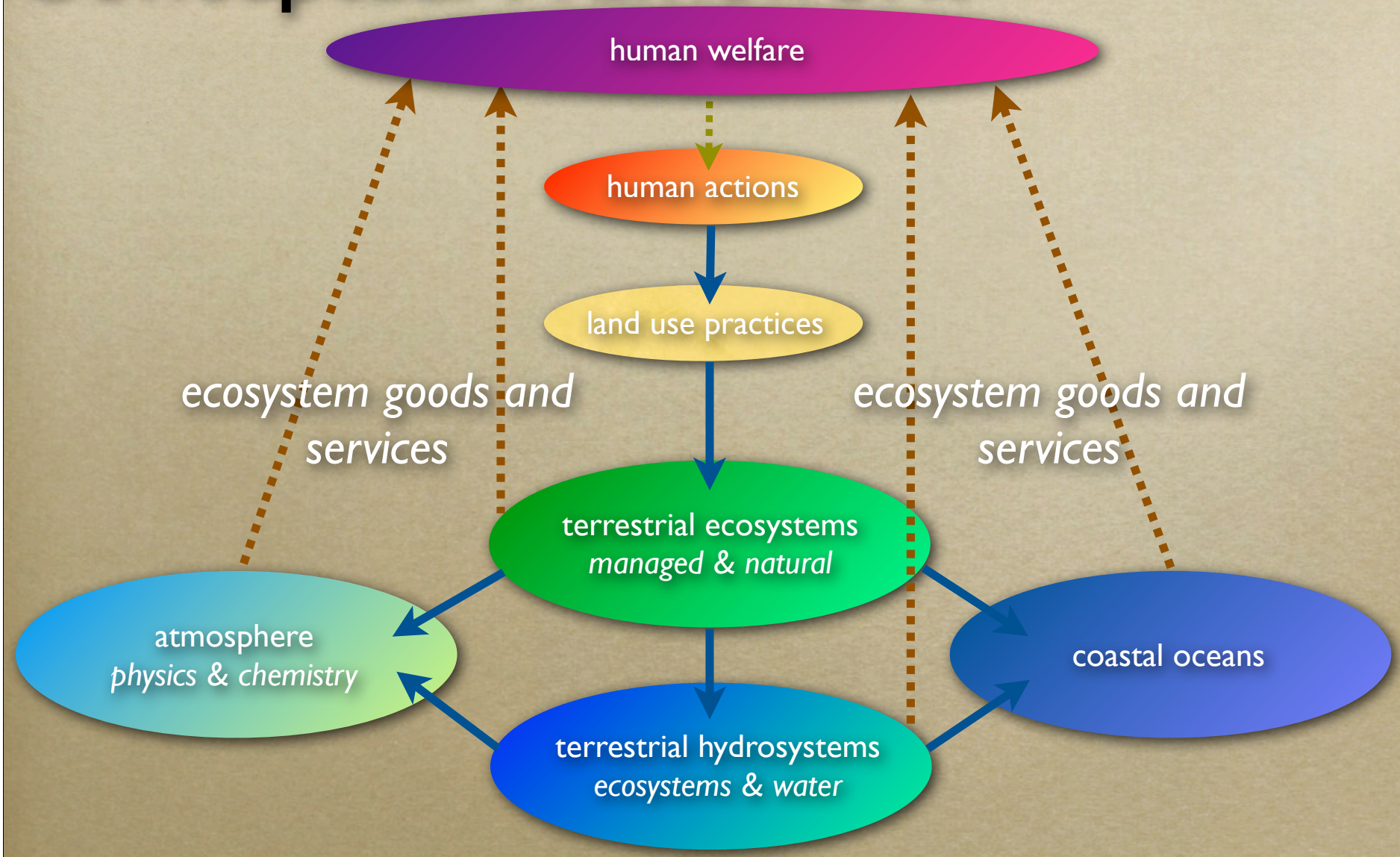
Global Change is Much More Than CO_2 and Global Warming

Reframe Global Change from a Human / Land-Based Perspective?

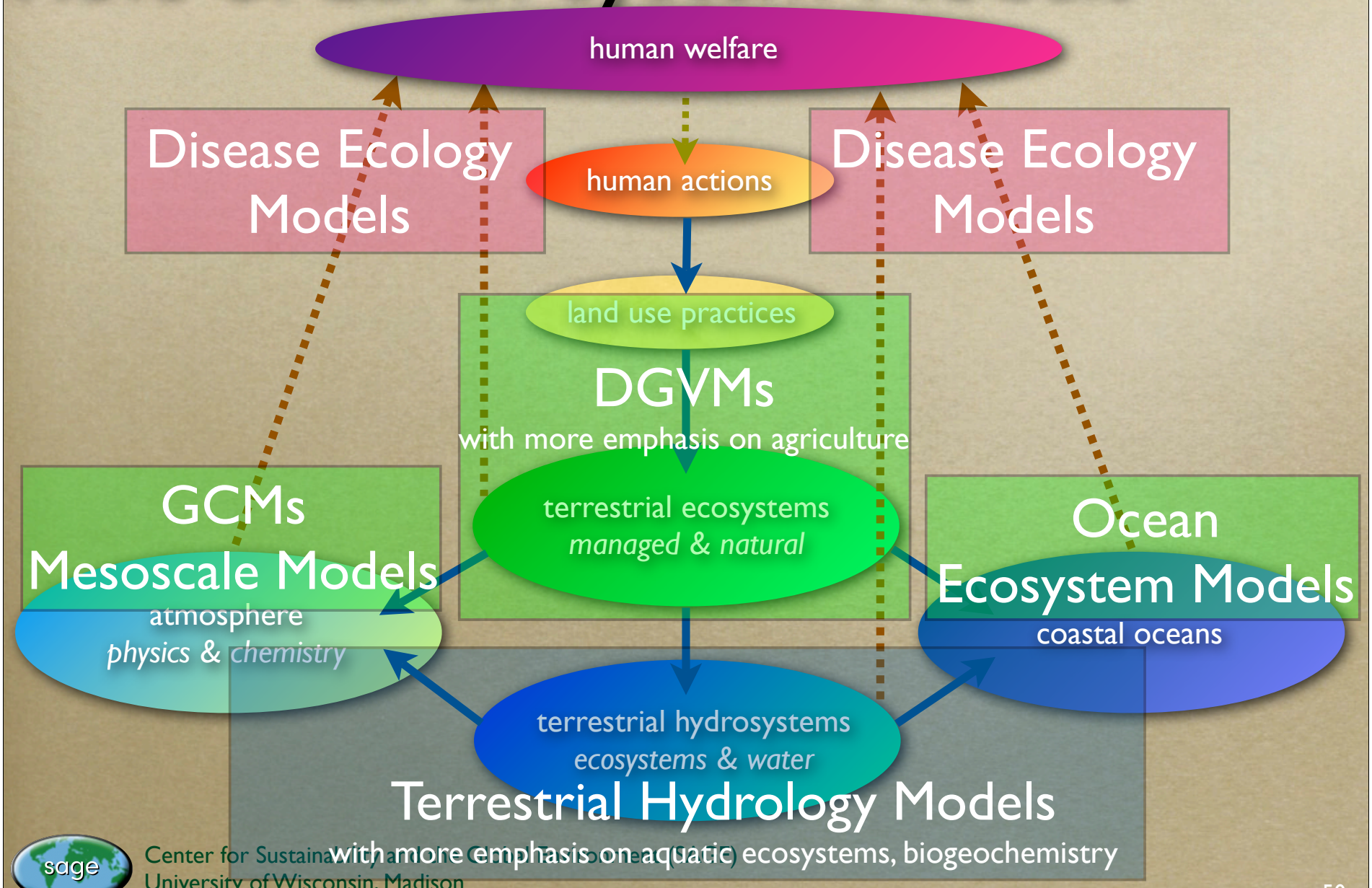
Conceptual Framework



Conceptual Framework



Role of Earth System Models



4 Things to Remember

Agriculture is a Major Planetary Force

Land Use Practices are Changing Much Faster than Land Cover

Current Focus on CO_2 / Climate Connection is Very Short Sighted

Need More Comprehensive Framework to Exploring Changes in Earth System


Thank You!