Agriculture and the Transformation of Planet Earth

NASA IDS Project
University of Wisconsin, Madison

Year 1 Status Report

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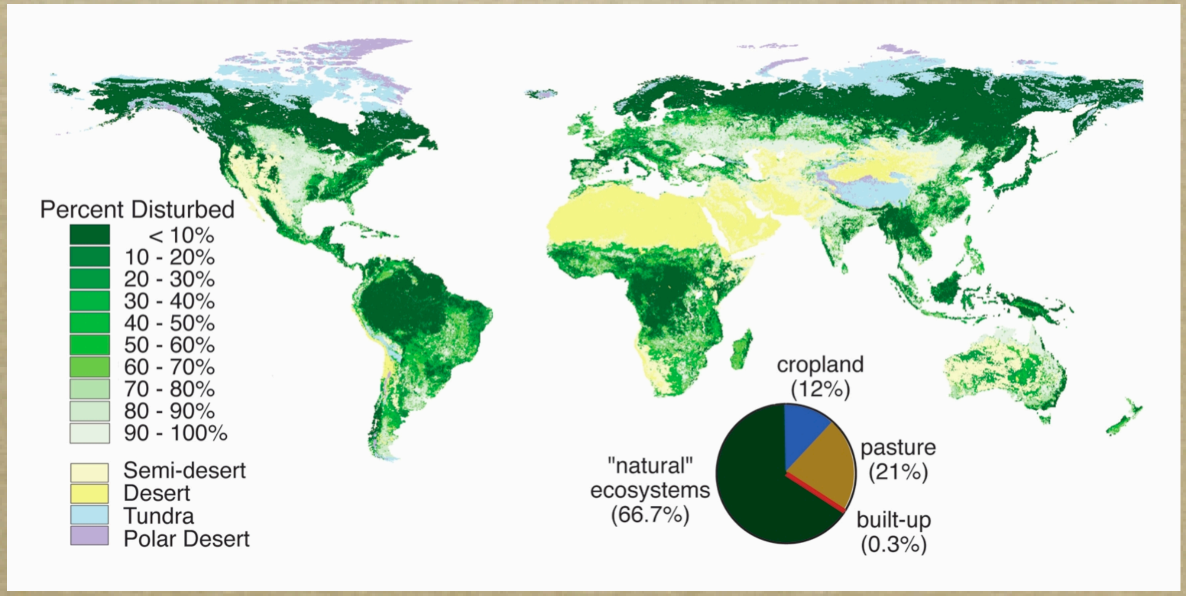
Massive Land Cover Change

- extensive land use
  - *~18 million km^2 in cultivation*
  - *~34 million km^2 in pastures*
  - *~3 million km^2 in urban areas*
  -

- significant impact
  - *cleared ~33% of the planet's land surface*
  - *use ~40% of global photosynthesis*

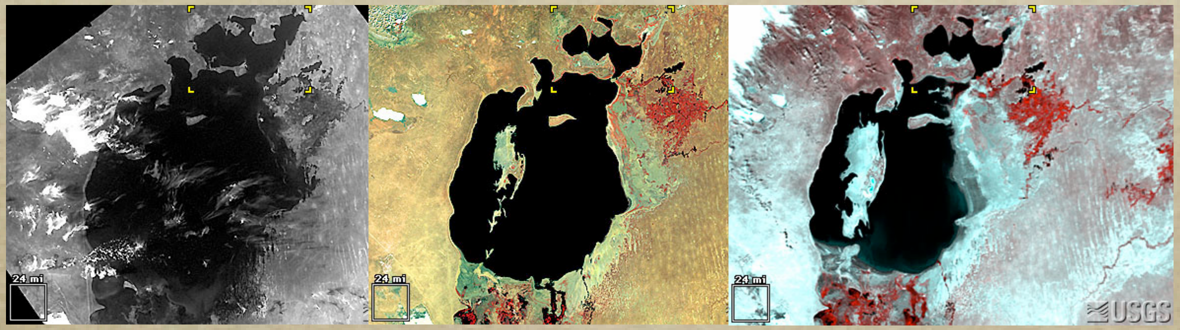


Source: Foley et al., 2003

Massive Water Use

- extensive water use
  - *annual use > volume of Lake Huron*
  - *using ~50% of "available" supply*
    - *70% for agriculture, 20% for industry, 10% for domestic use*

- significant impacts
  - *declining water supply, quality*
  - *increased water stress*



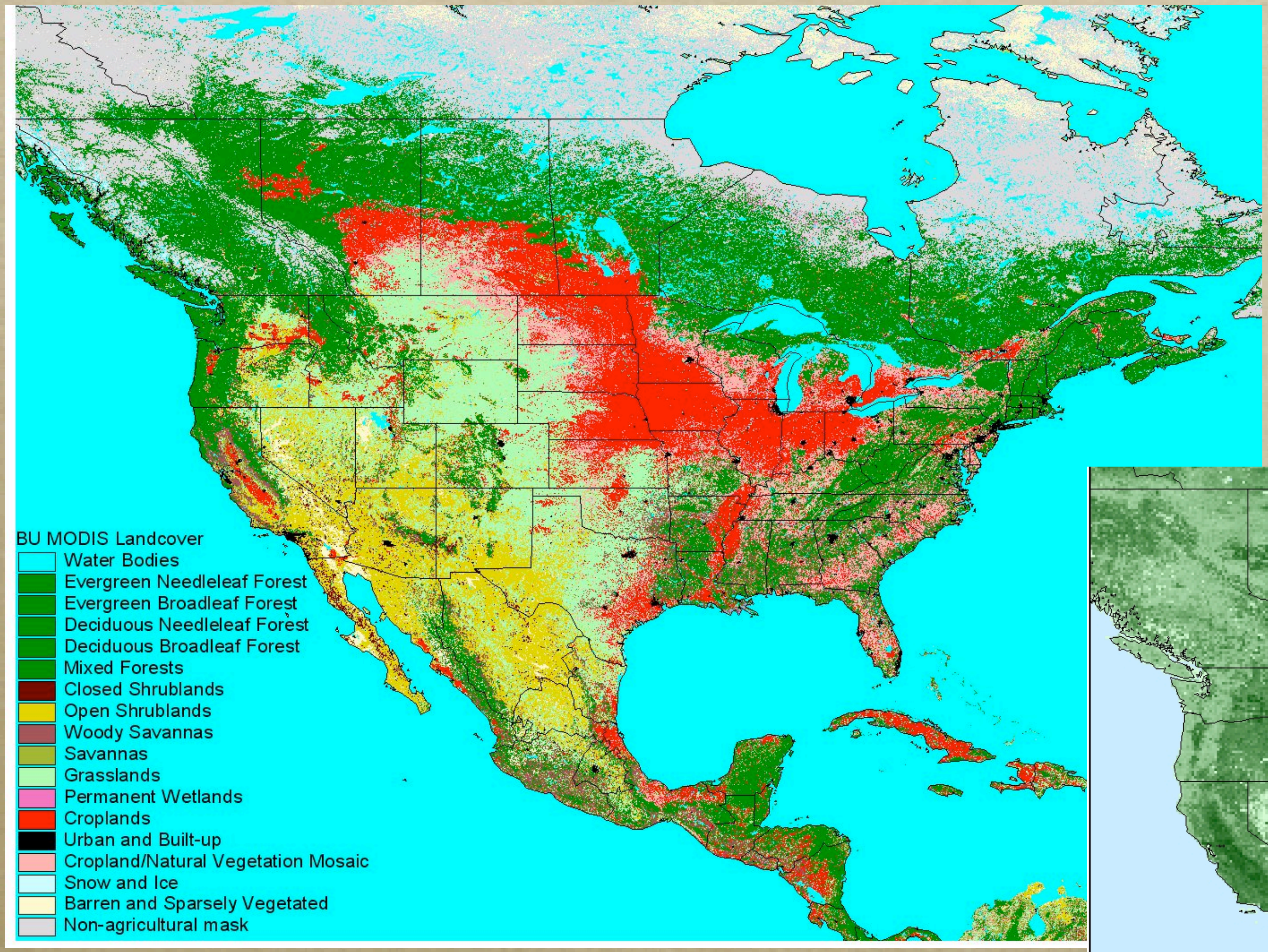
Food, Water

Carbon, Climate

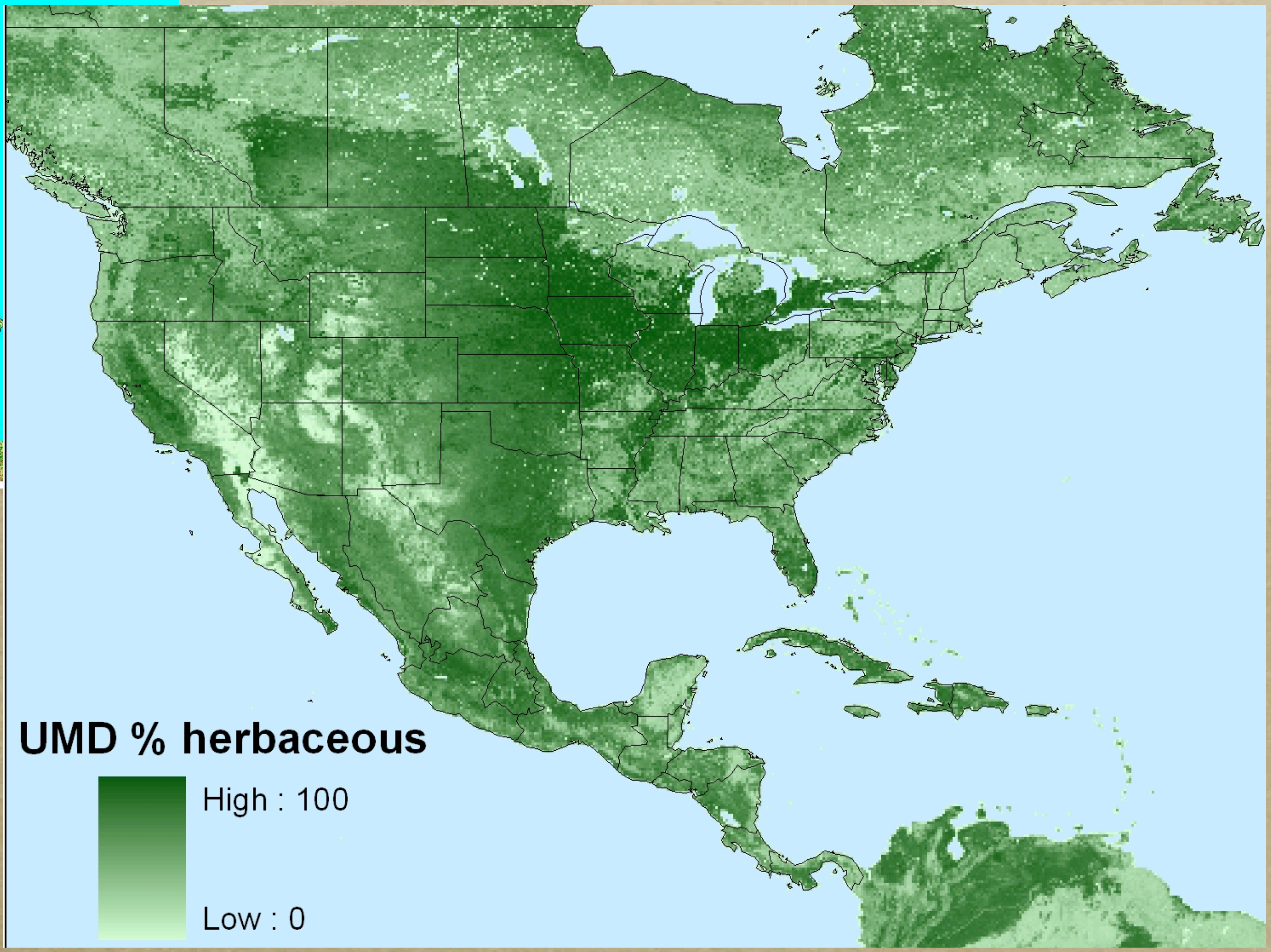
Objective #1

Documenting Global Patterns of Agricultural Land Use and Land Cover

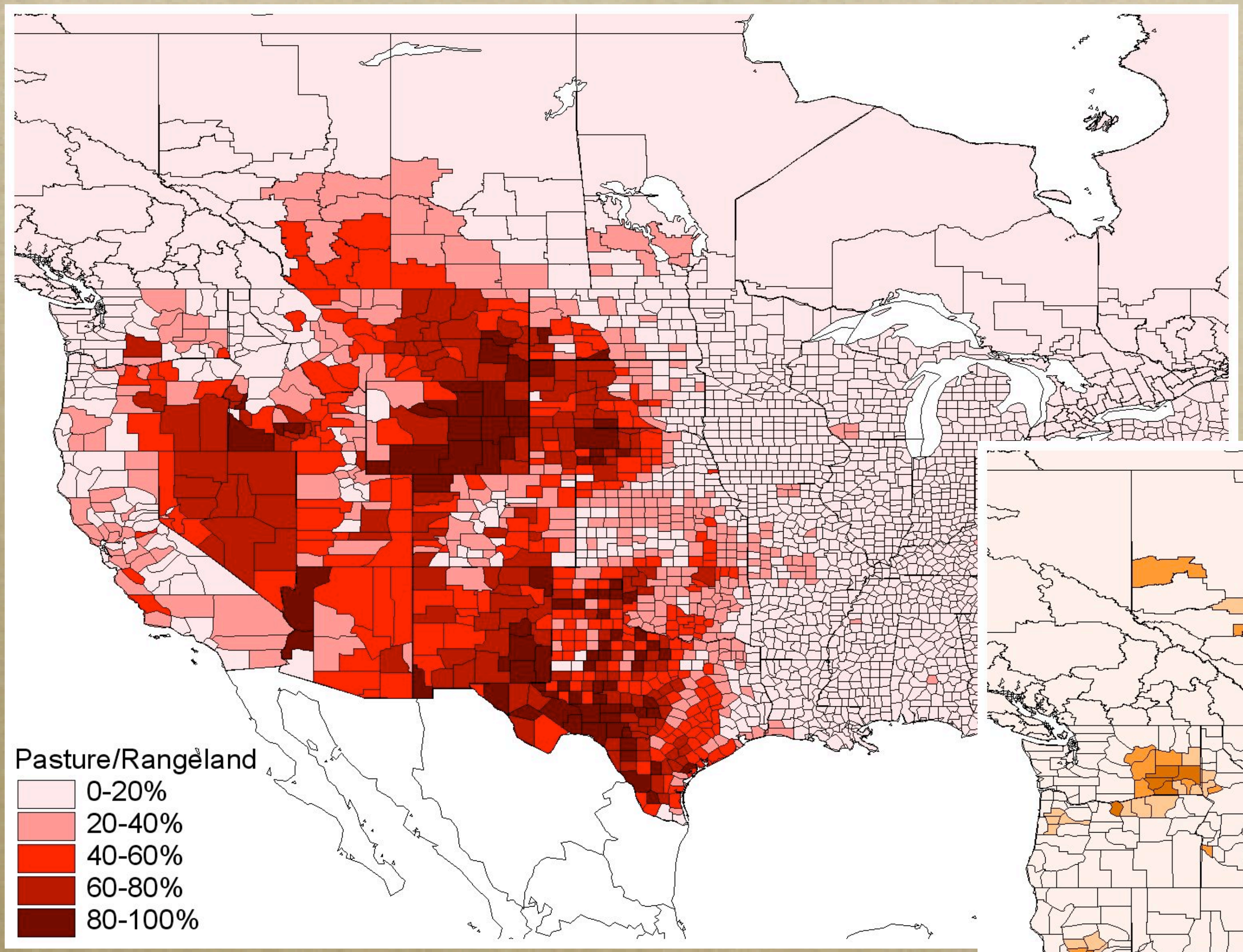
Satellite Data



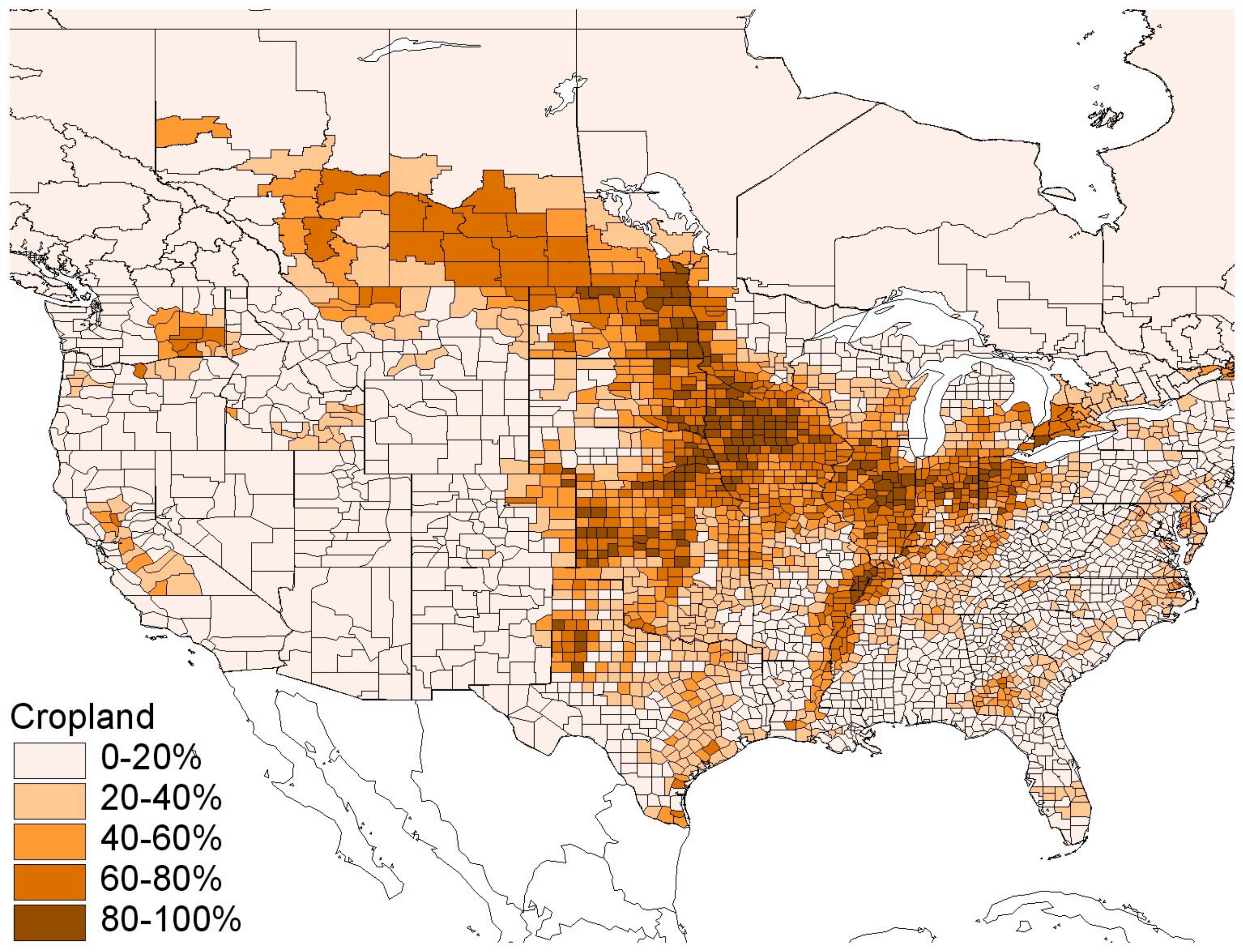
MODIS landcover classes (BU)
MODIS continuous fields (UMD)



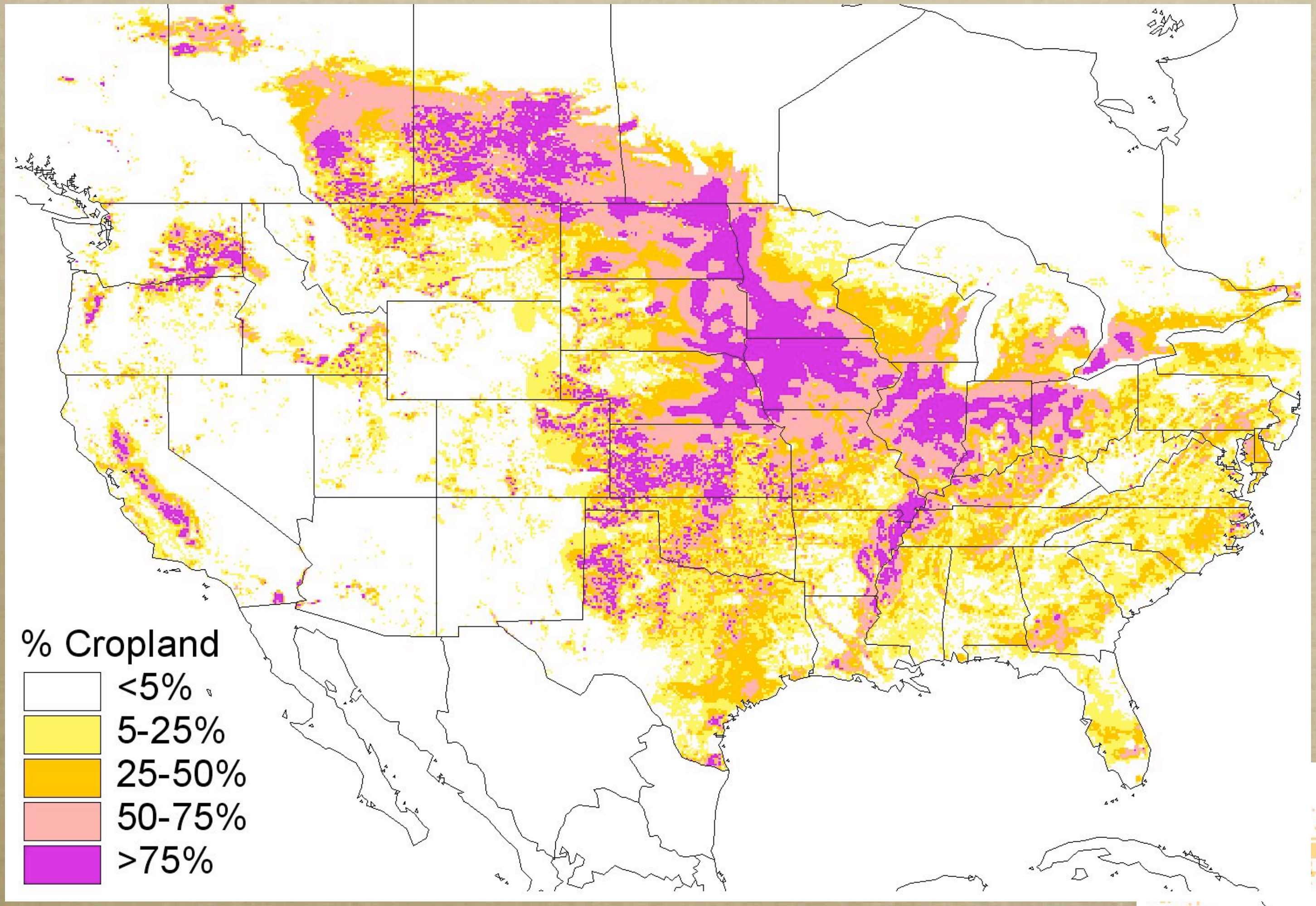
Census Data

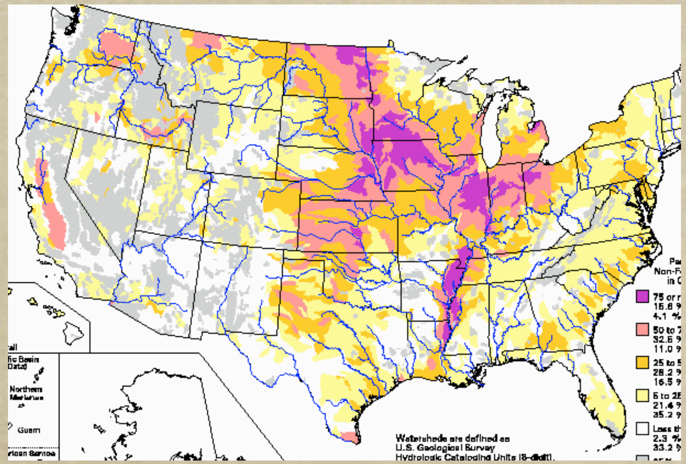


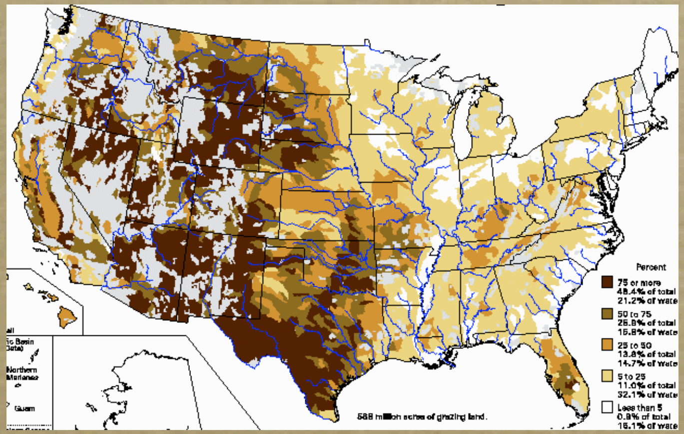
'national' data - global
'state' data - global
'county' data - many countries

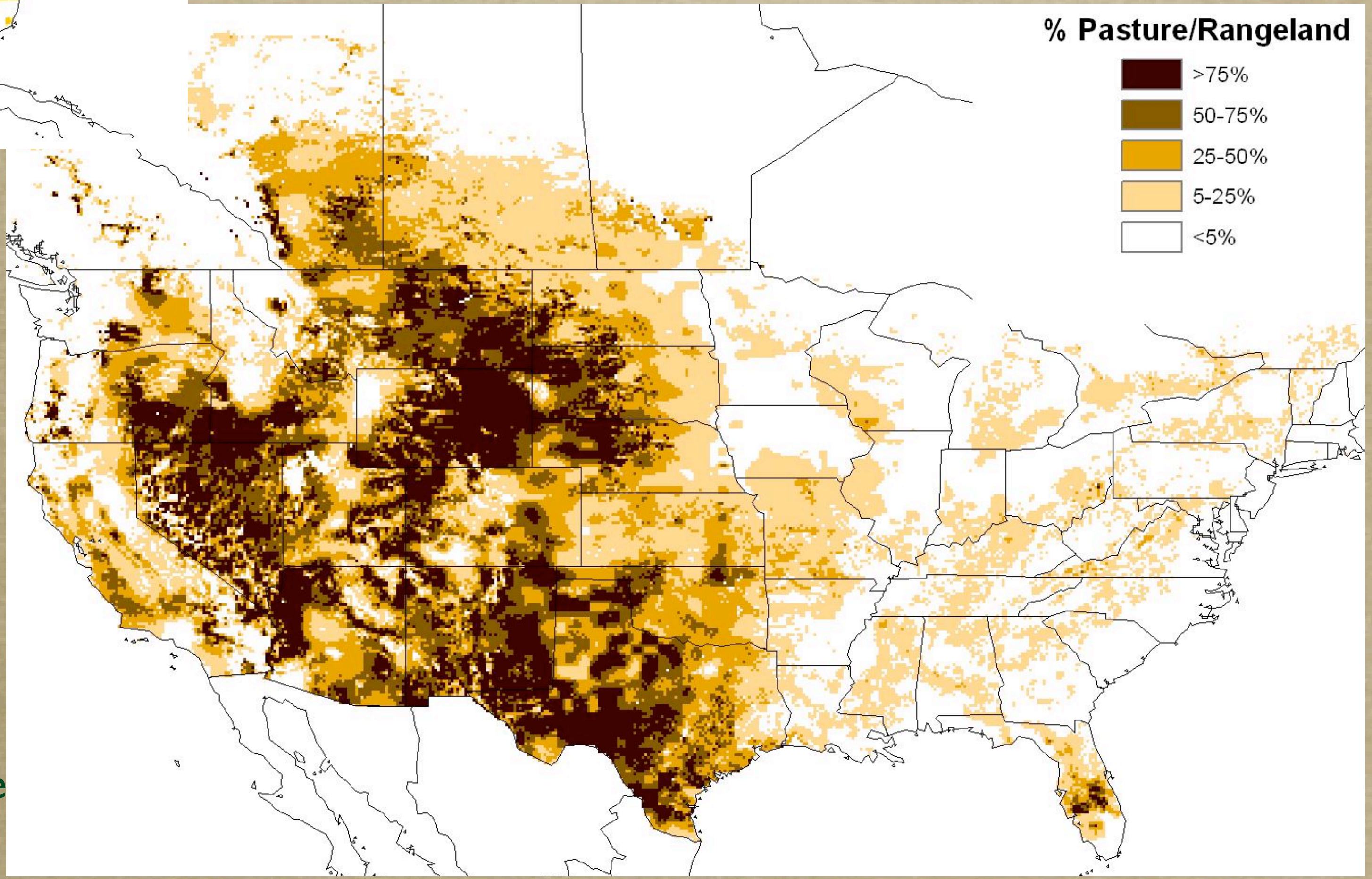


Croplands and Pastures (2000)

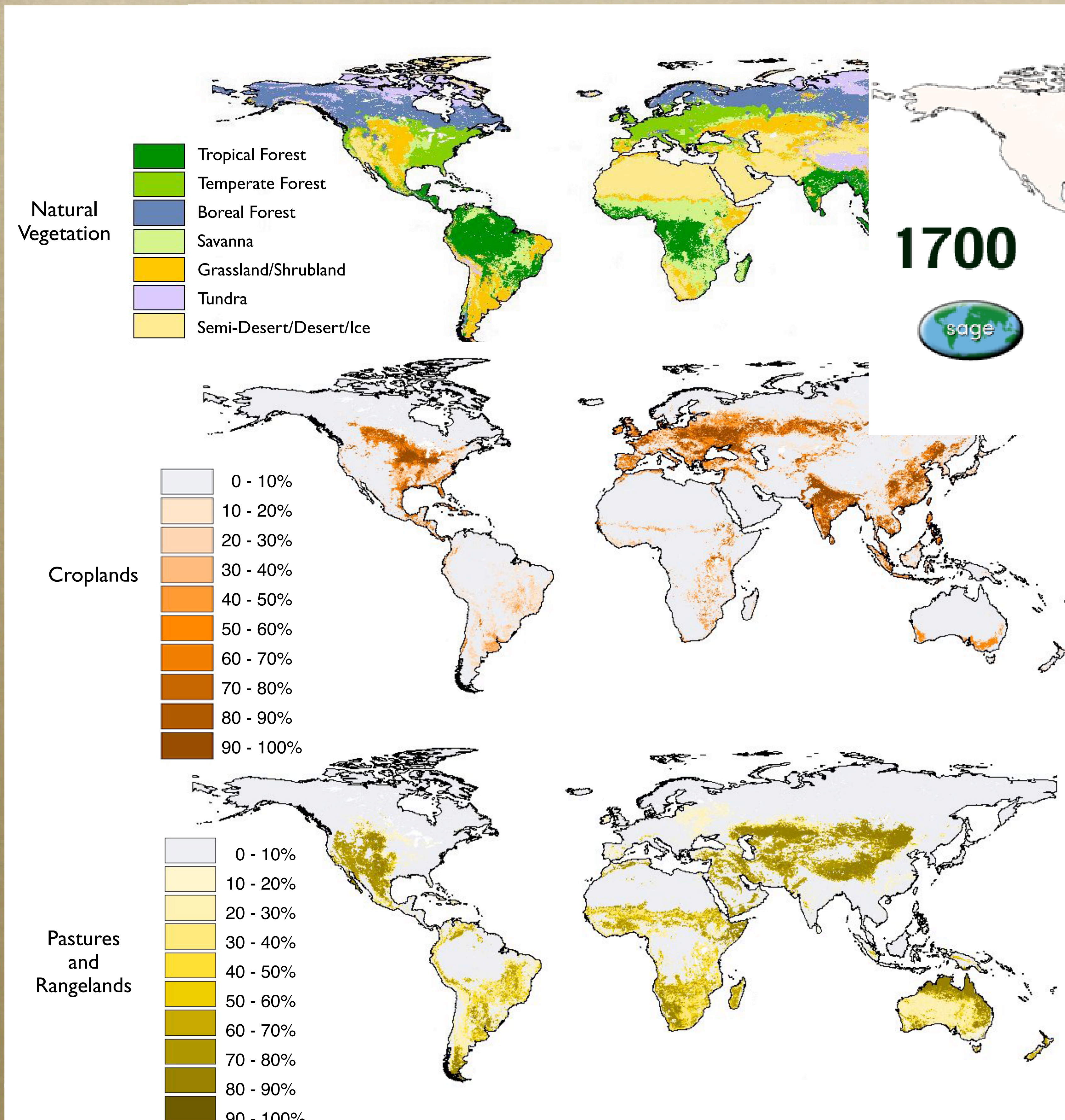


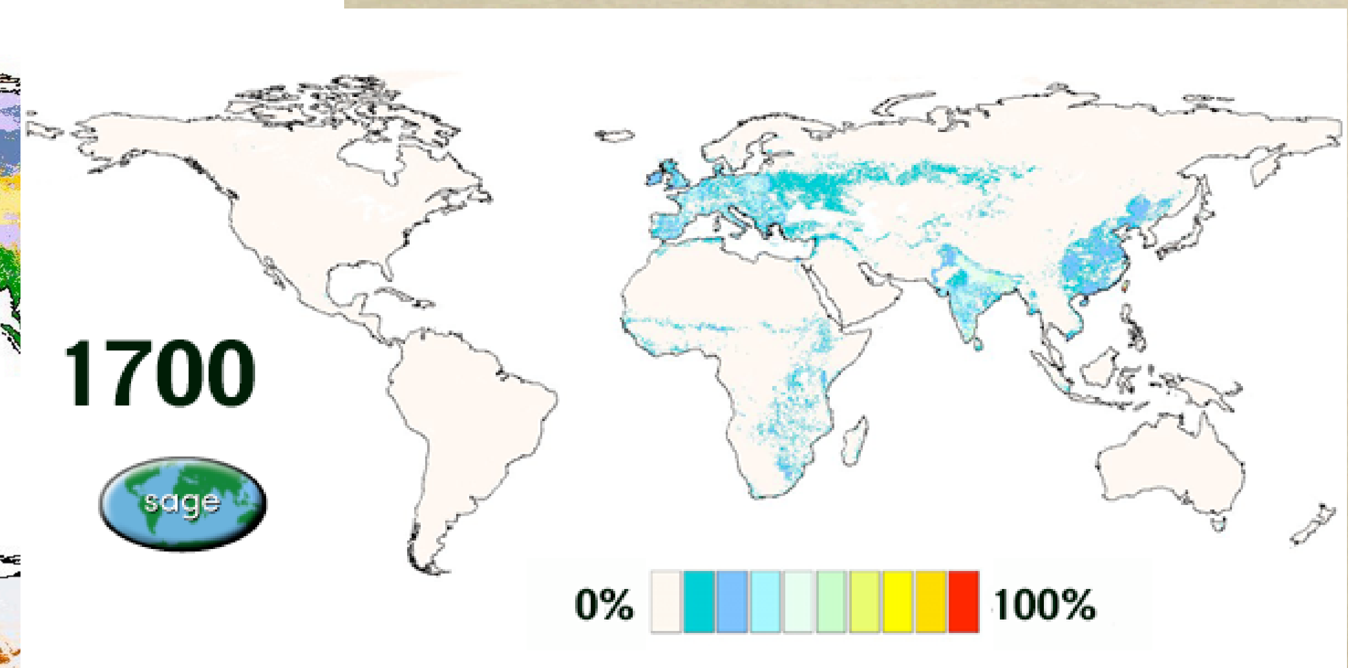






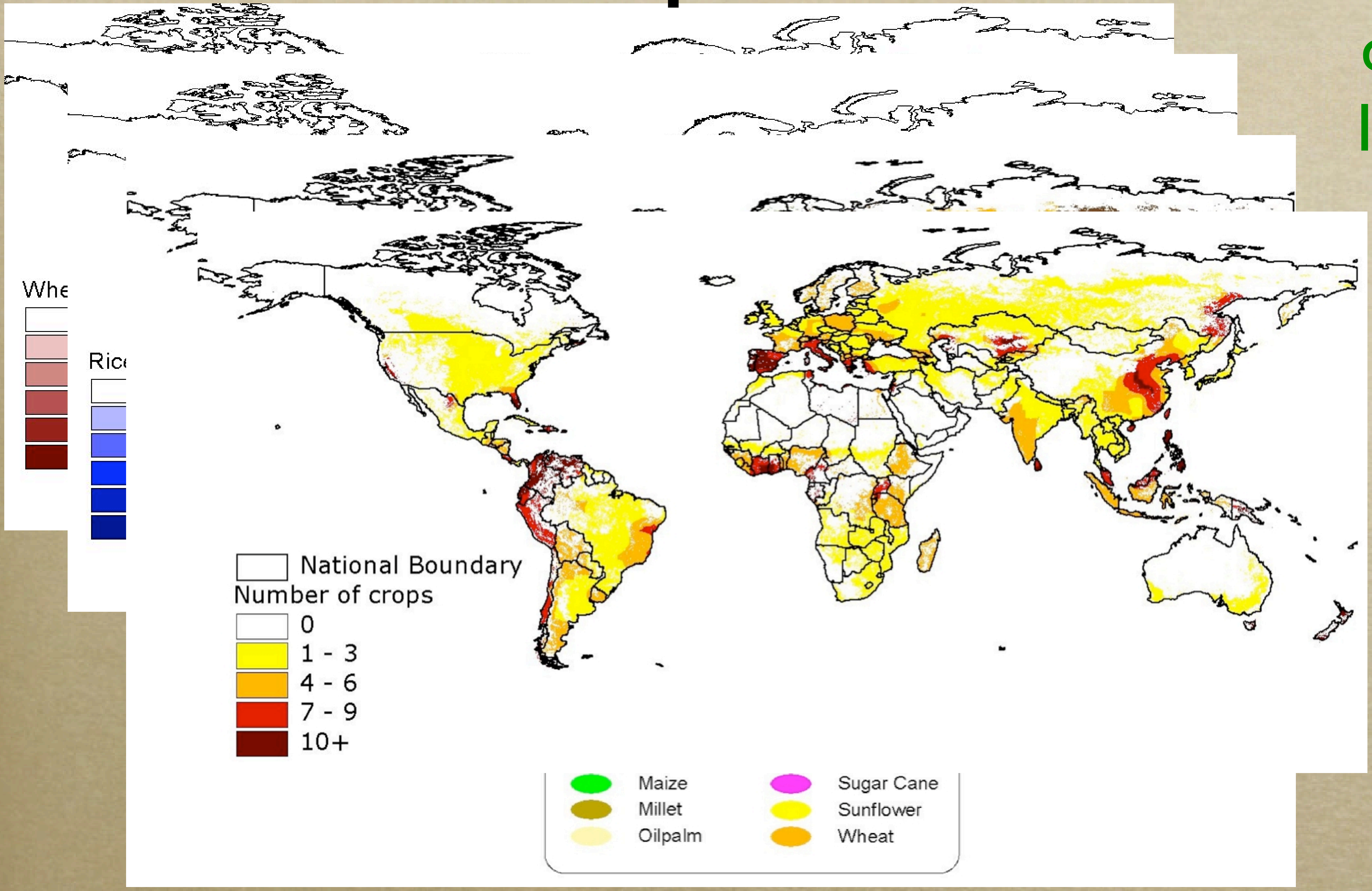
Global Data: Modern, Historical





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

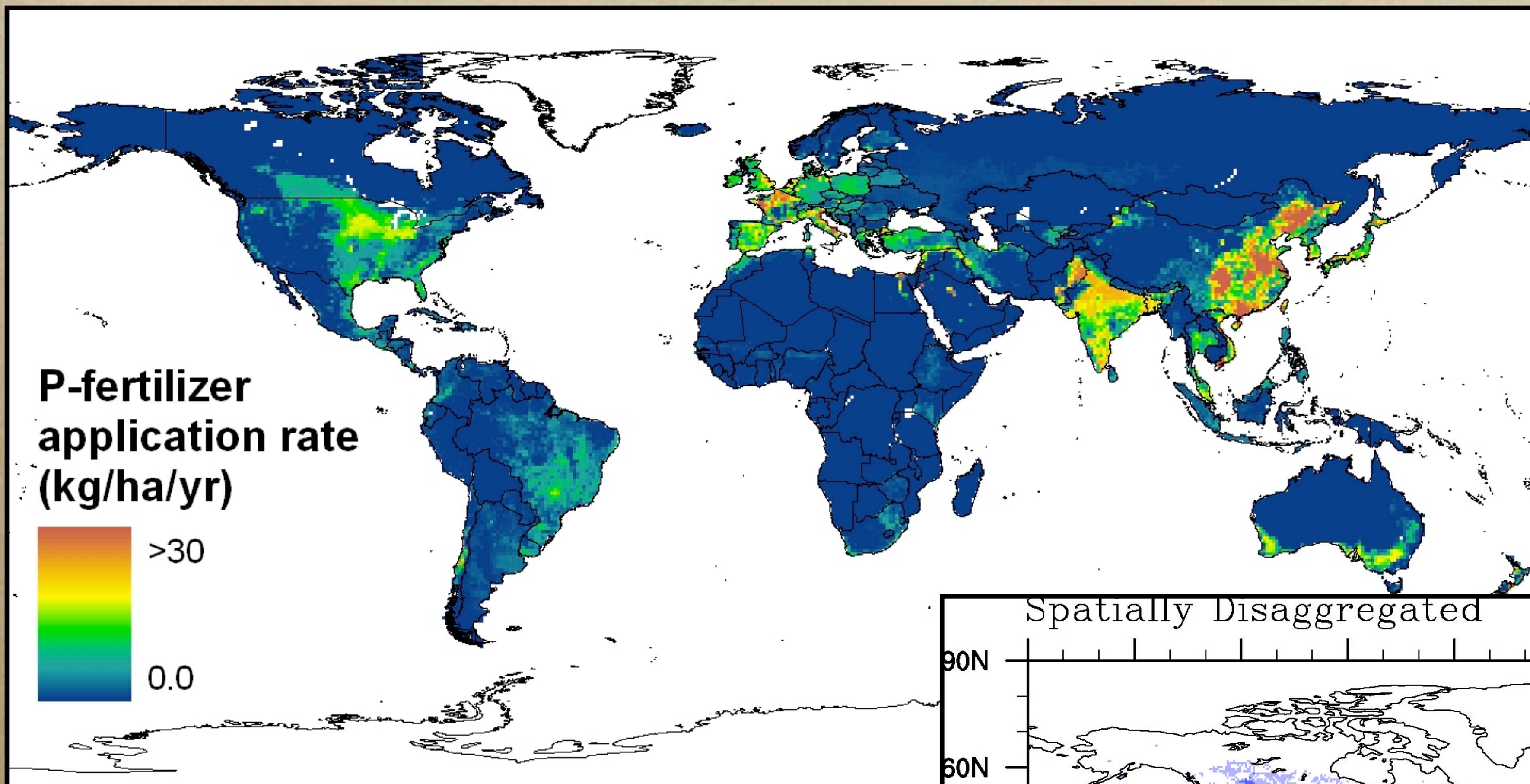
Individual Crop Areas, Yields



data for
18 crops

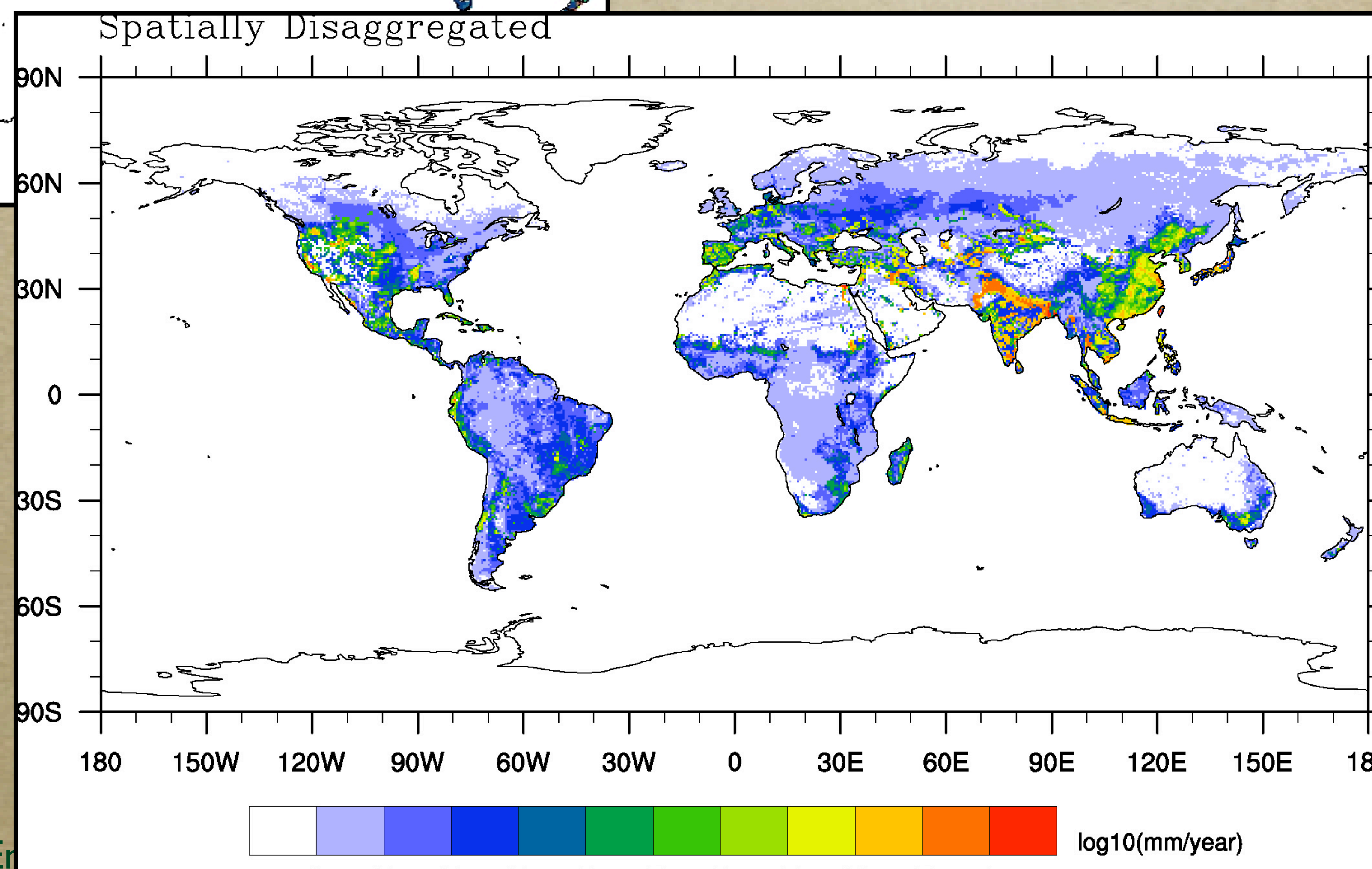
Preliminary Data in Leff et al. 2003; updated by Monfreda et al., in prep.

Agricultural Inputs



data for
N/P/K fertilizers

irrigation
extent, amounts



Source: J. Helkowski, M.S. Thesis, University of Wisconsin, 2004

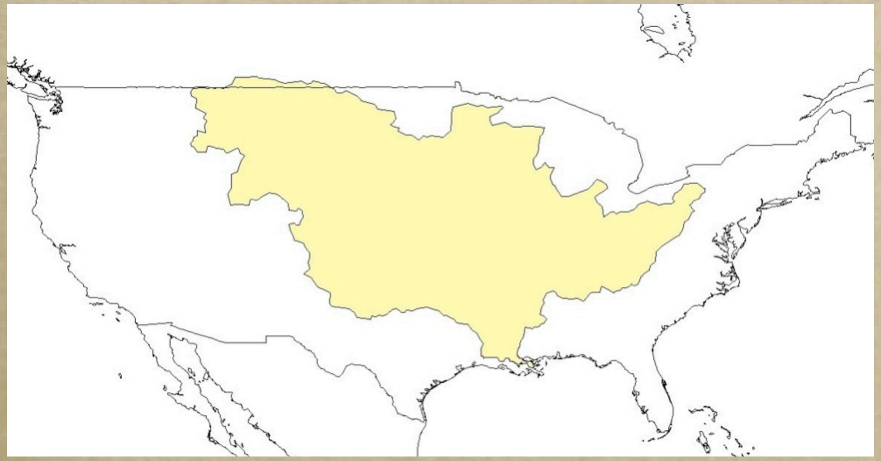
Objective #2

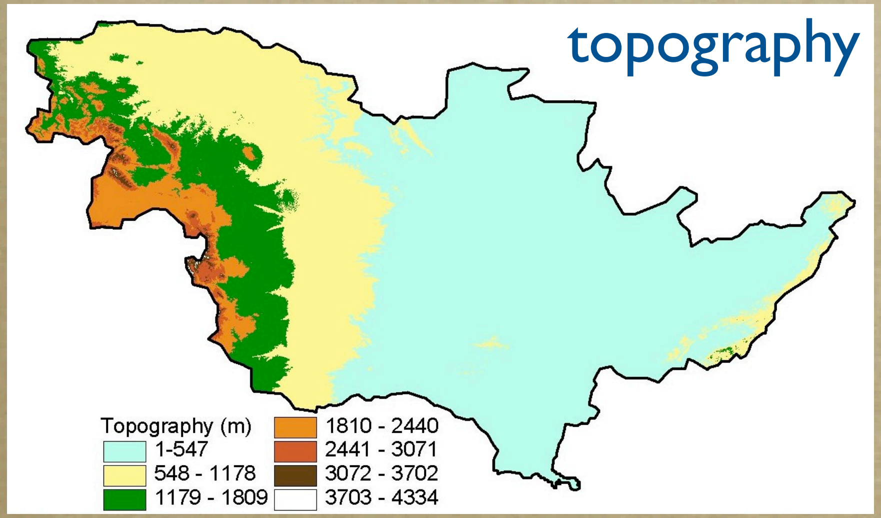
Understanding Changes in Agroecosystems

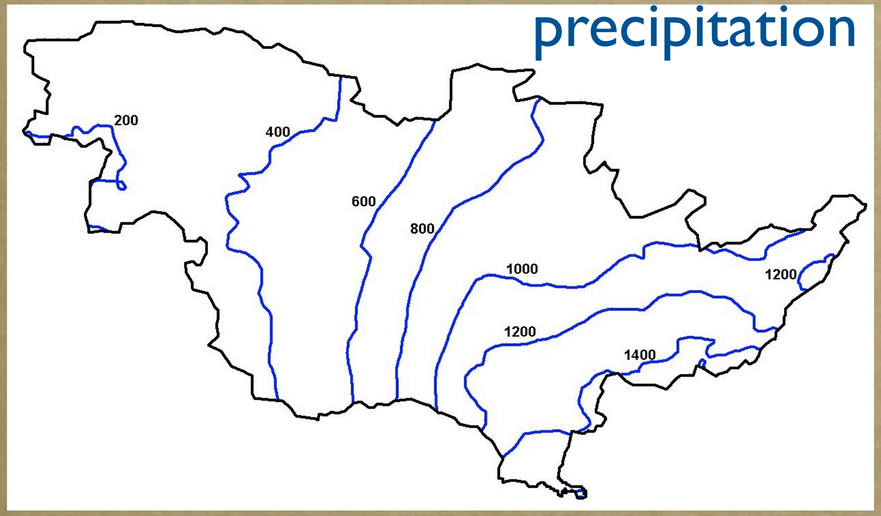
Mississippi Basin

Where Are We?

Mississippi Basin







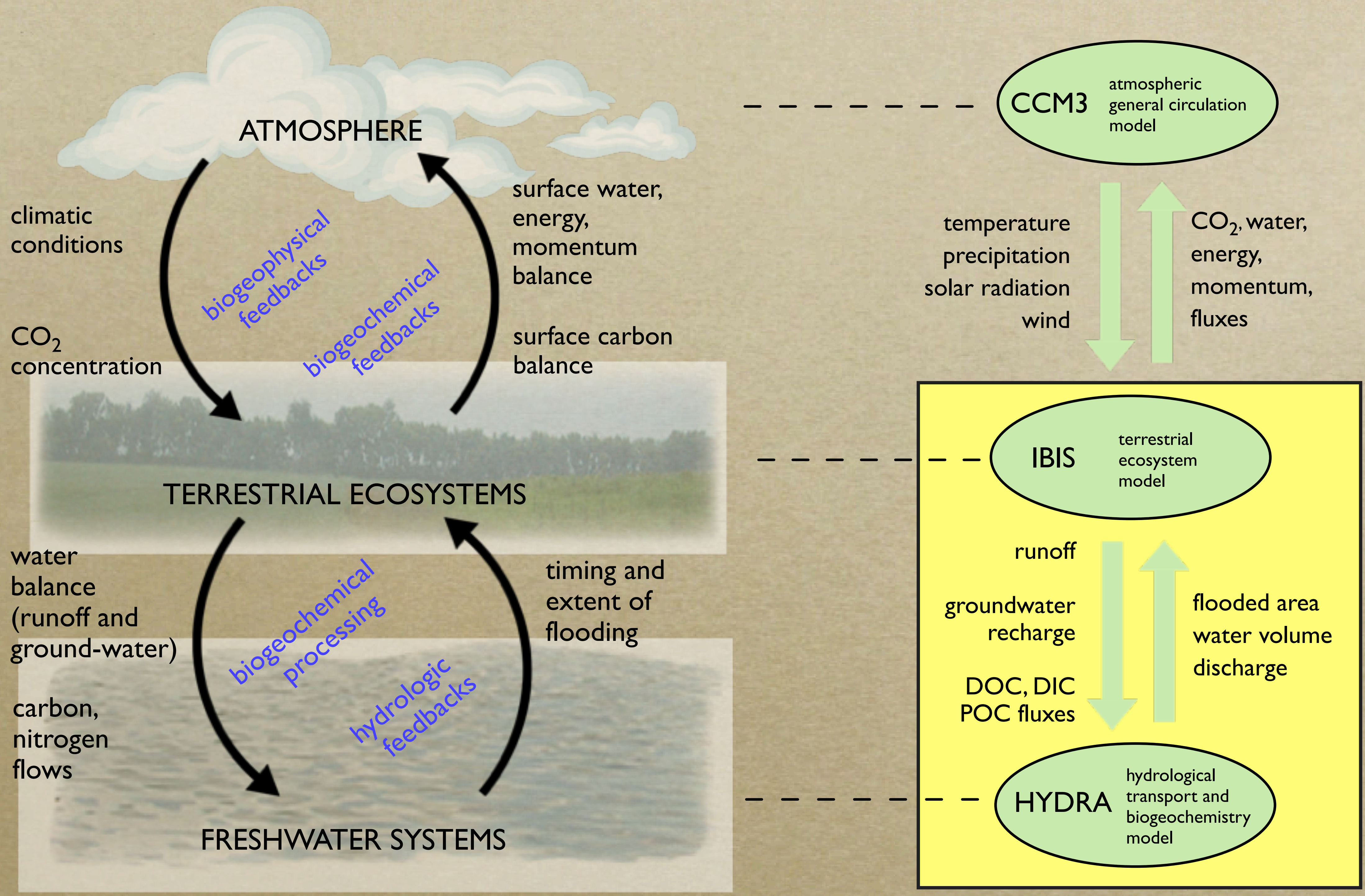
3rd largest basin in world
- 3.2 million sq km
- 48% of continental U.S.

important region
- home to ~70 million people
- ~$100 billion / yr agricultural economy

extensively used
- ~35% cropland
- ~2000 large dams

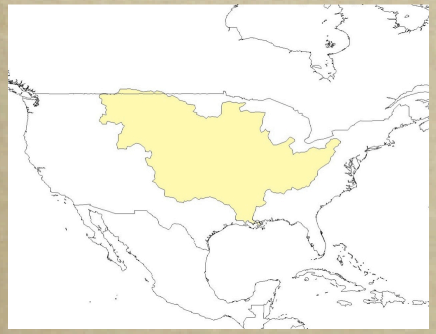
Atmosphere-Ecosystems-Rivers

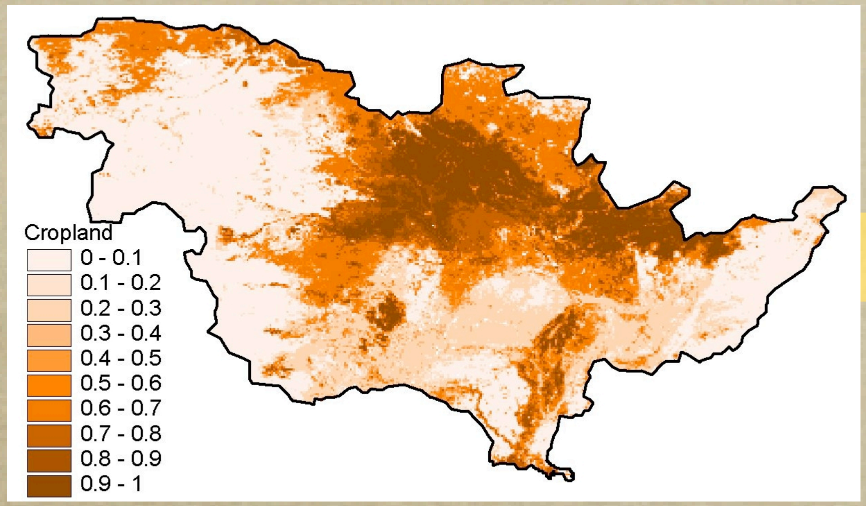
Conceptual and Modeling Framework

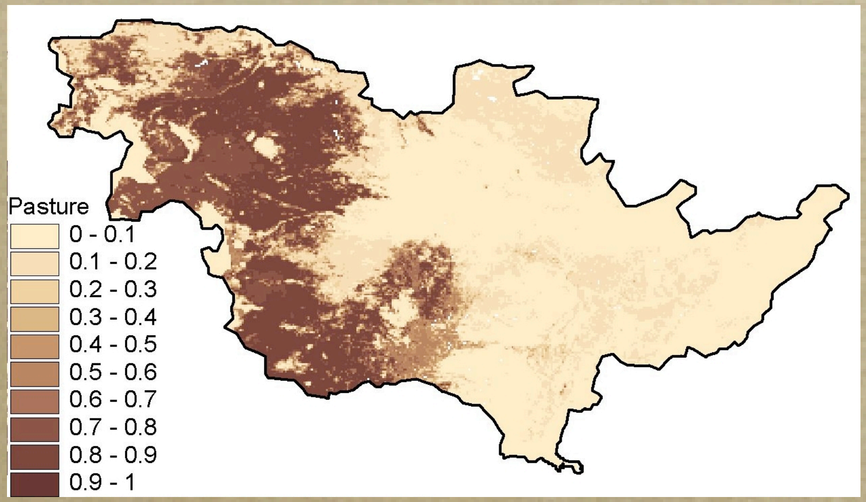


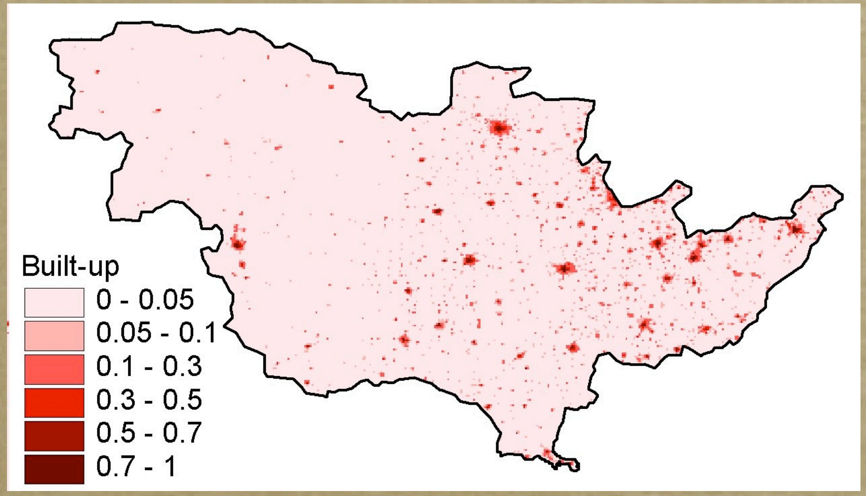
Land Use / Land Cover

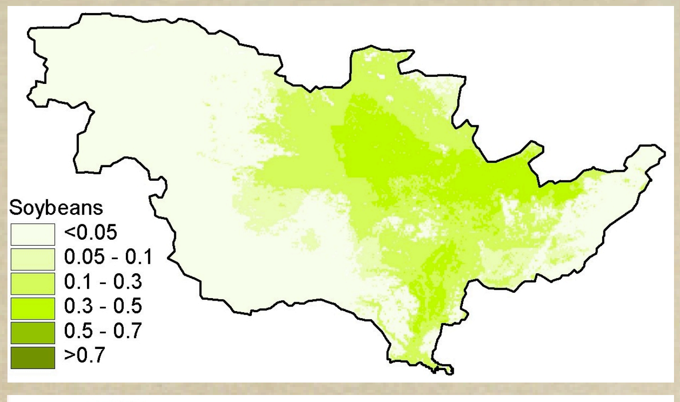
Describing Management: Cropping, Fertilizers

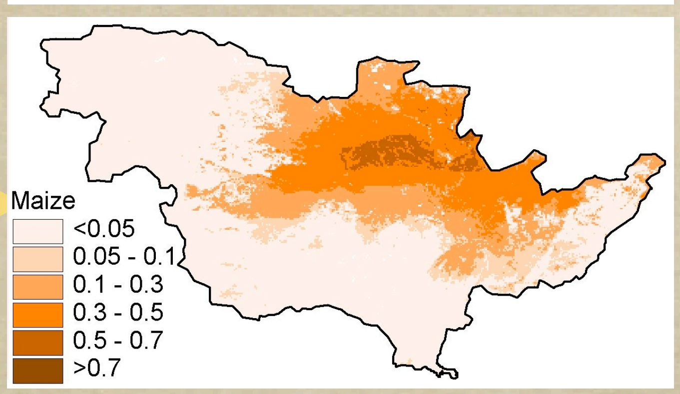


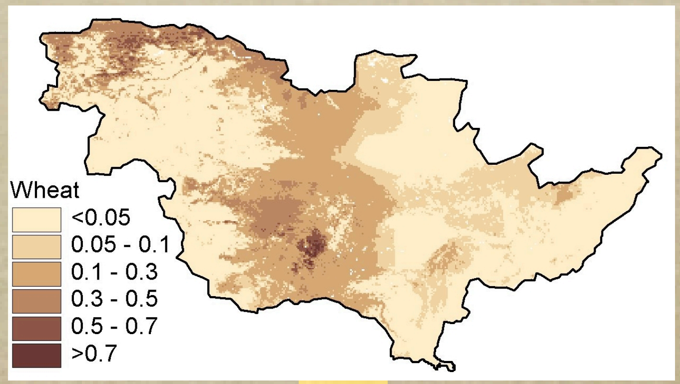


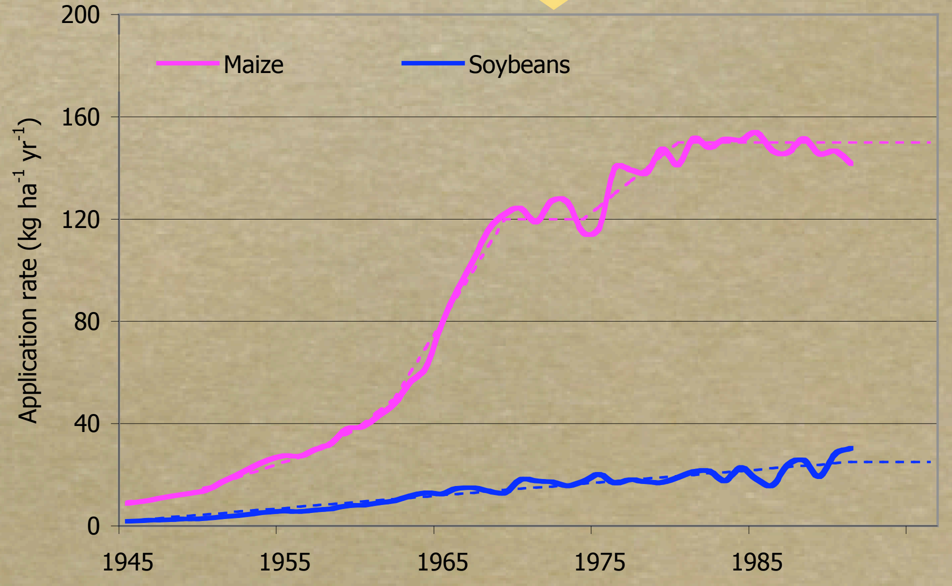












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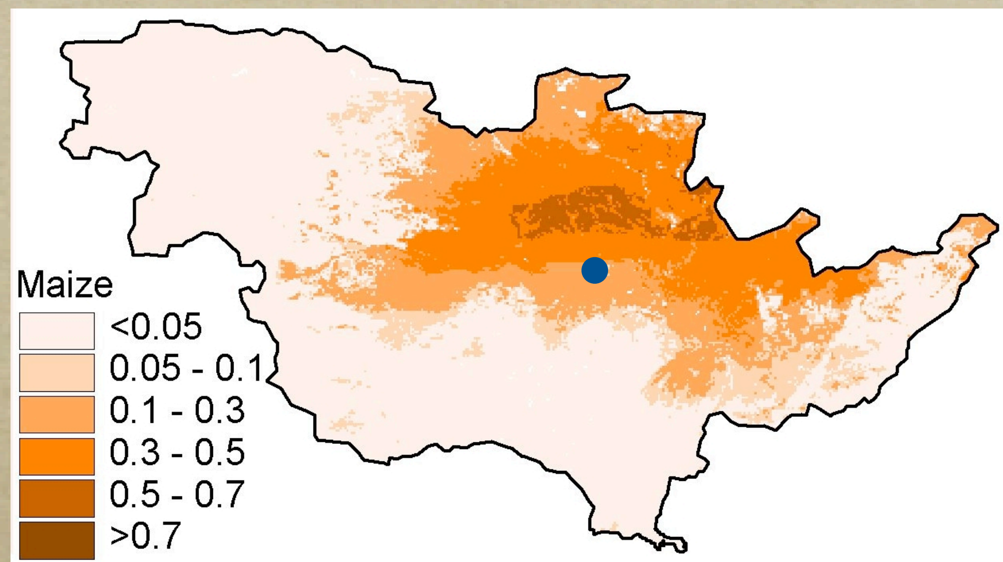
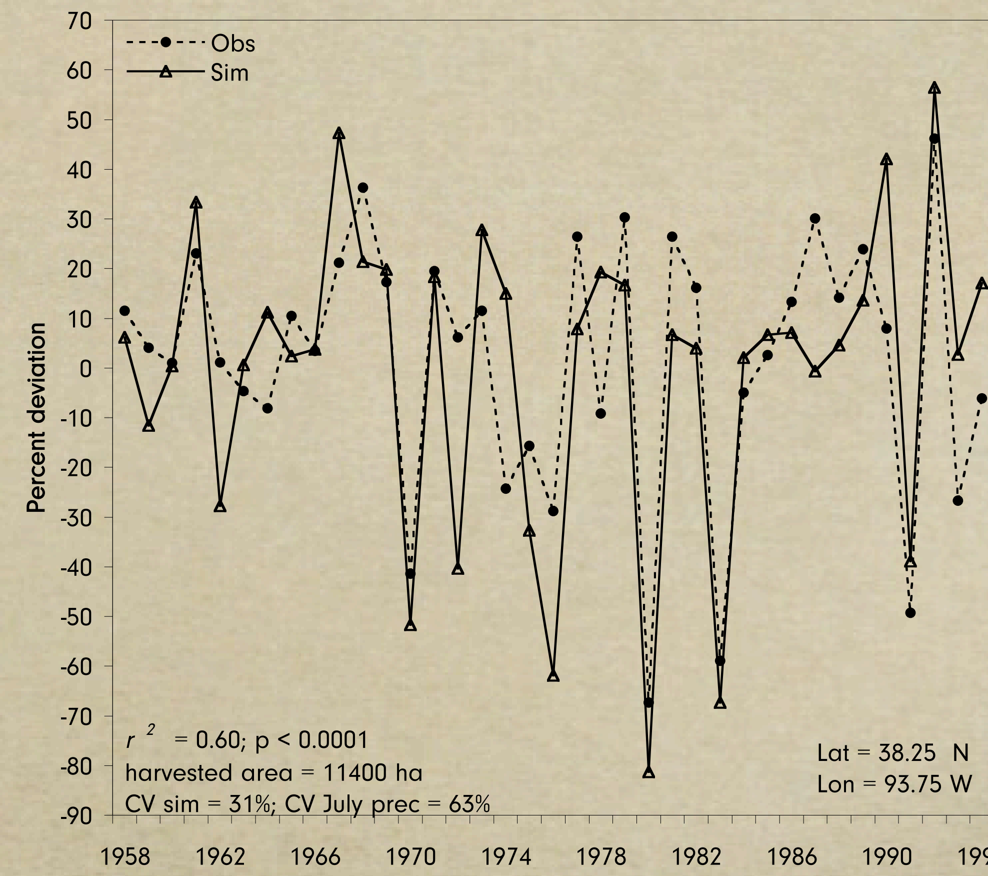
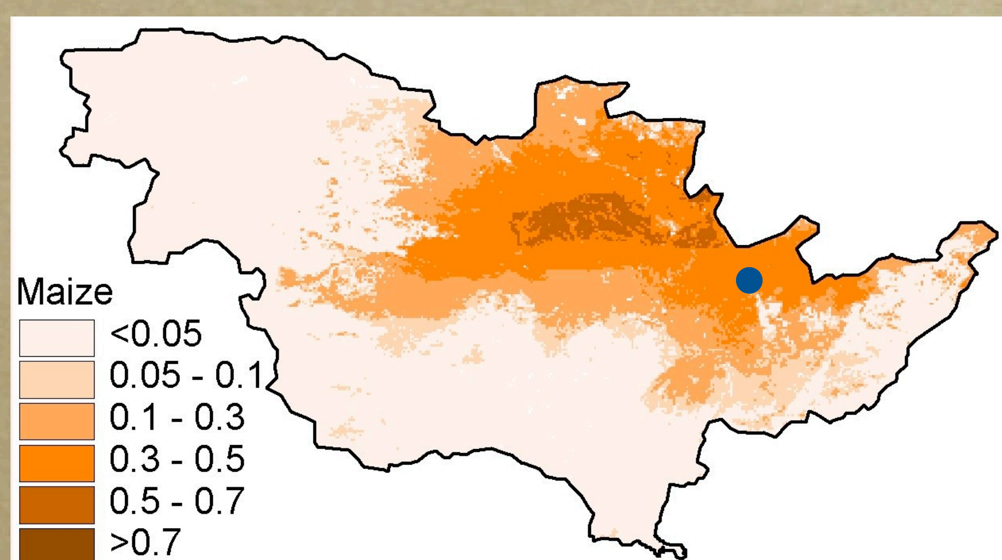
adapted from Donner, *in press;* Leff *et al., submitted;* Ramankutty *et al., in prep*

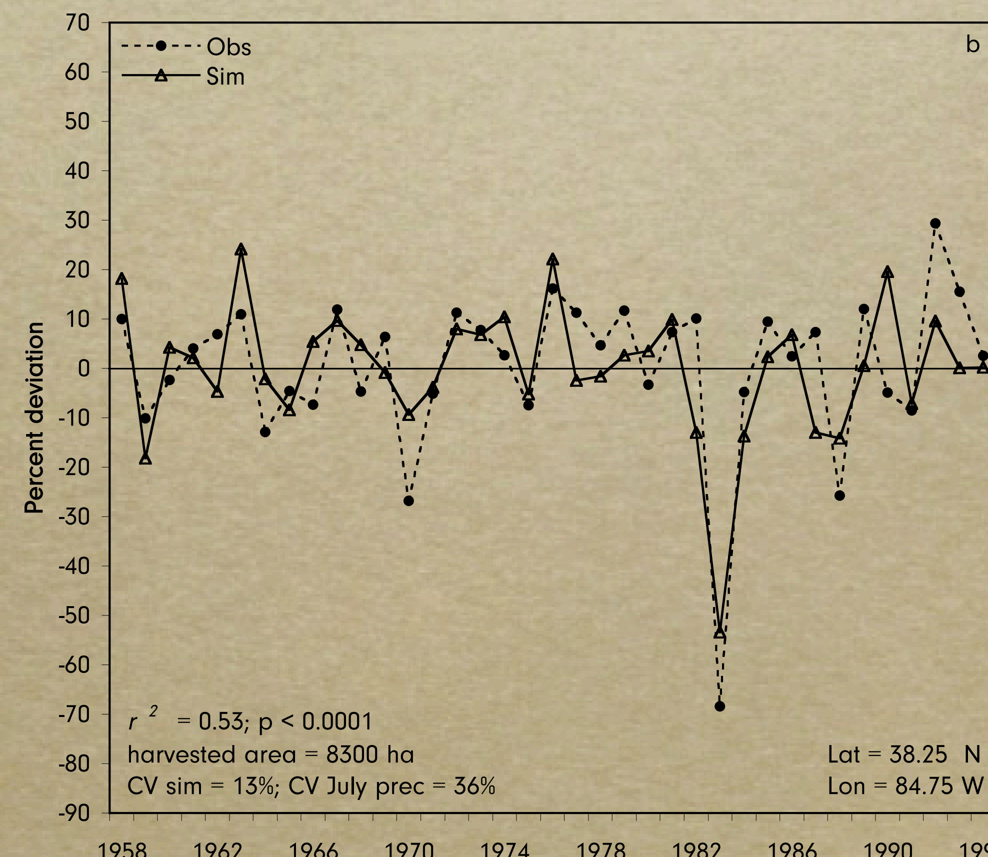
Crop Yields

Effects of Climatic Variability





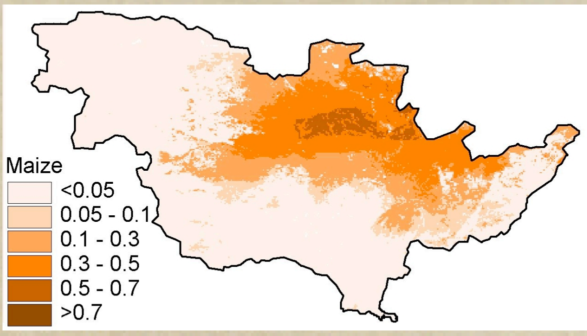




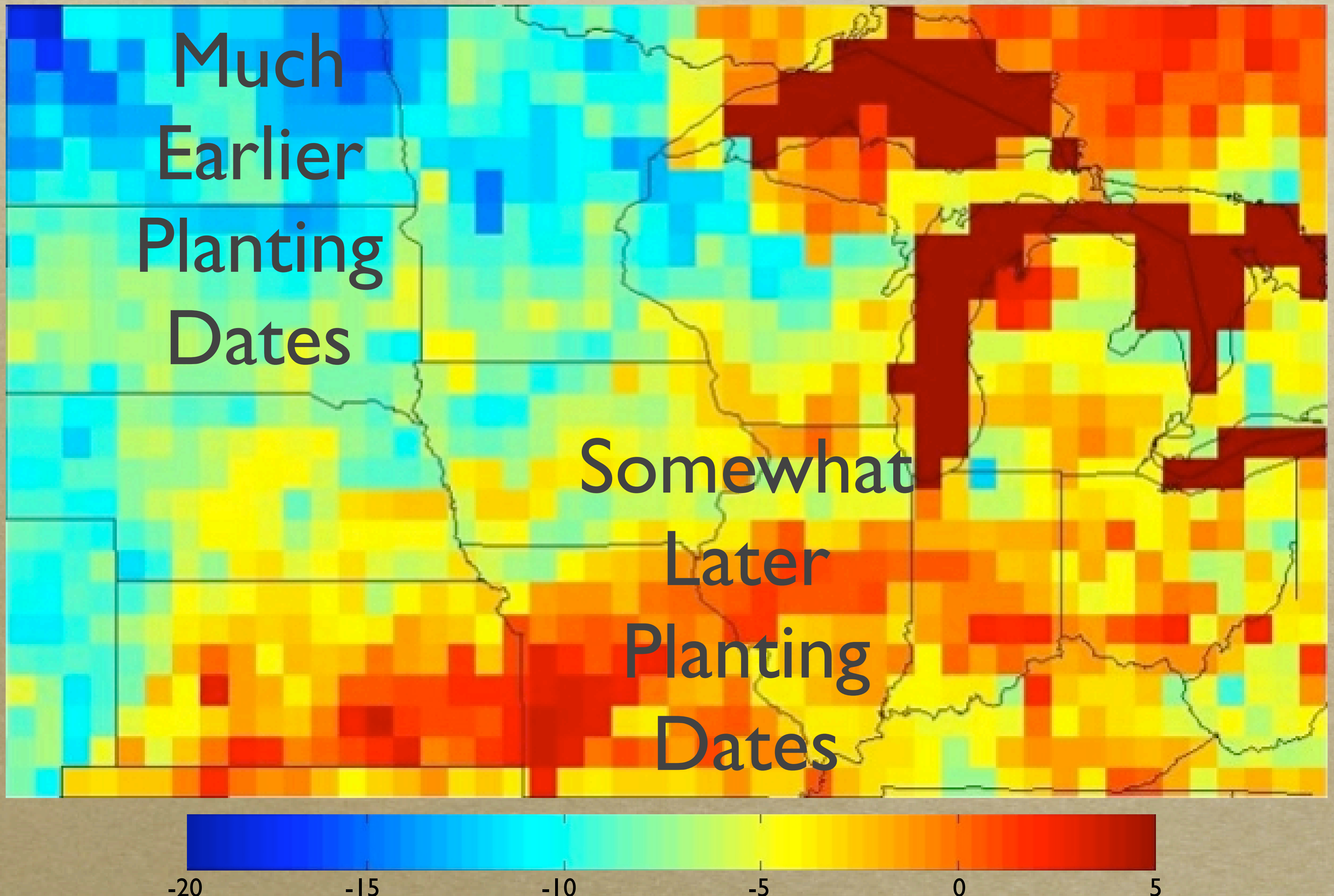
Kucharik et al., *in press*

Crop Yields

Effects of *Decadal* Climatic Variability



Change in Planting Simulated Optimal Planting Date
1990s-1960s



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Crop Yields

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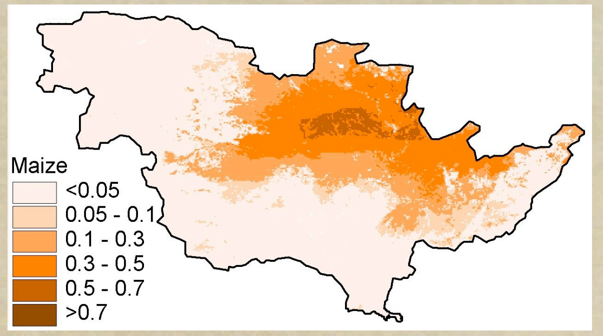
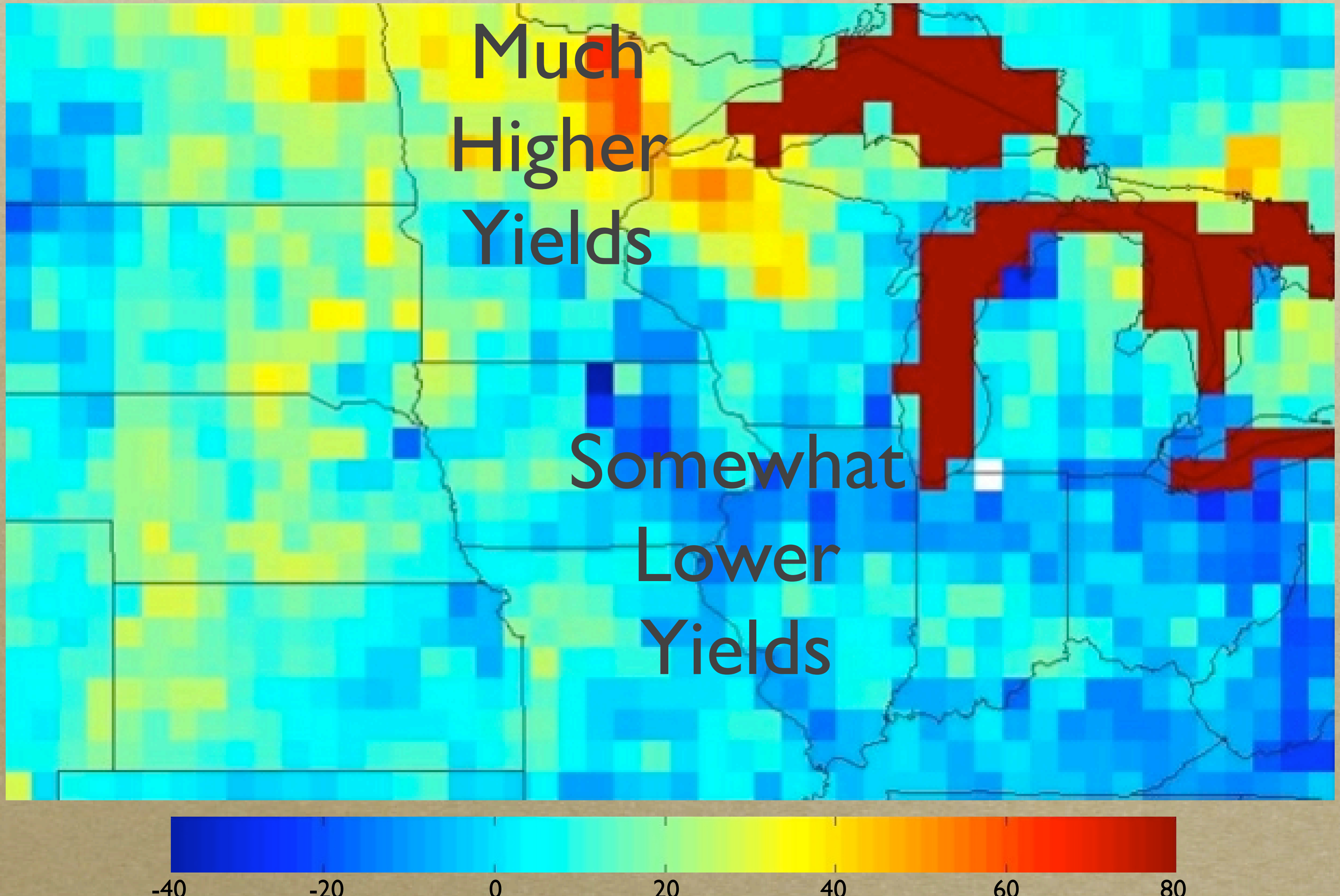


Change in Simulated Yield (1400 GDD Maize)
1990s-1960s



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Kucharik et al., *in press*

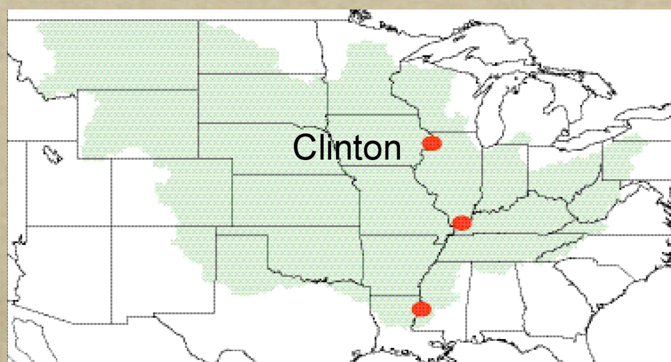
Objective #3

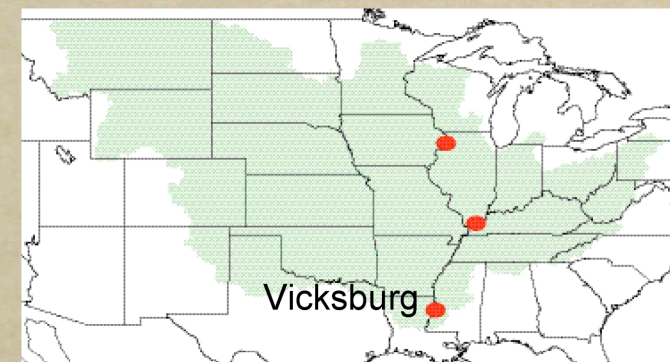
Understanding Changes in Freshwater Resources

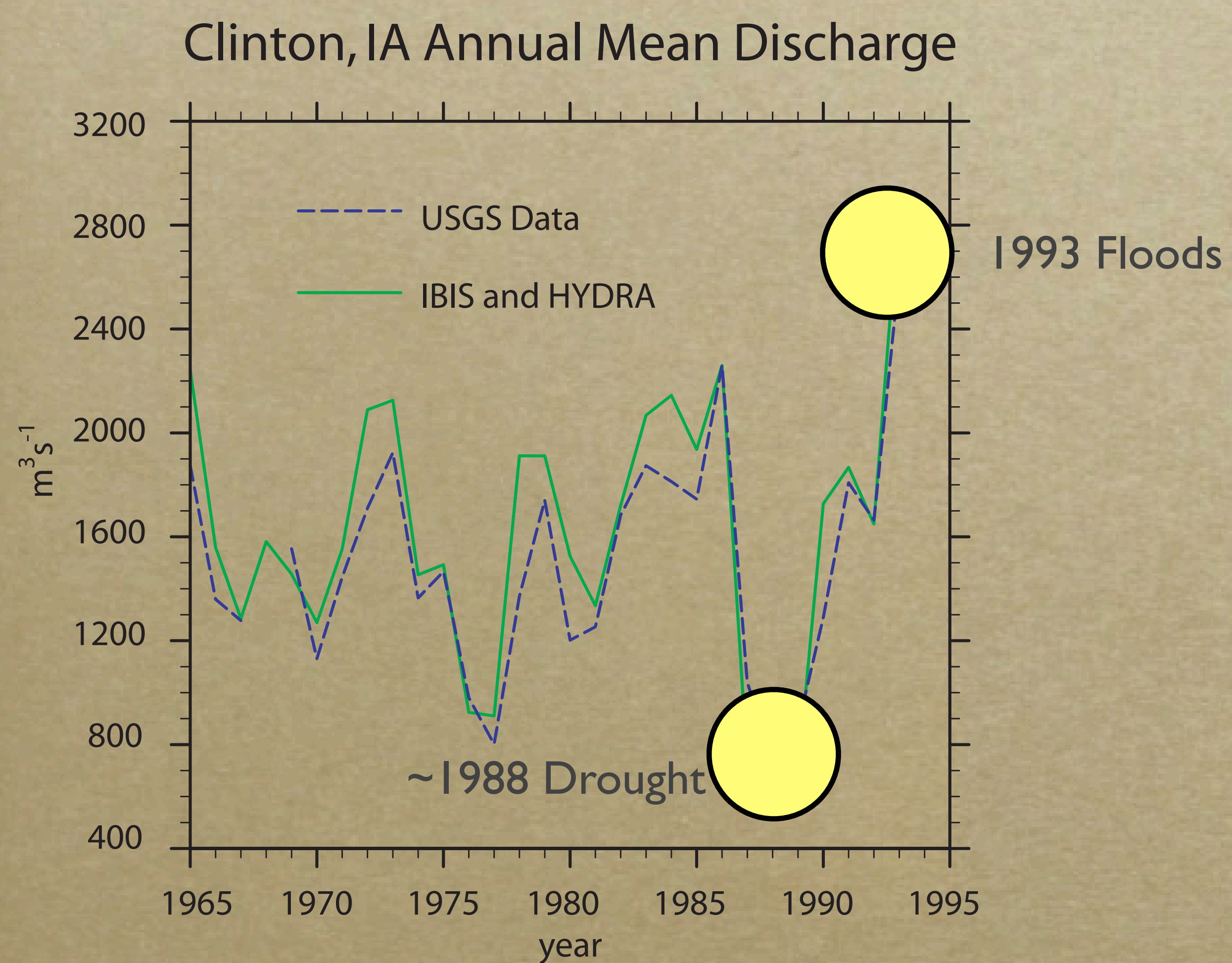
Mississippi Basin

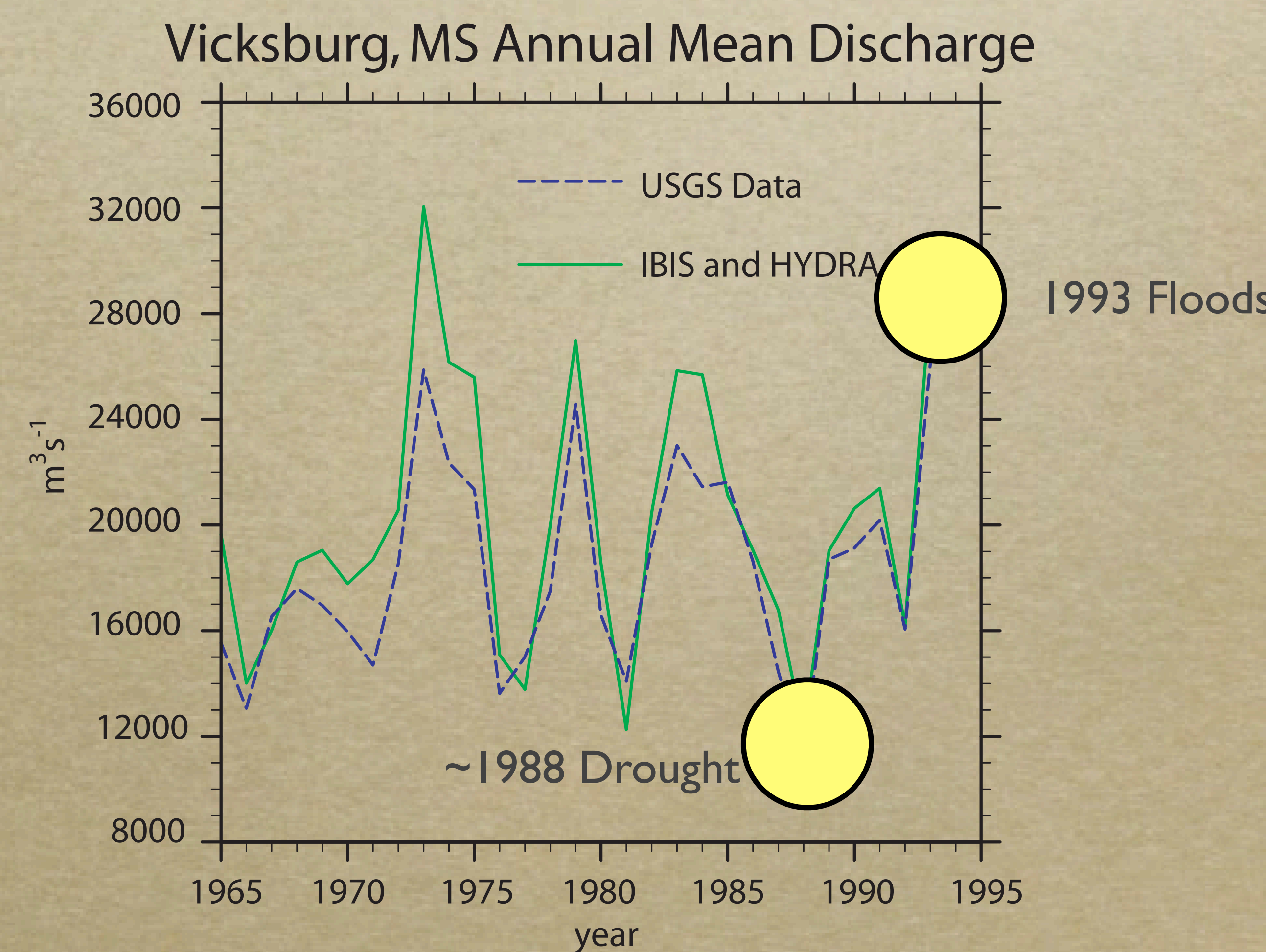
Hydrology of Land and Rivers

Effects of Climatic Variability







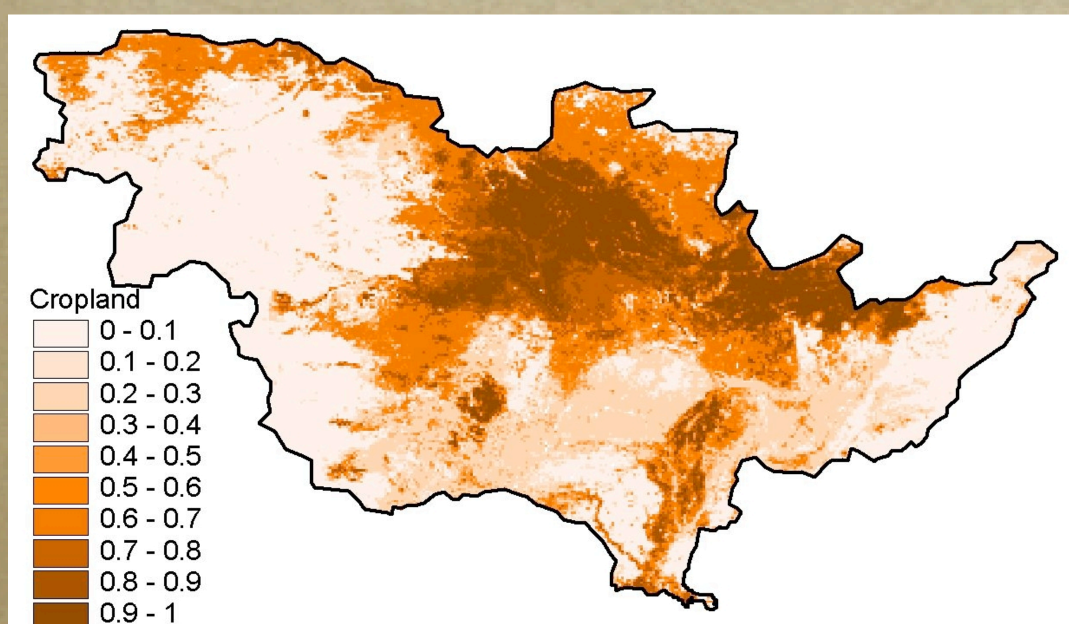


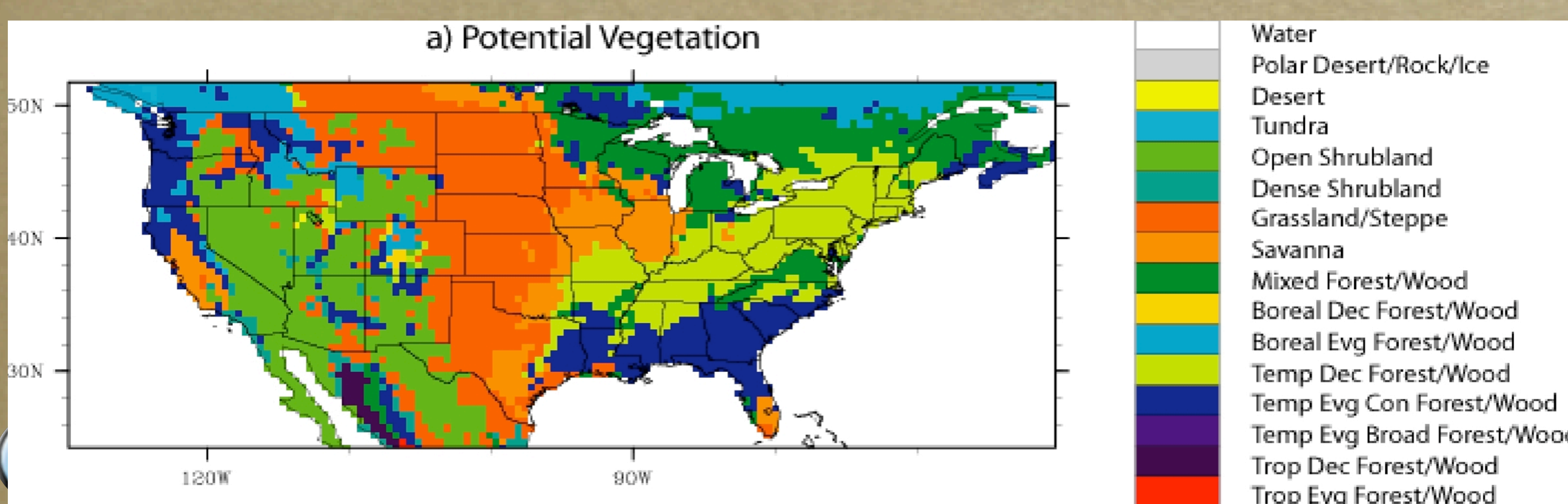
Twine *et al.*, *in prep.*

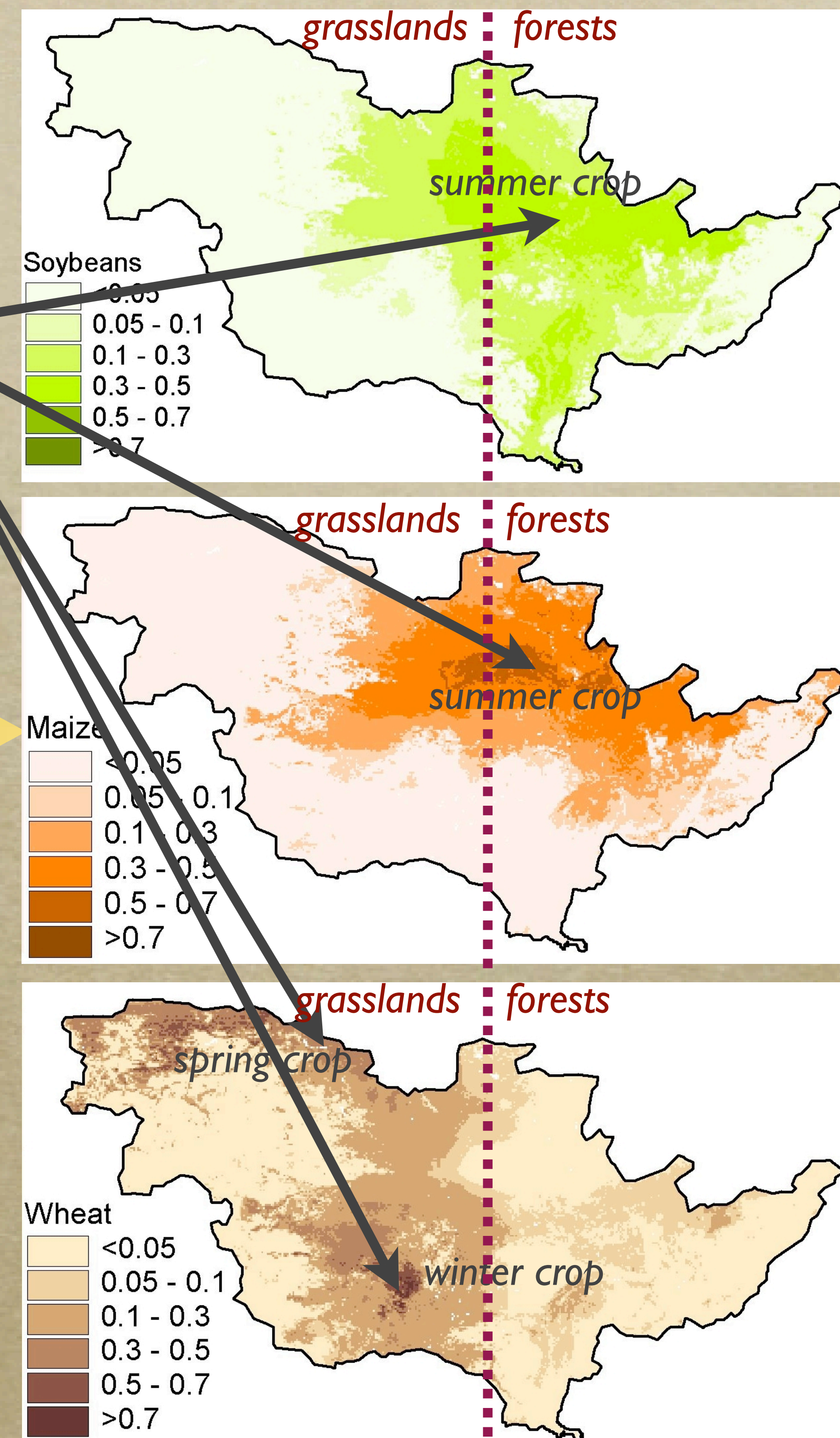
Changes in Water Flow

Sensitivity to Land Cover Change

what happens to evapotranspiration?
what happens to runoff?
what happens to groundwater recharge?

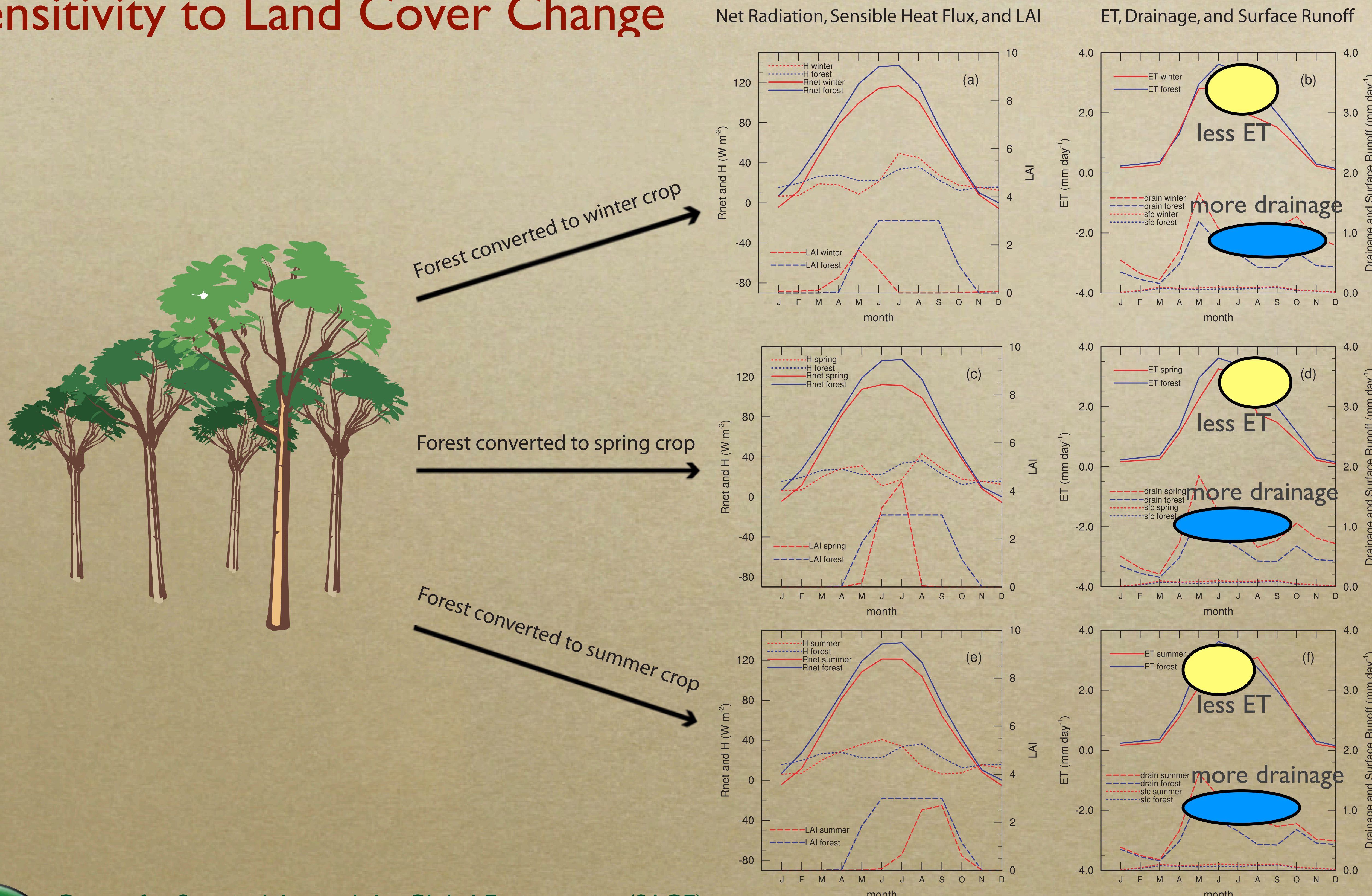






Changes in Water Flow

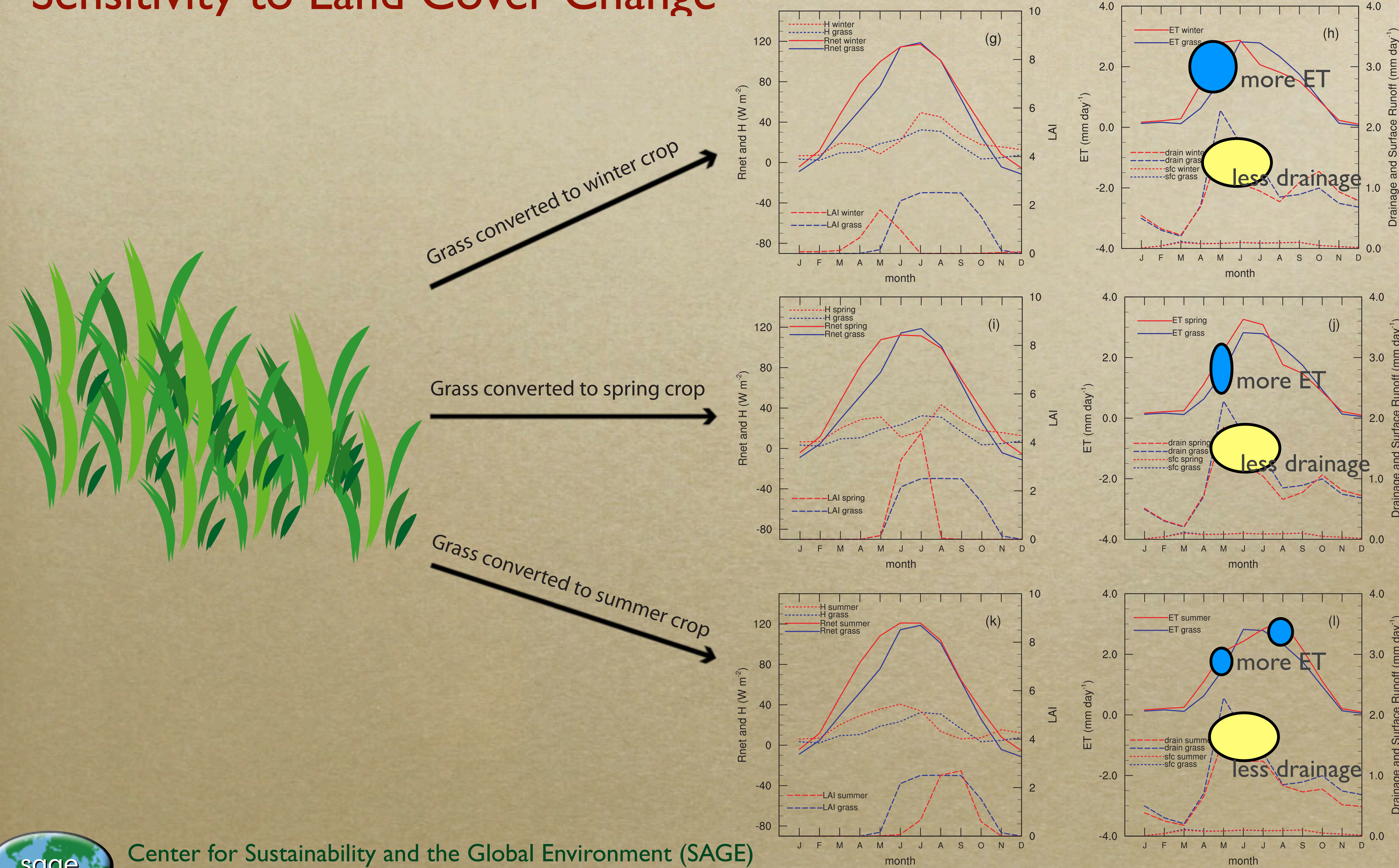
Sensitivity to Land Cover Change



Twine *et al.*, 2004

Changes in Water Flow

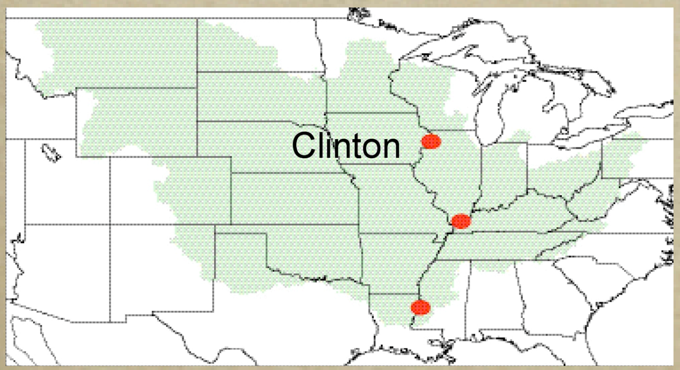
Sensitivity to Land Cover Change



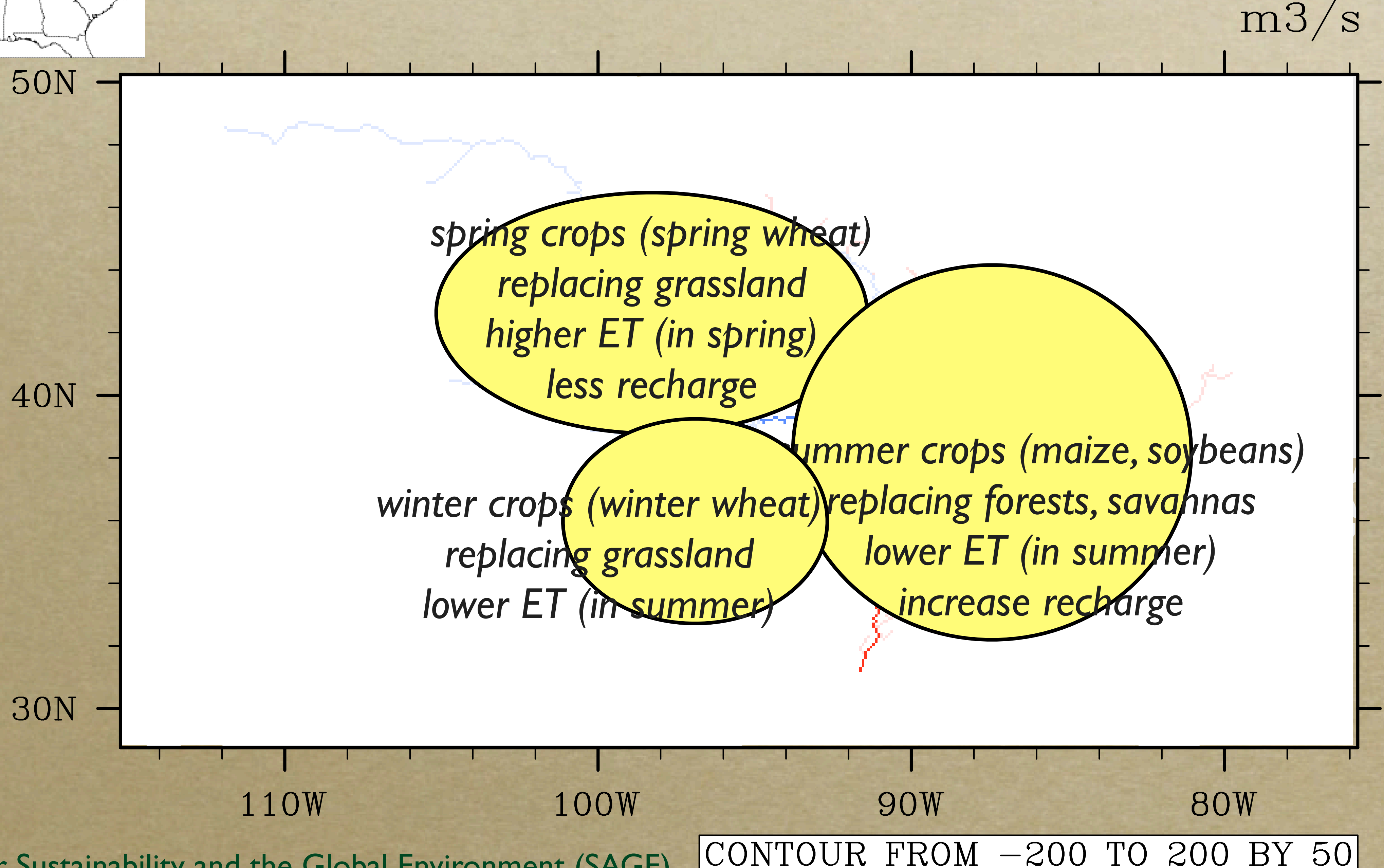
Twine *et al.*, 2004

Changes in Water Flow

Sensitivity to Land Cover Change



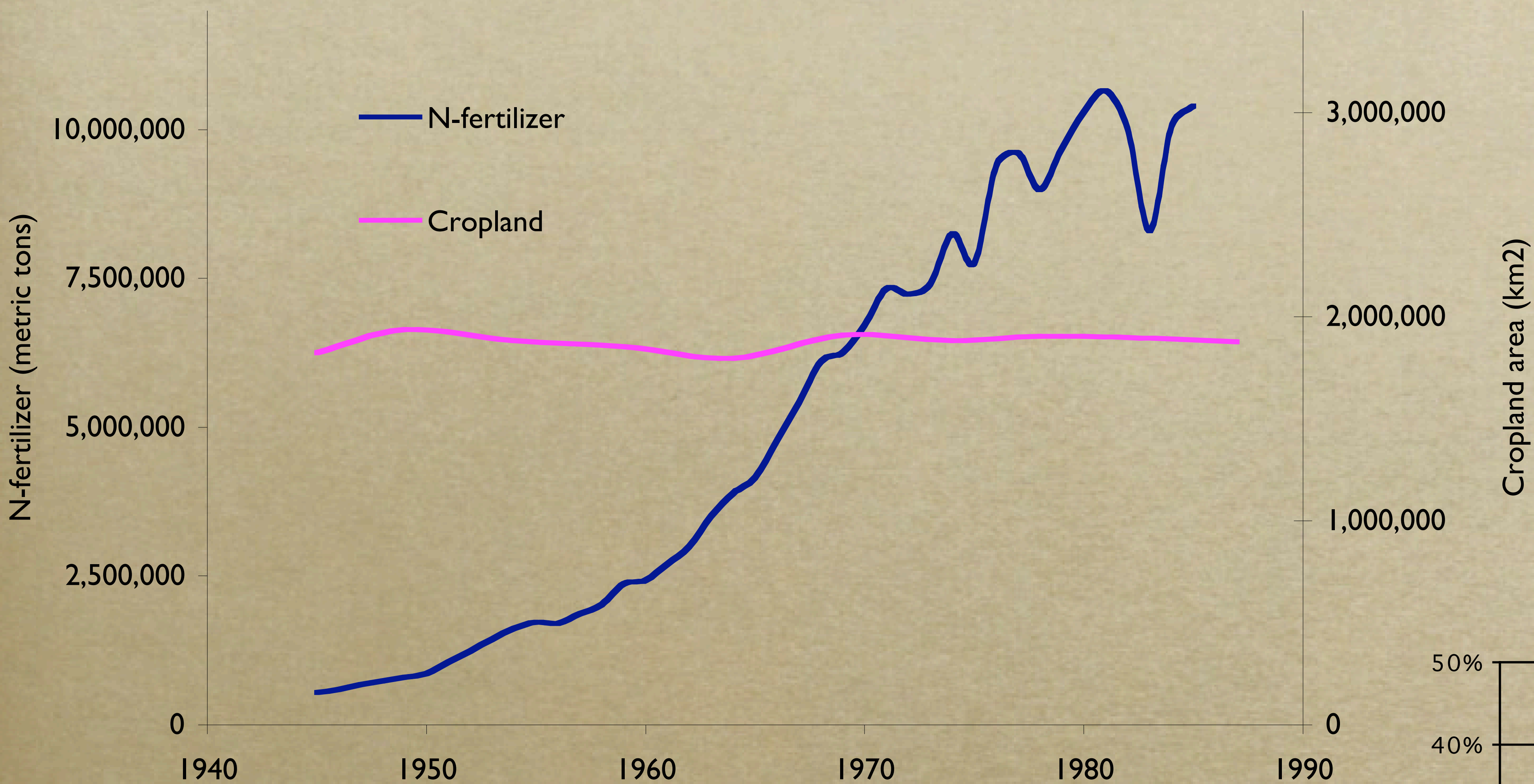
Change in Annual Streamflow 1931-1995

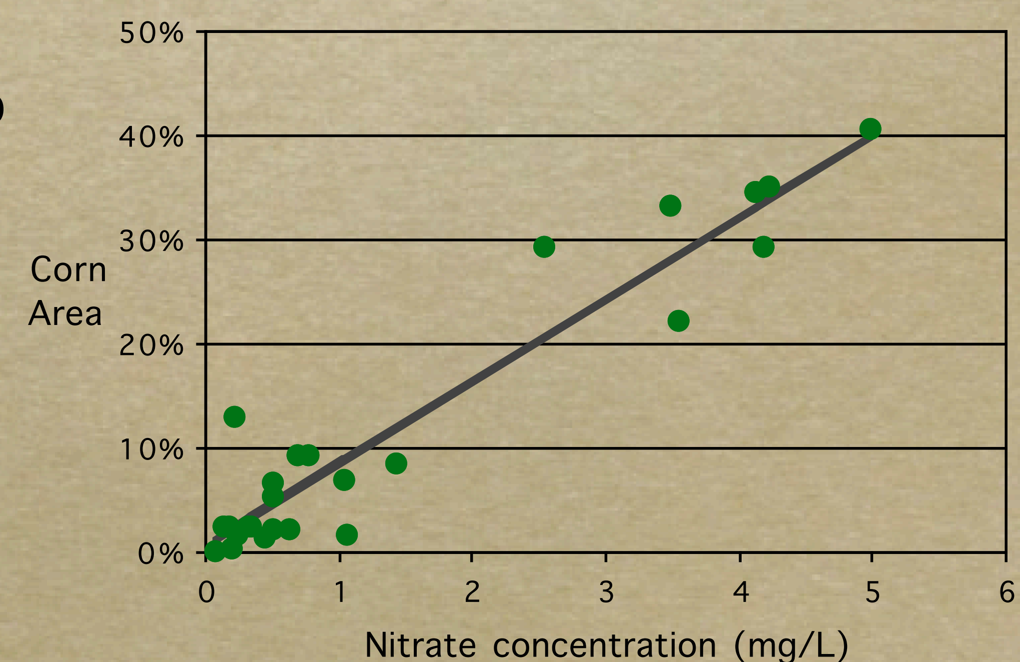


Twine *et al.*, submitted

Nitrogen and Water Quality

A "Good" Thing, Right?





Donner *et al.*, 2004

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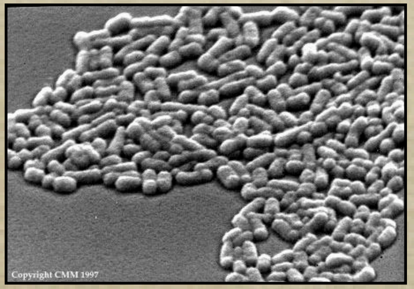
Nitrate

Too Much of a Good Thing...

Impacts of aquatic N loading

Coastal environment
- destruction of fisheries, change in community structure

Human health
- high NO_3 levels in groundwater, toxic algal blooms

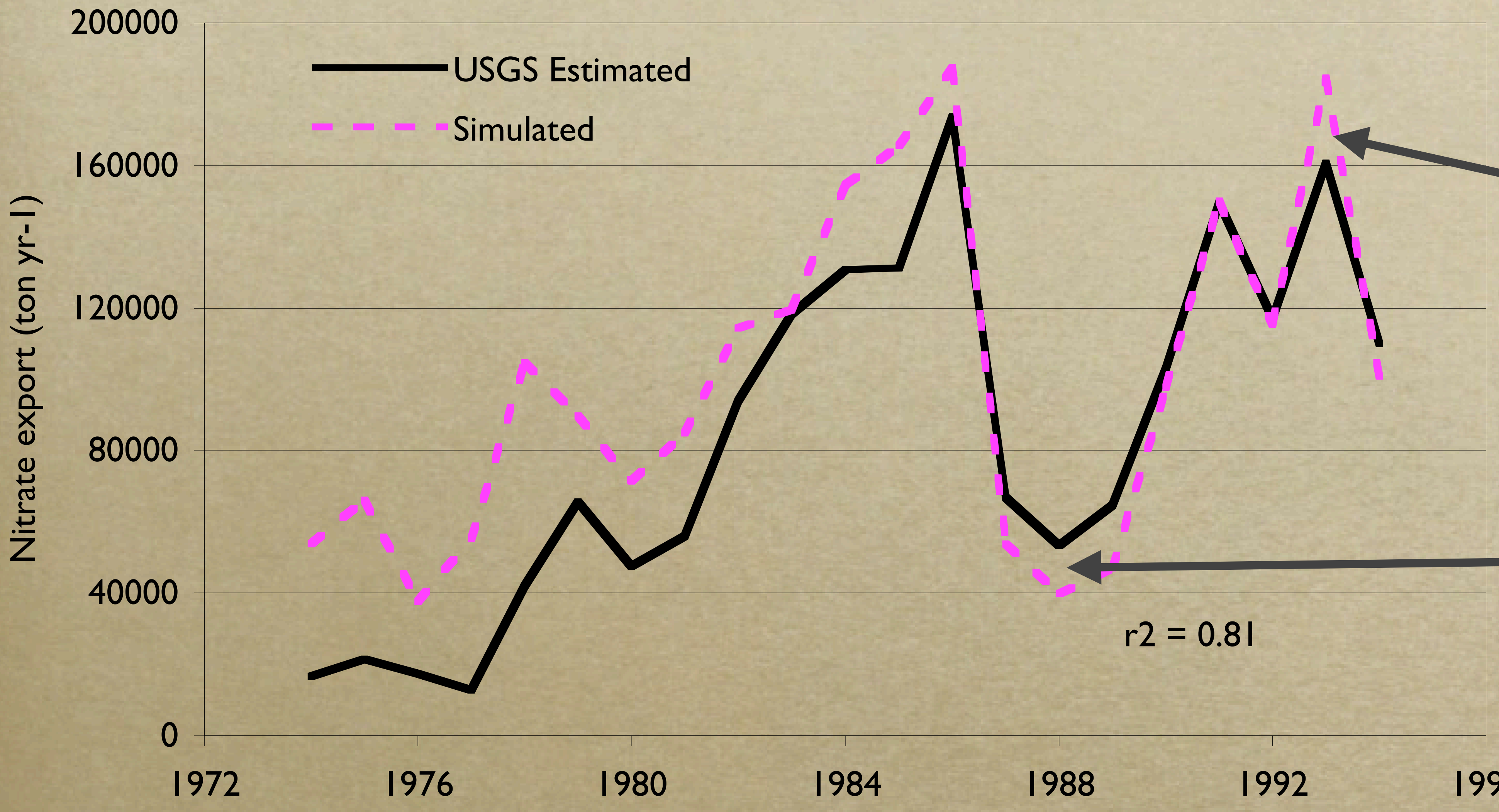


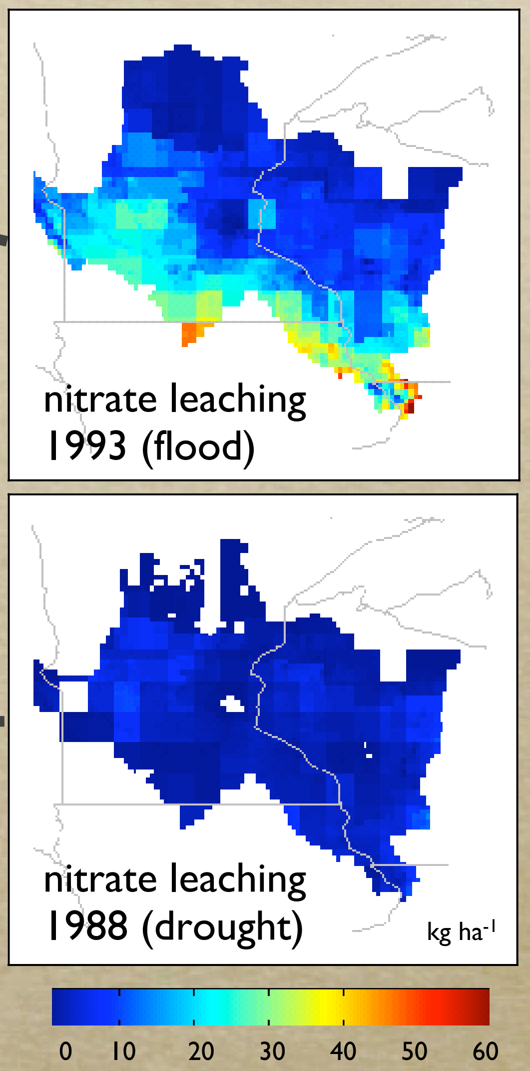
Atmosphere
- increased emission of N_2O, a powerful greenhouse gas

Economy
- hypoxia damages fisheries and tourism (eg. Black sea)
- nitrate represents a loss from agriculture and industry

Nitrate in the Mississippi

Pinning Down "Hot Spots"



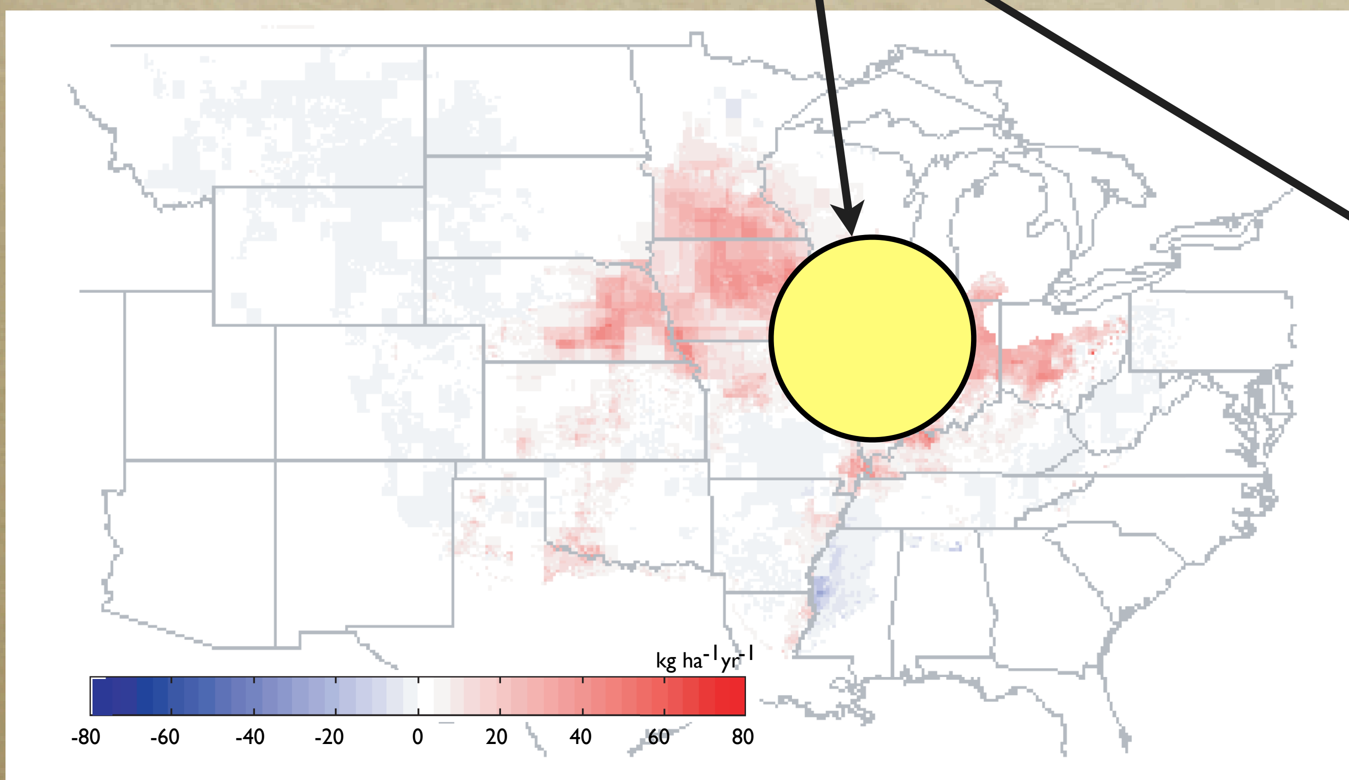


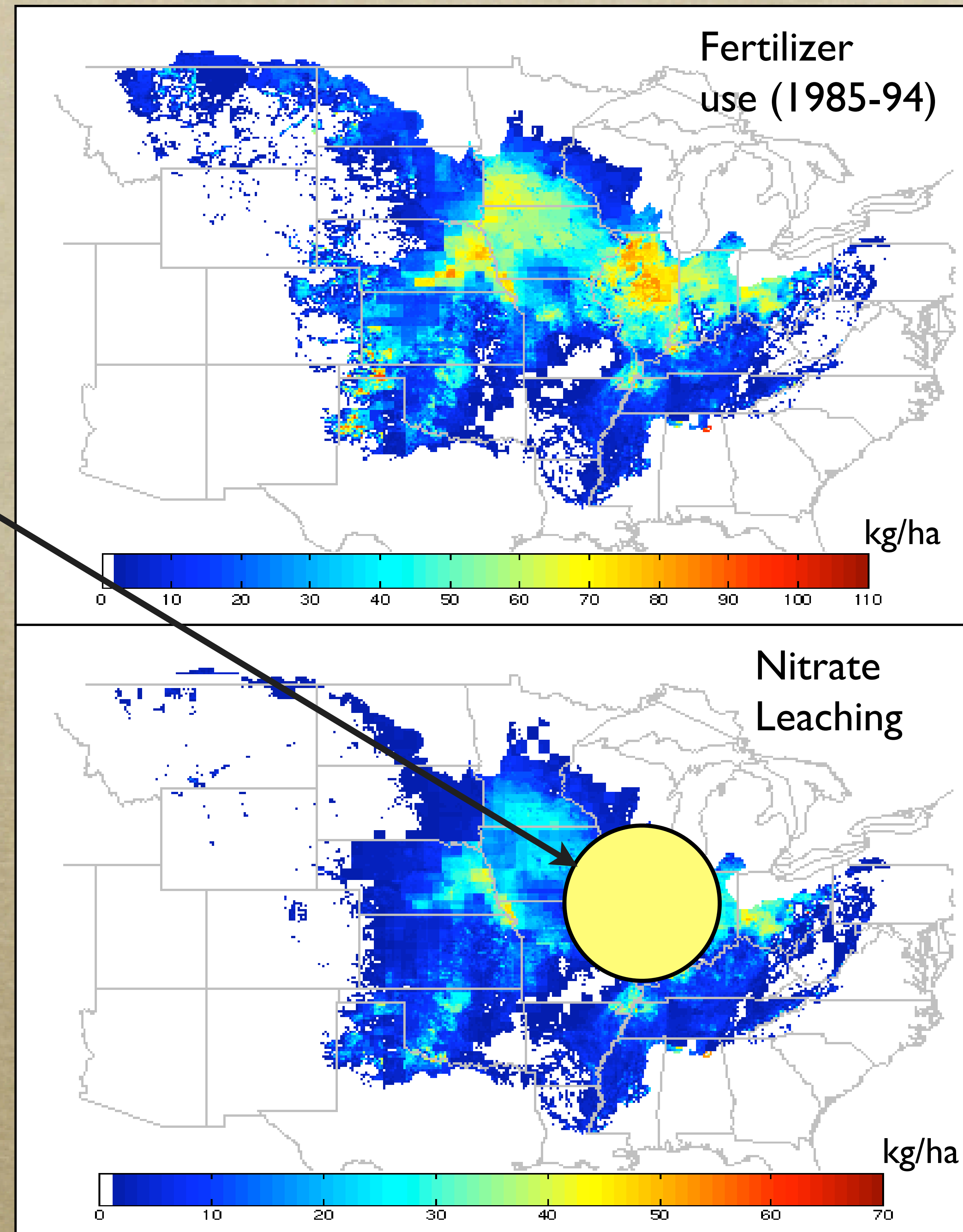
Nitrate in the Mississippi

Pinning Down "Hot Spots"

increasing fertilizer inputs and wet, highly variable climate

Change in DIN Leaching: 1990-1994 minus 1960-1964

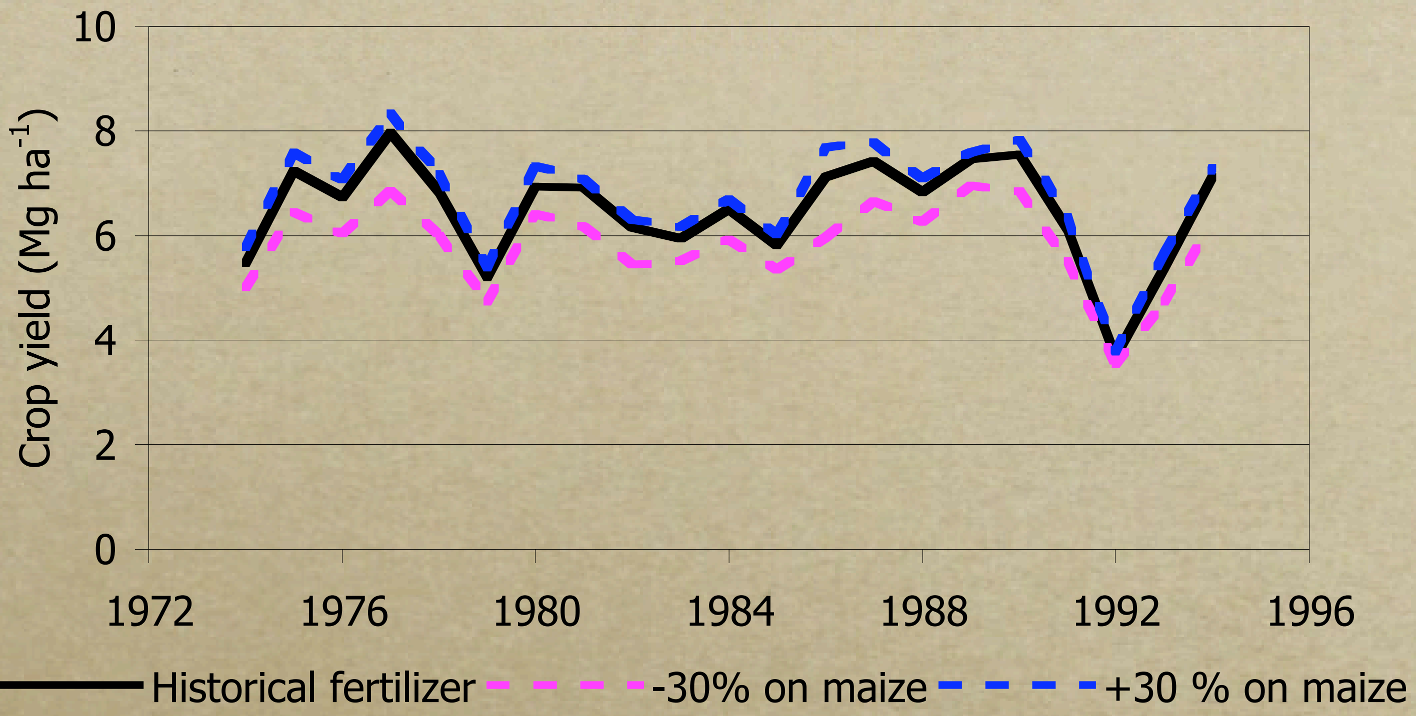


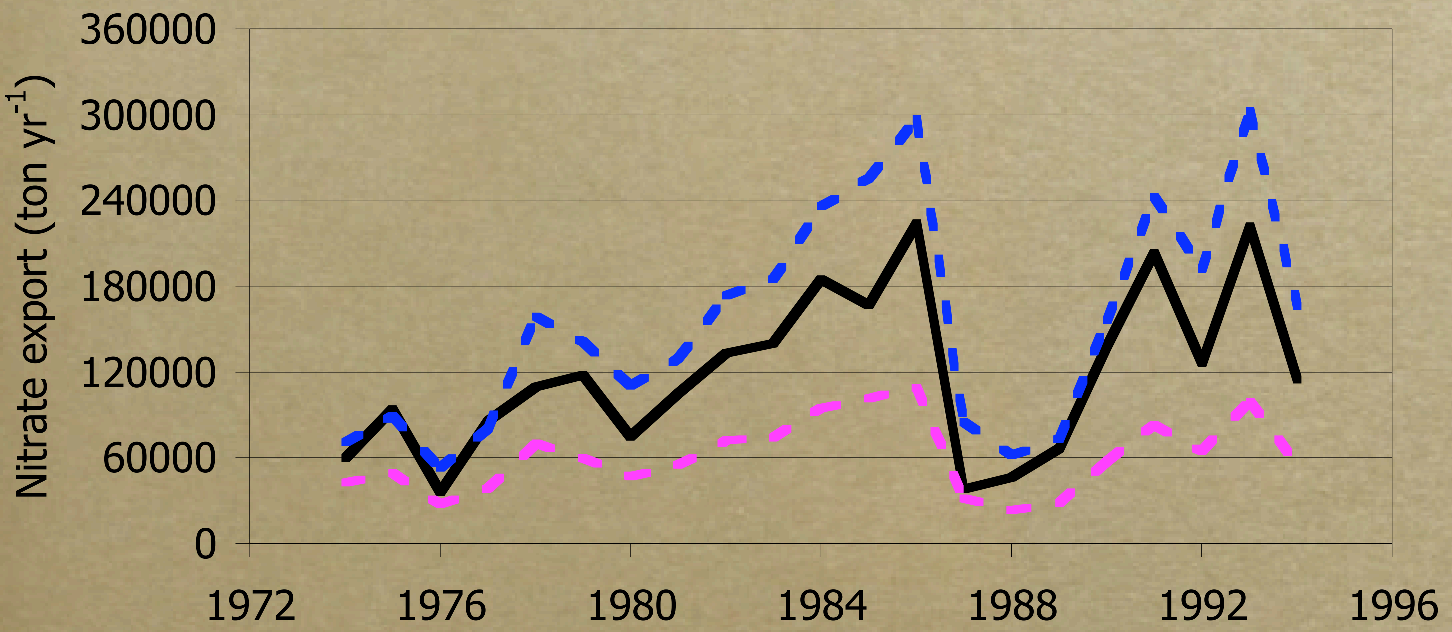


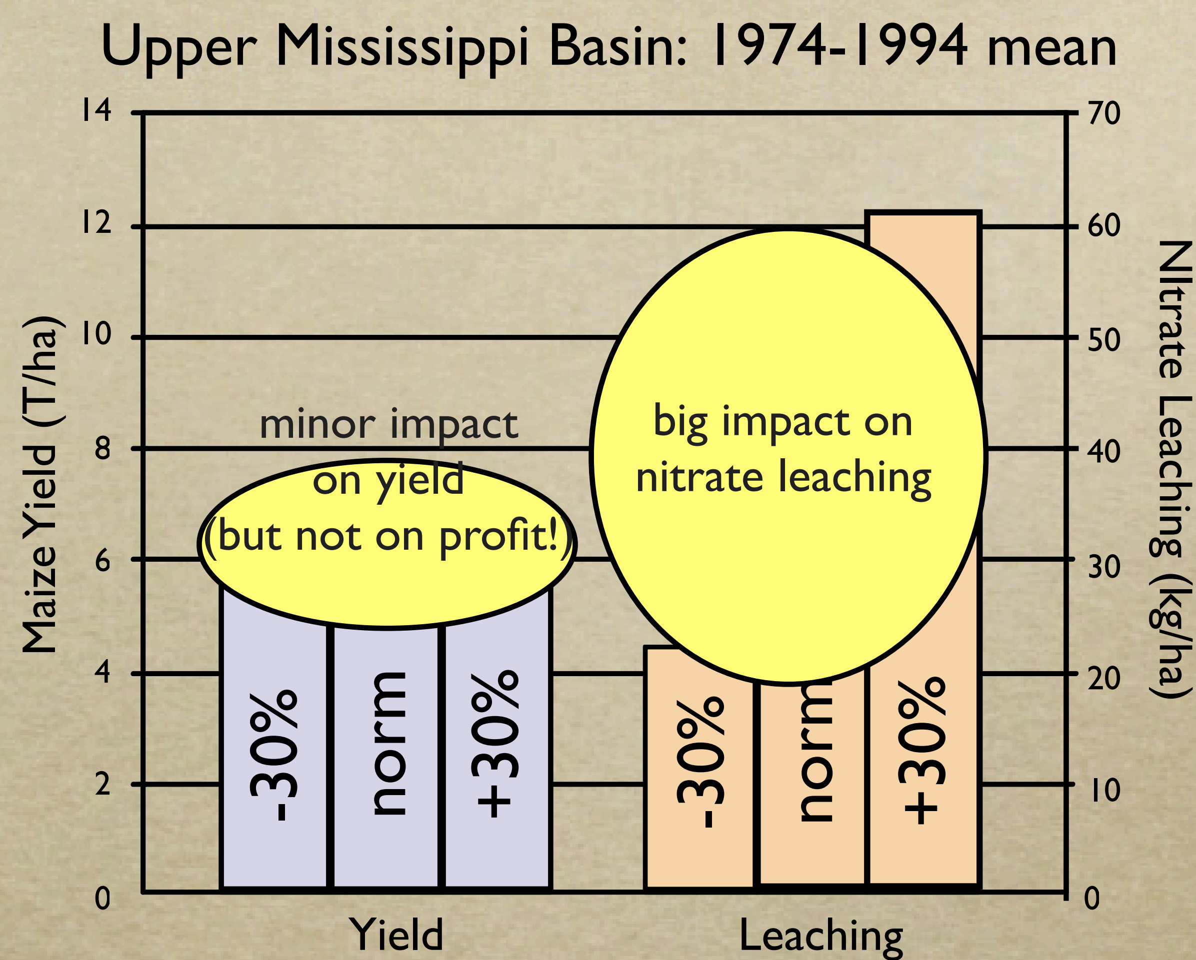
Donner *et al.*, 2004

Nitrate - Yield *versus* Water

A Potential Policy Action







a potential lever?
how can the economics be made to work?

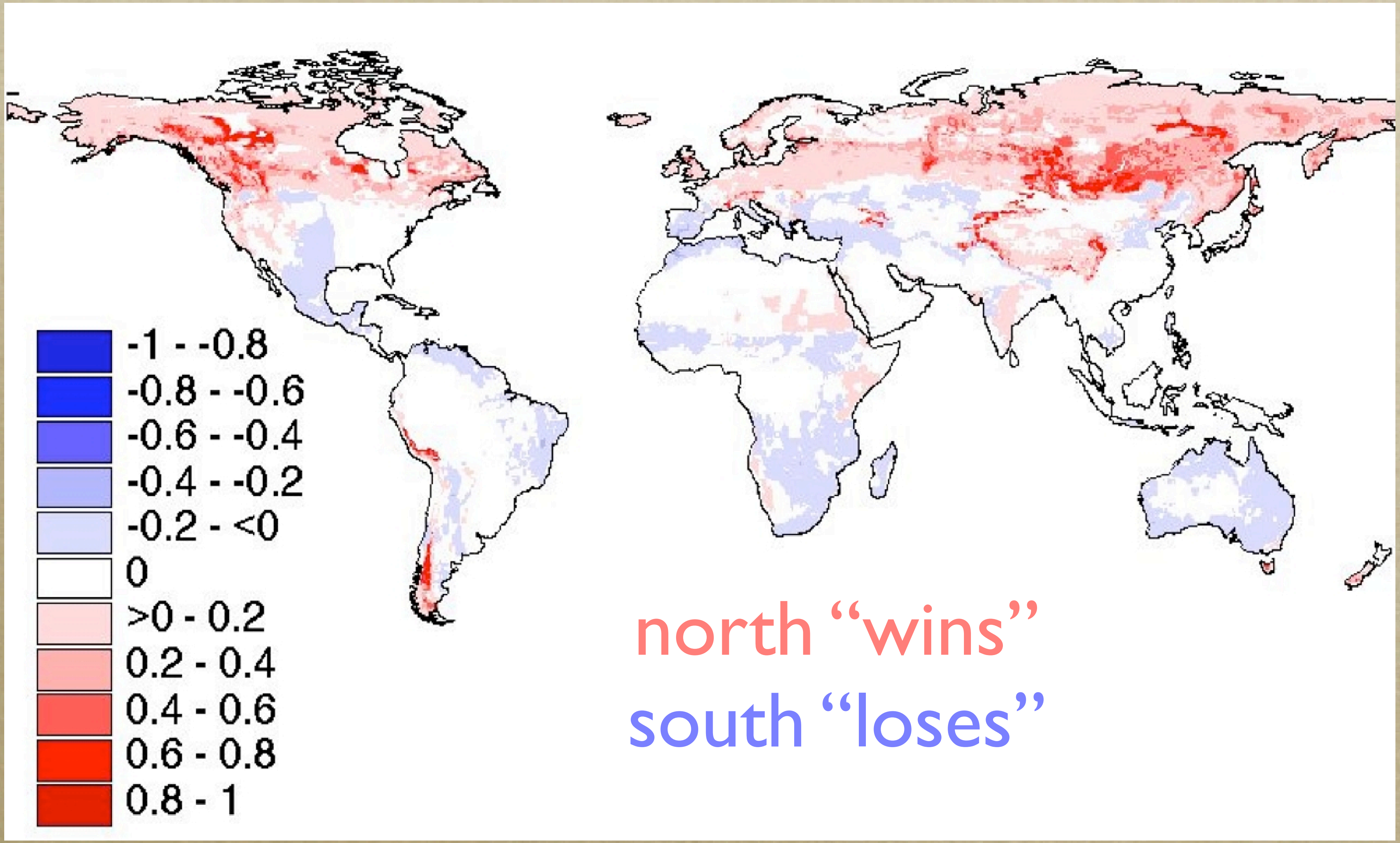
Objective #4

Exploring Global Responses to Agricultural Change

Evaluating Changes in Global Ecosystem Services

Future Climate Change?

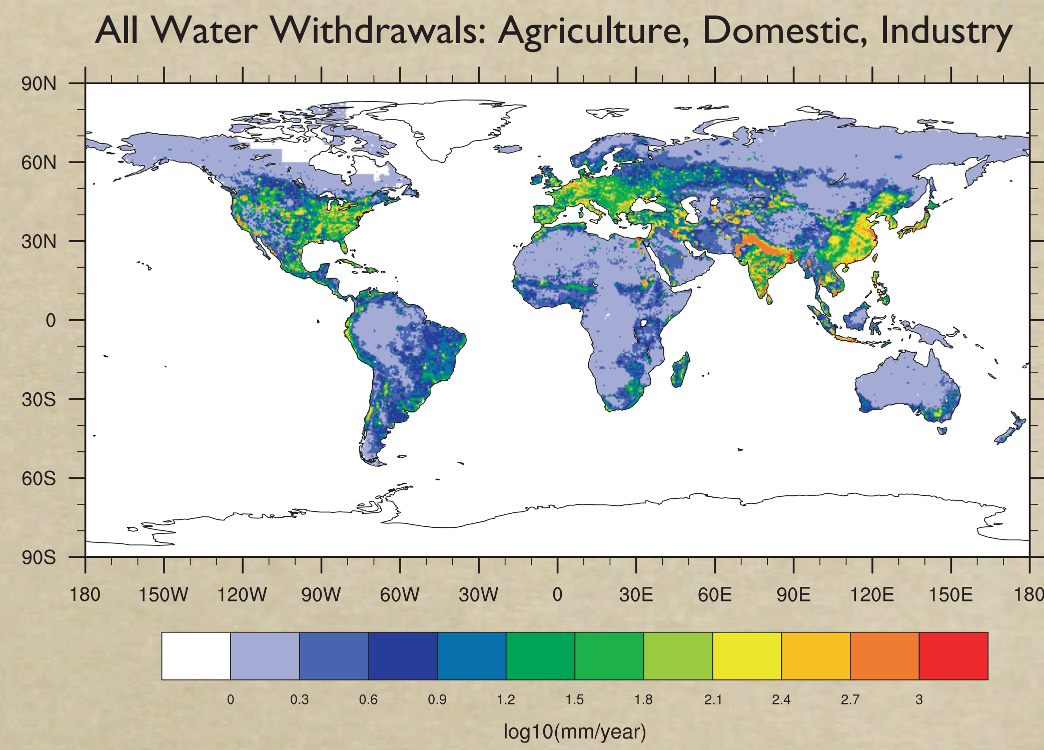
- changes in agricultural production?

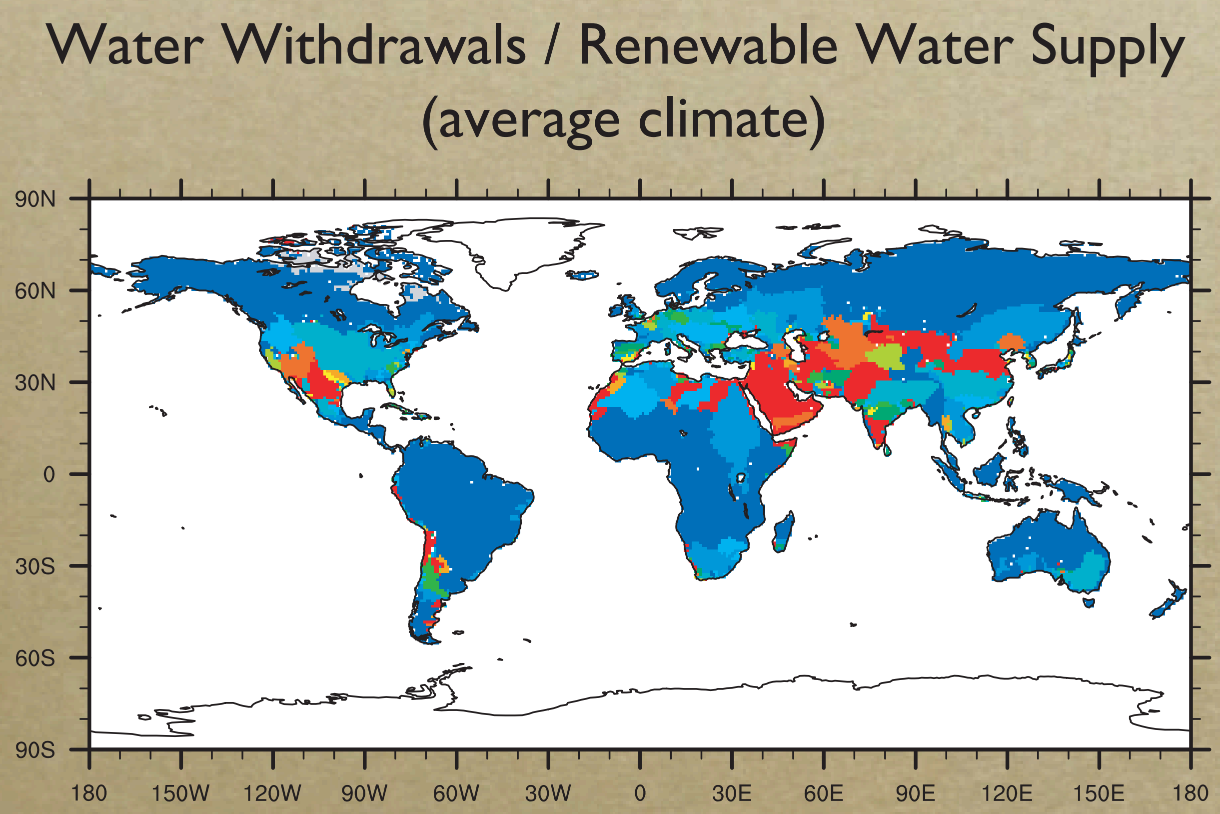


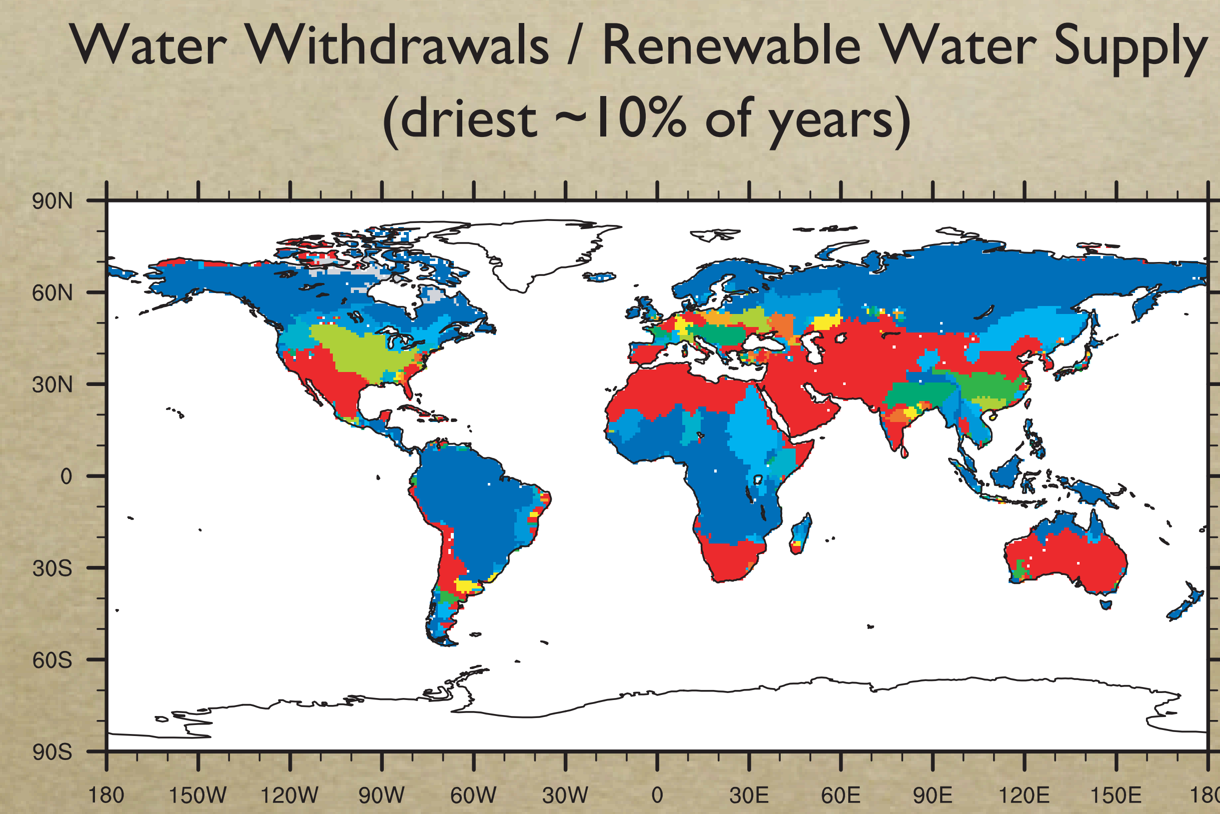
Source: Ramankutty et al., 2002

Water Resources

Effects of Water Use, Climate







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Source: J. Helkowski, M.S. Thesis, University of Wisconsin, 2004

Bottom Line

Big Questions

- how are large regions changing from agriculture?
  - *multiple dimensions*
  - *focus on human welfare*

- changing ability to provide multiple ecosystem goods and services?
  - *provide agricultural, forest goods*
  - *maintain water flows, water chemistry*
  - *store carbon, modulate regional climate*
  - *mitigate disease transmission*

- feedbacks to larger earth system?