Land Cover and Land Use Change and its Effects on Carbon Dynamics in Monsoon Asia Region

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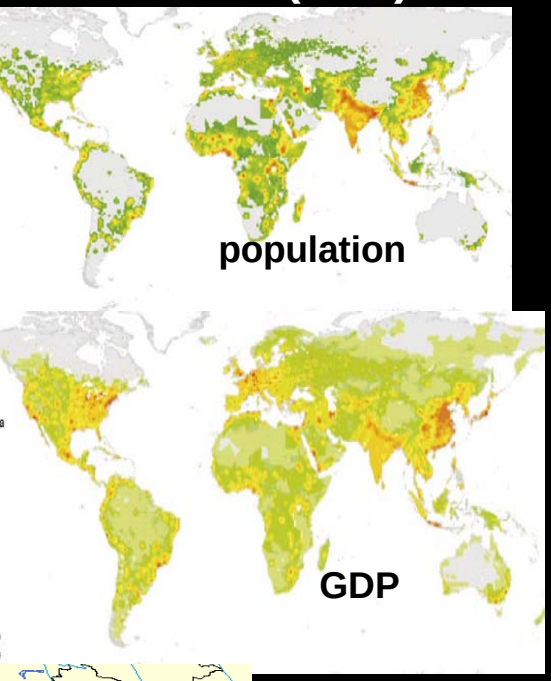
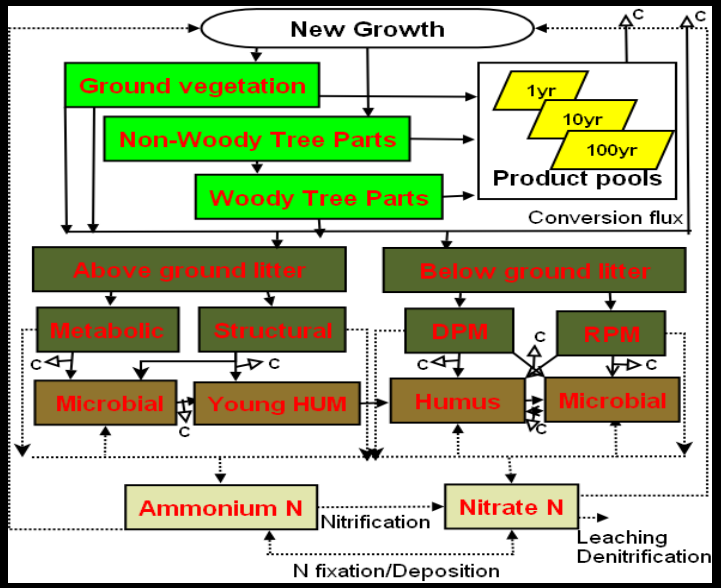
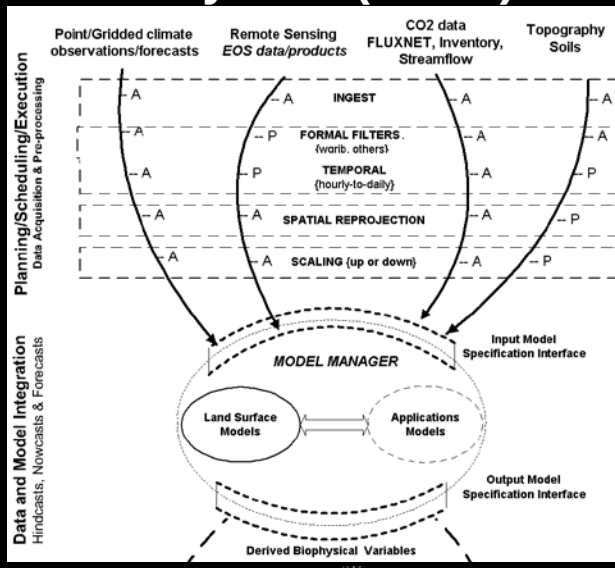
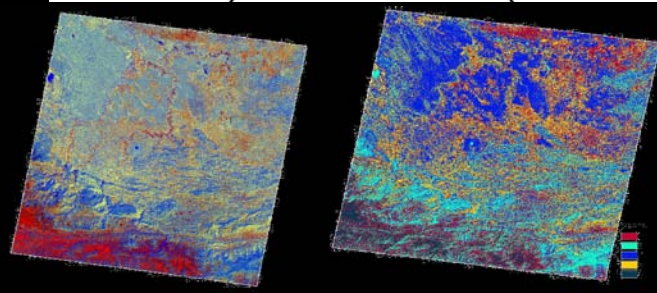
Terrestrial Ecosystems, Land Use Changes and Carbon Dynamics

Socio-Economic Model (PET) ⟷ ISAM Model ⟷ The Terrestrial Observation and Prediction System (TOPS)

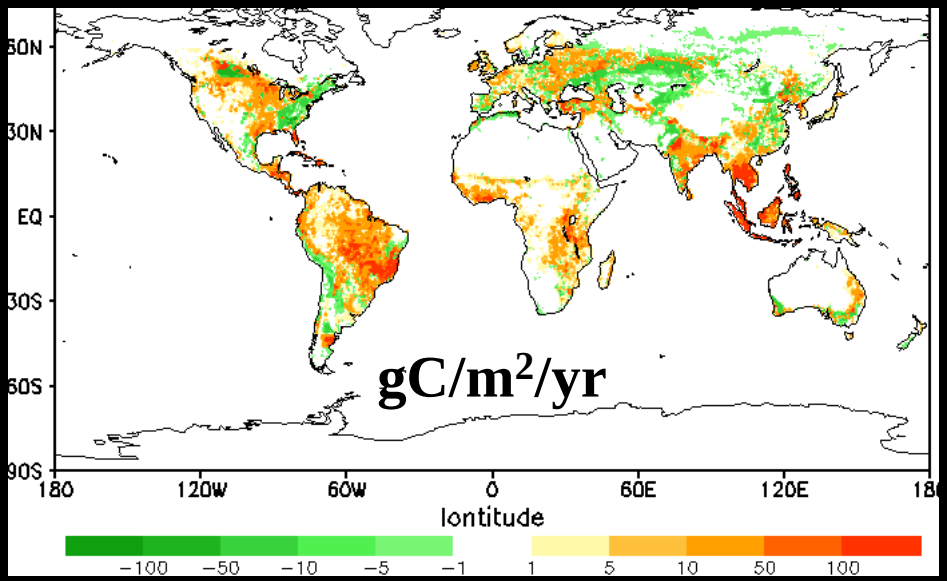




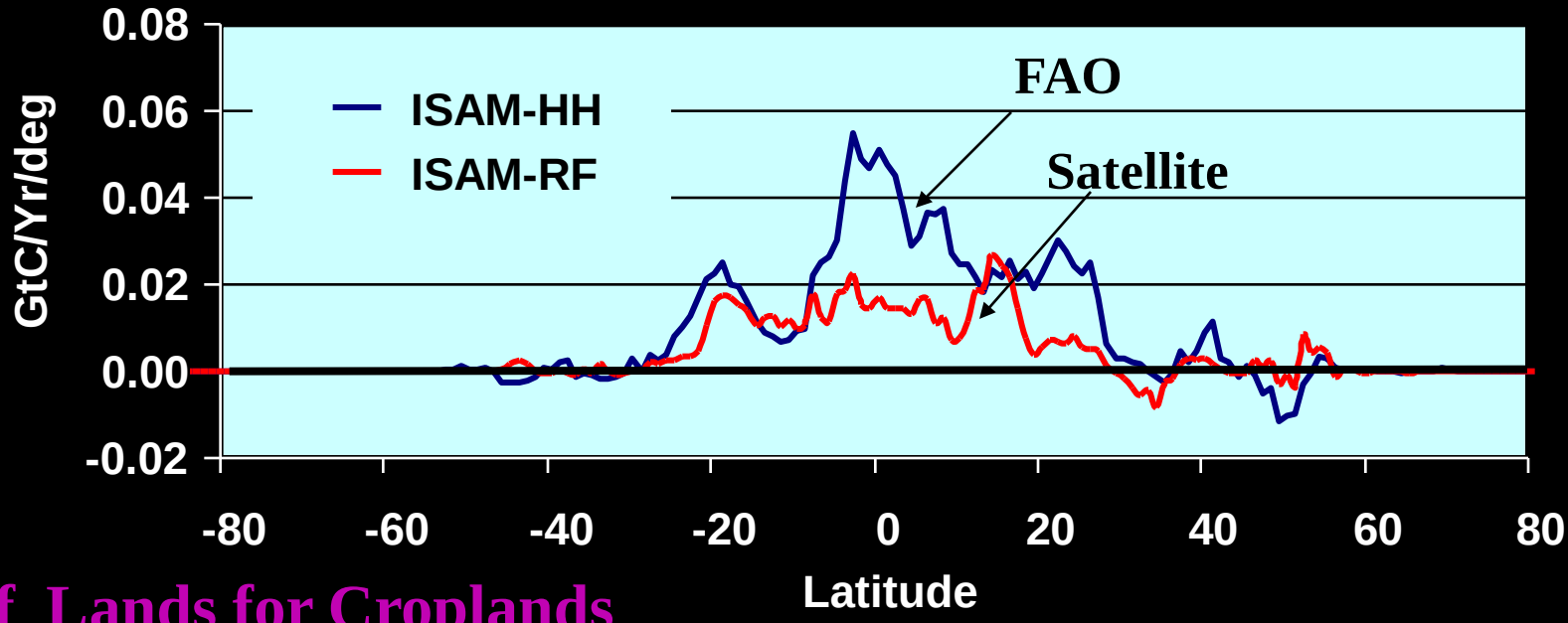




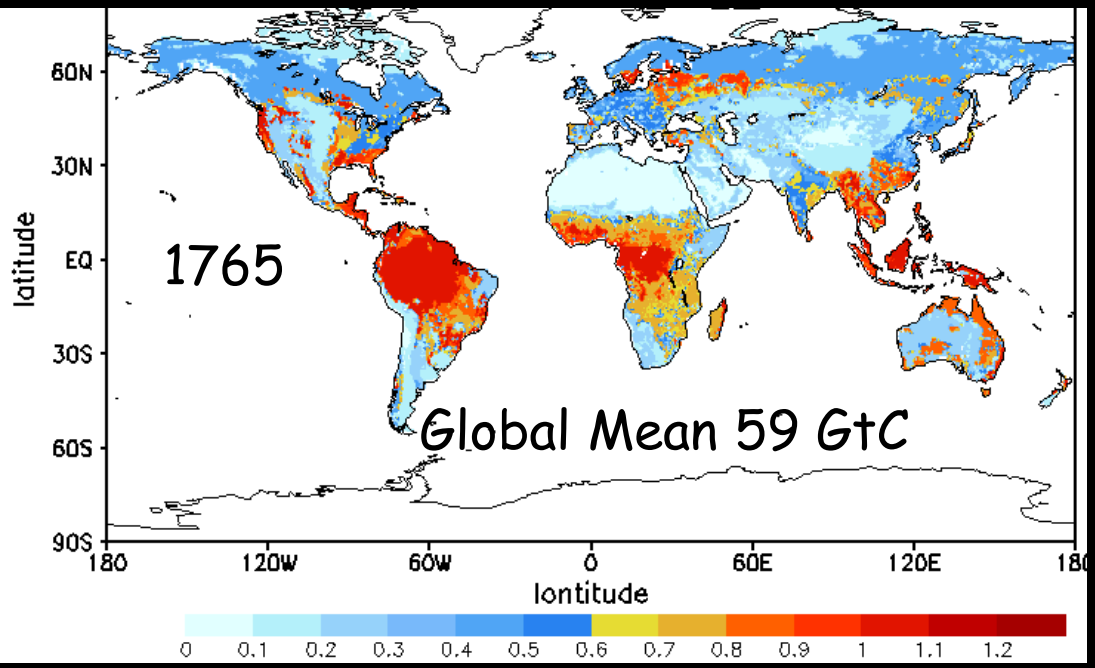
ISAM Estimated Land Use Emissions (1980s*)



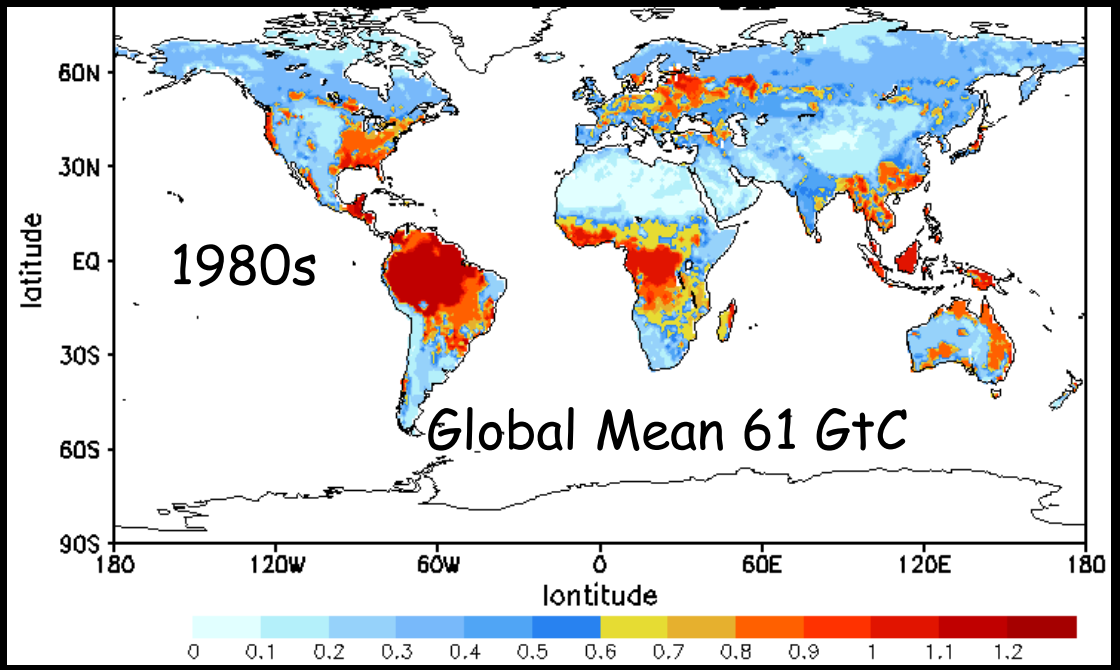
Jain and Yang (2005)



*Clearing of Lands for Croplands

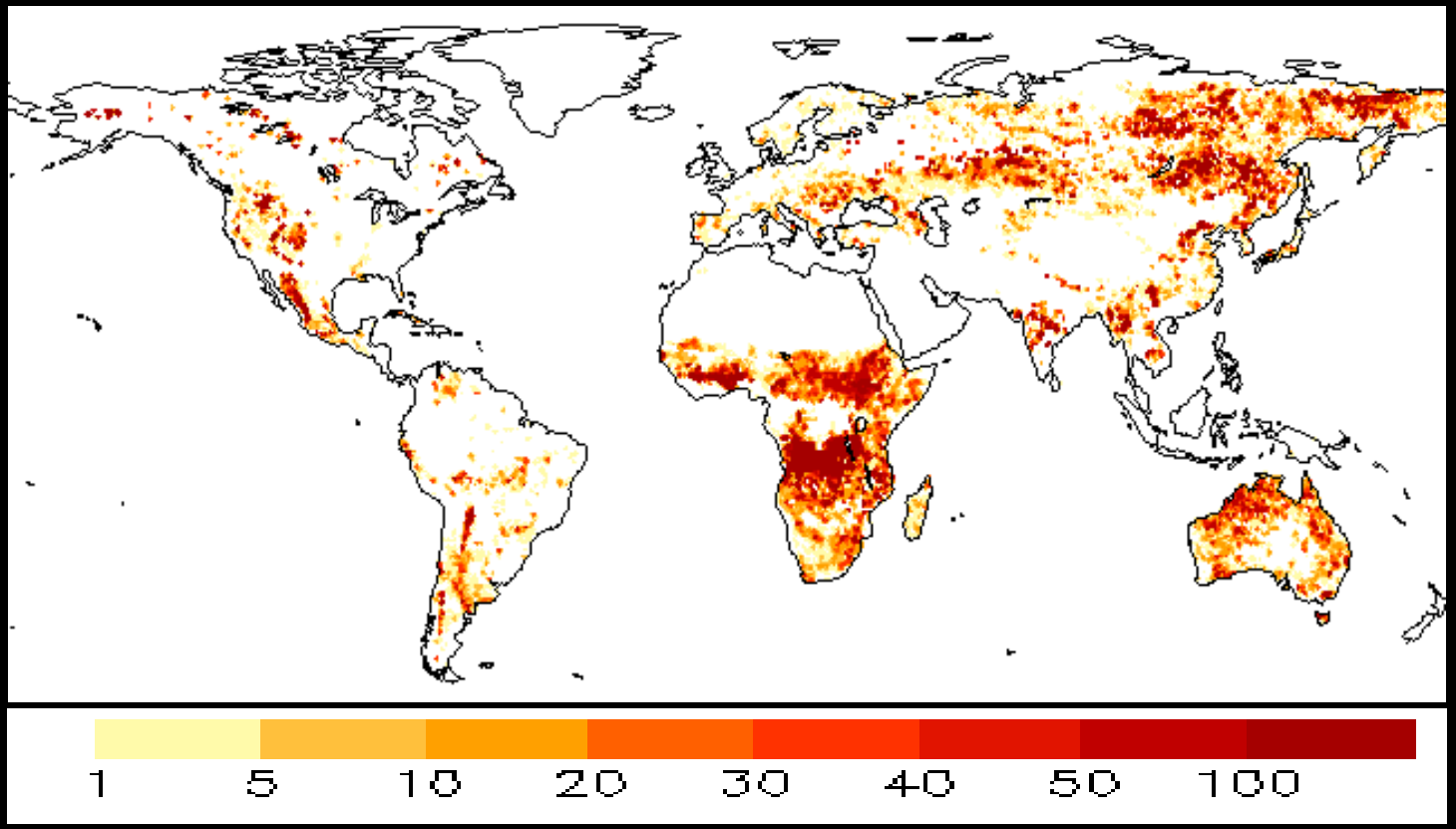


Estimated Net Primary Productivity ($kg\text{-}cm^{-2}yr^{-1}$)



Tao and Jain (2005)

Open Fire CO2 Emissions ($gC/m^2/yr$) 1990s

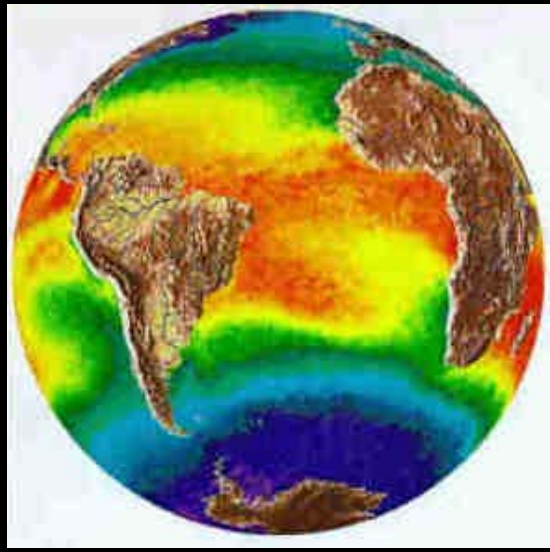


Application of MODIS, GLOBSCAR & GBA

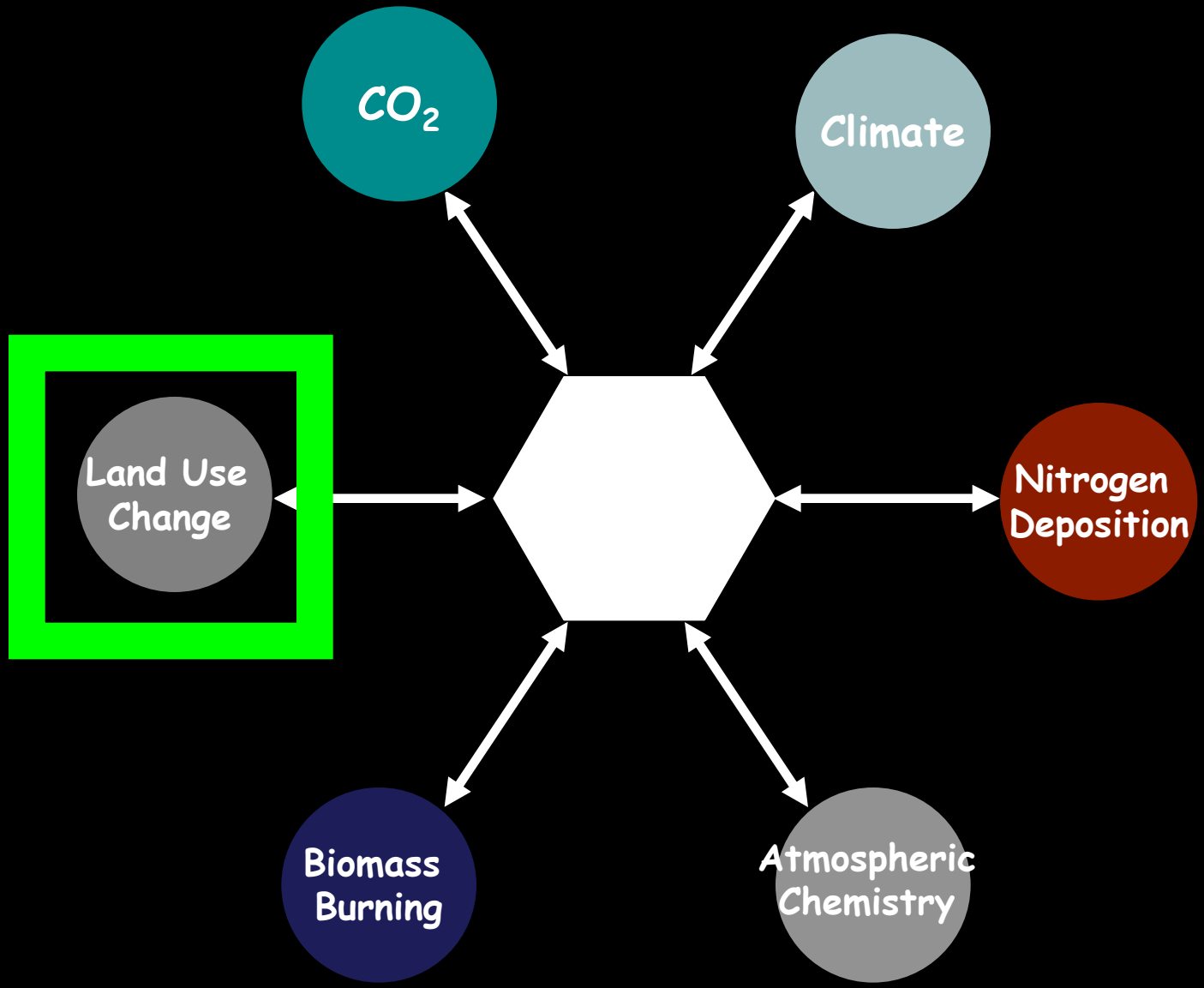
Jain et al. (2006), Jain (2007)

How do We Estimate The Effect of Land Use on Carbon Storage

- *Disturbance history*
- *Stand type*
- *forest age*
- *Ecosystem processes &*
- *Climate Change*



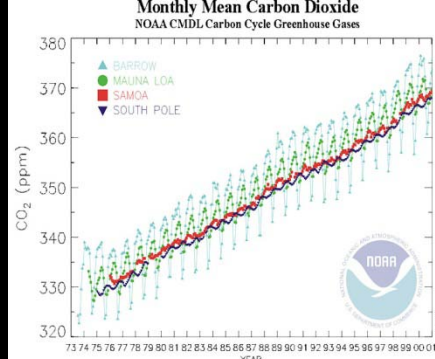
Integrated Science Assessment Model (ISAM)

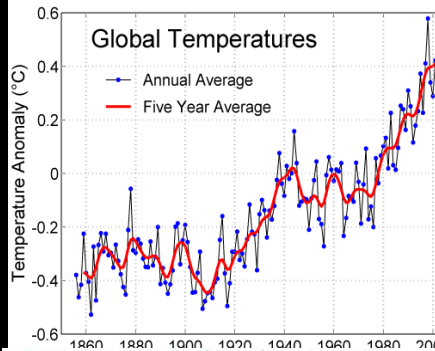


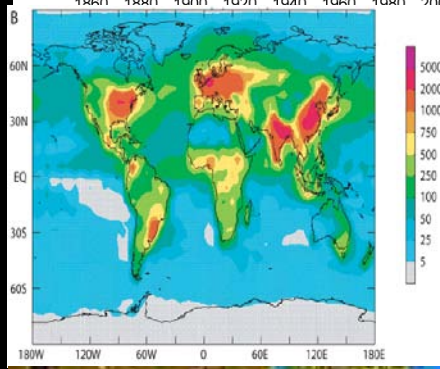
Questions?

- What are the relative contributions of
  - Land use
  - natural ecosystem dynamics
  - fire
  - climate variability
  - N deposition

  on forest and carbon dynamics in tropical forests?
- What are their synergistic effects?
- What are their potential future trends?



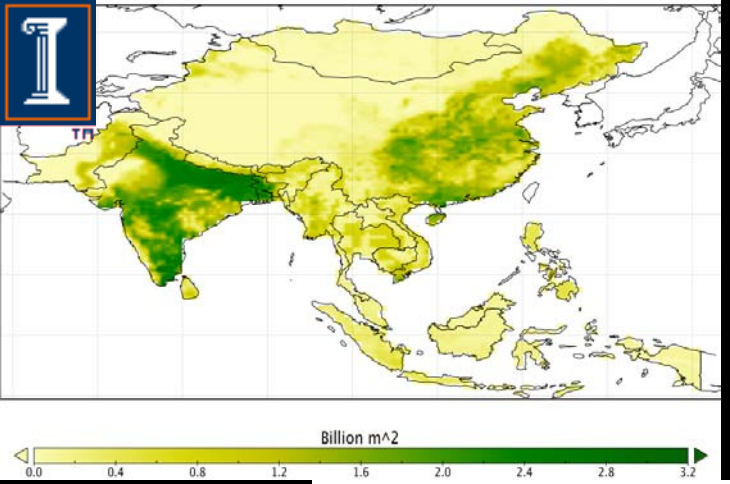


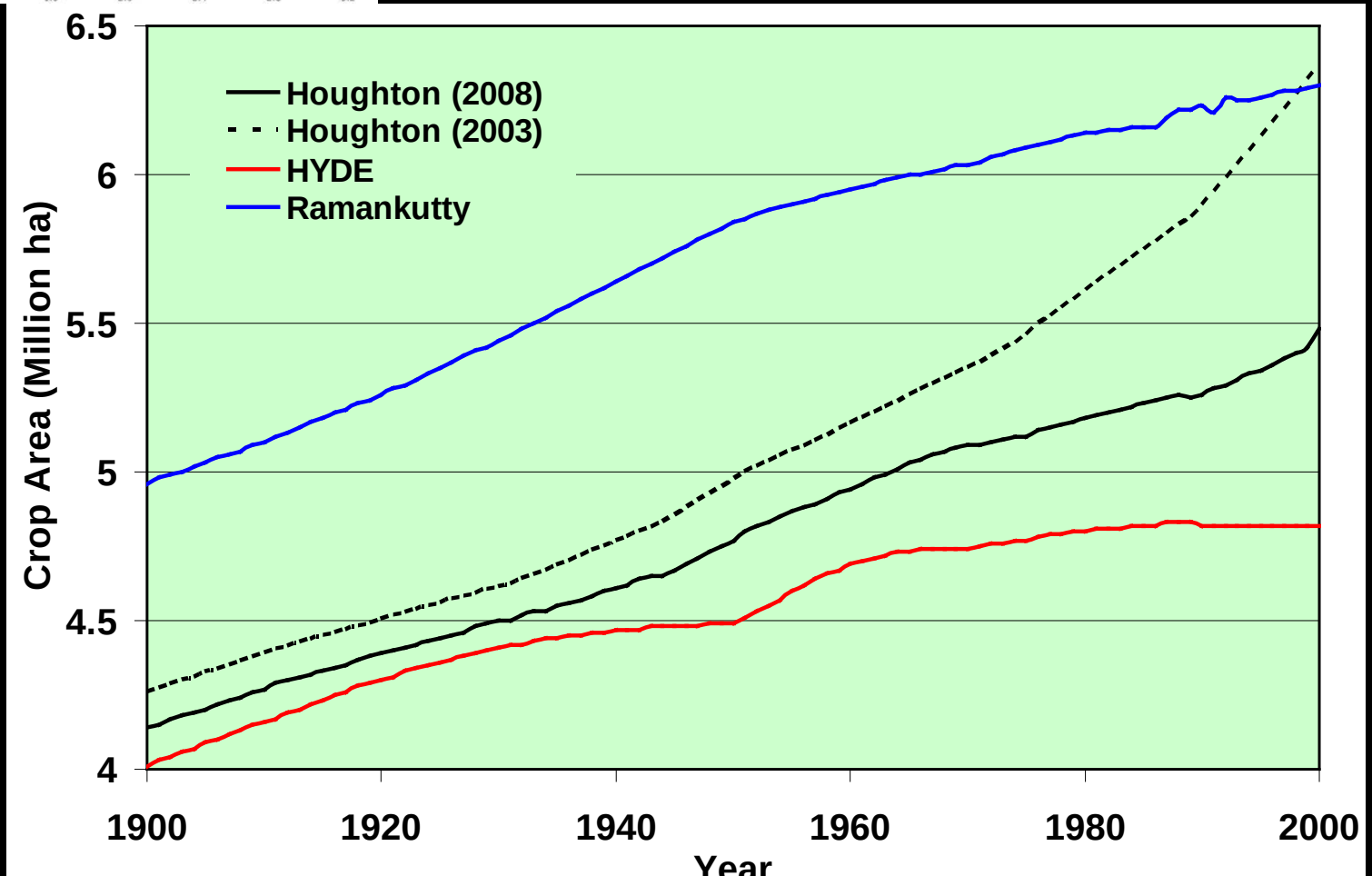


Changes in Land Use

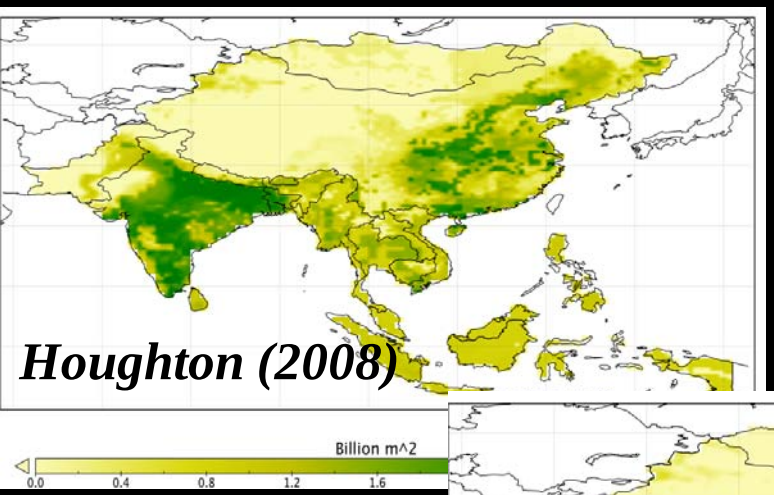
- Changes in area
  - Croplands (clearing and abandonment)
  - Pastures
  - Wood harvest & recovery (primary and secondary forest)
- Changes in carbon stocks
  - Fire
  - Management practices

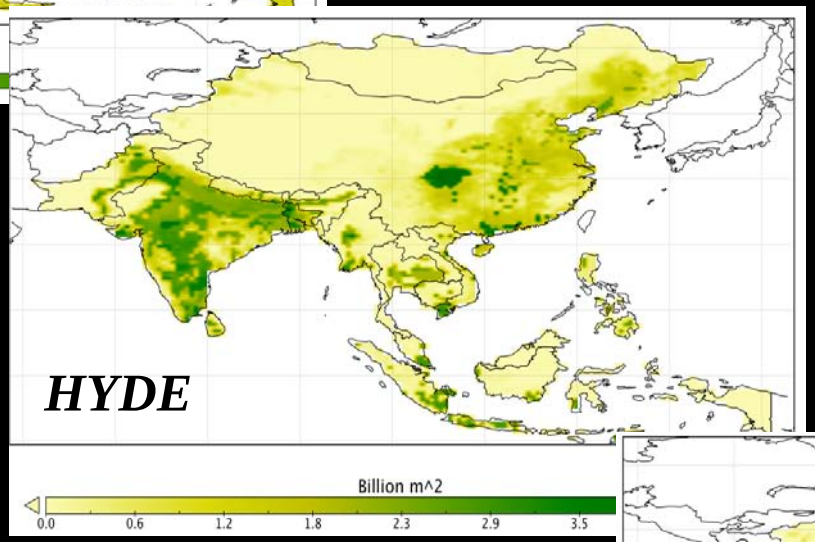
Historical Land Use Changes for Croplands

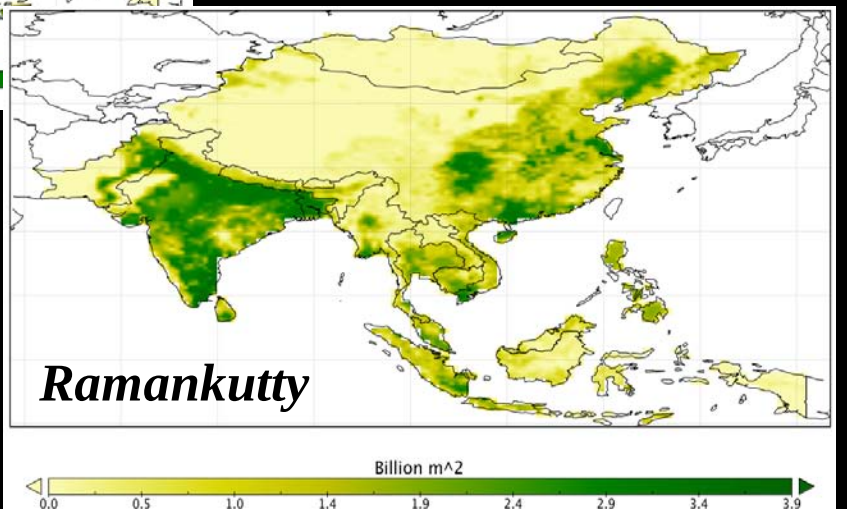




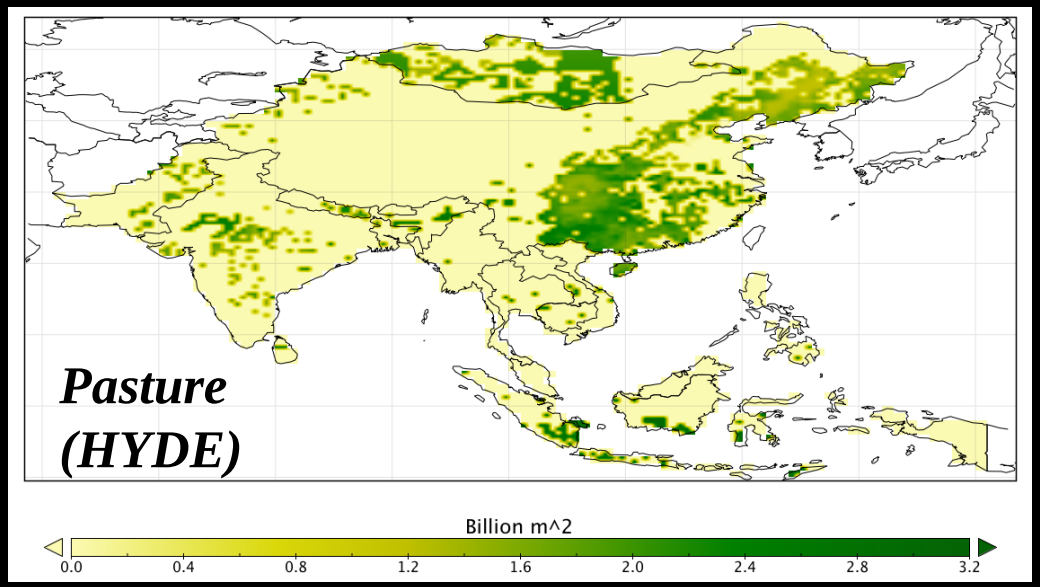
Land Use Changes - Croplands (2000)

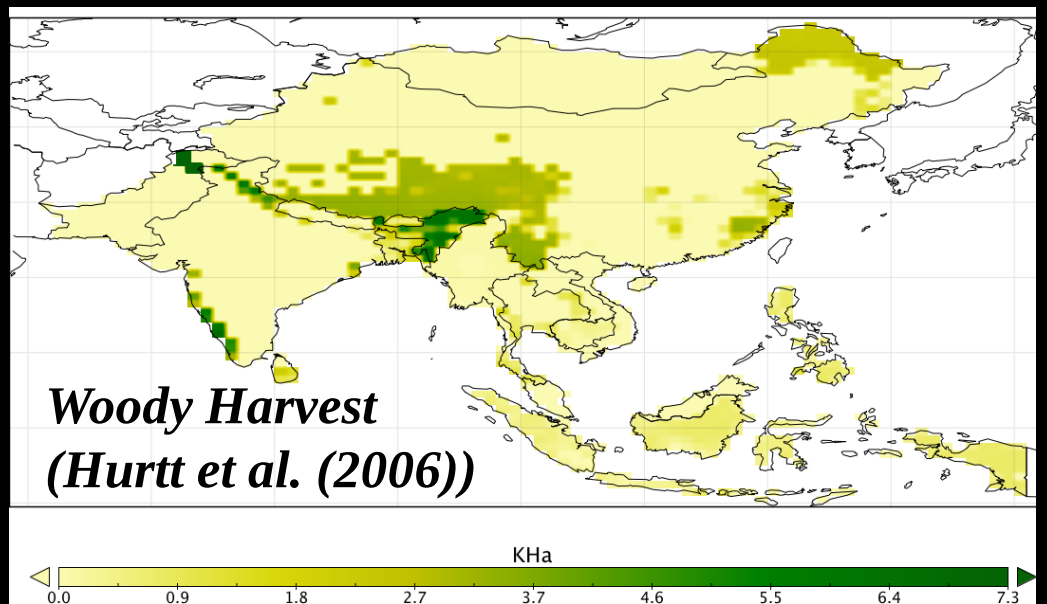






Land Use Changes - Pasture and Wood Harvest (2000)



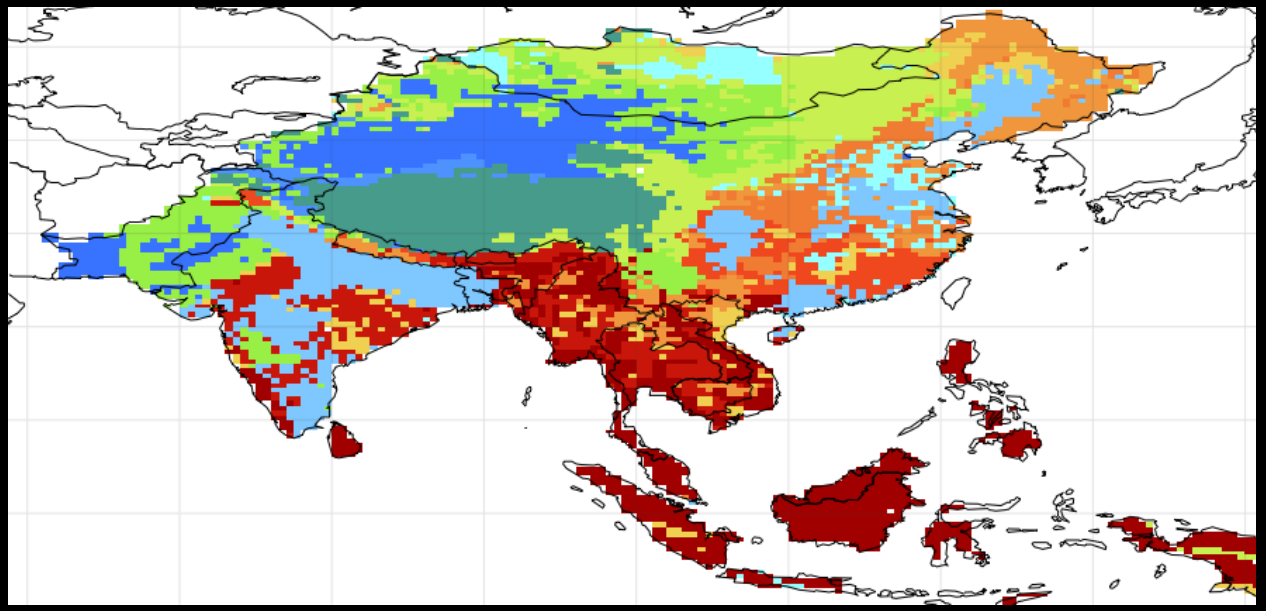


Estimation of Carbon Emissions from Land-Use Change and Net Carbon Storage/Release Across Monsoon Asian Region

Global C sources or release (+) and sinks or storage (-)

Global Terrestrial C-N ISAM

- 13 Biome types
- 0.5 x 0.5 degree resolution
- Carbon cycle
- Nitrogen cycle
- Feedbacks: Climate-C-N-LUC…

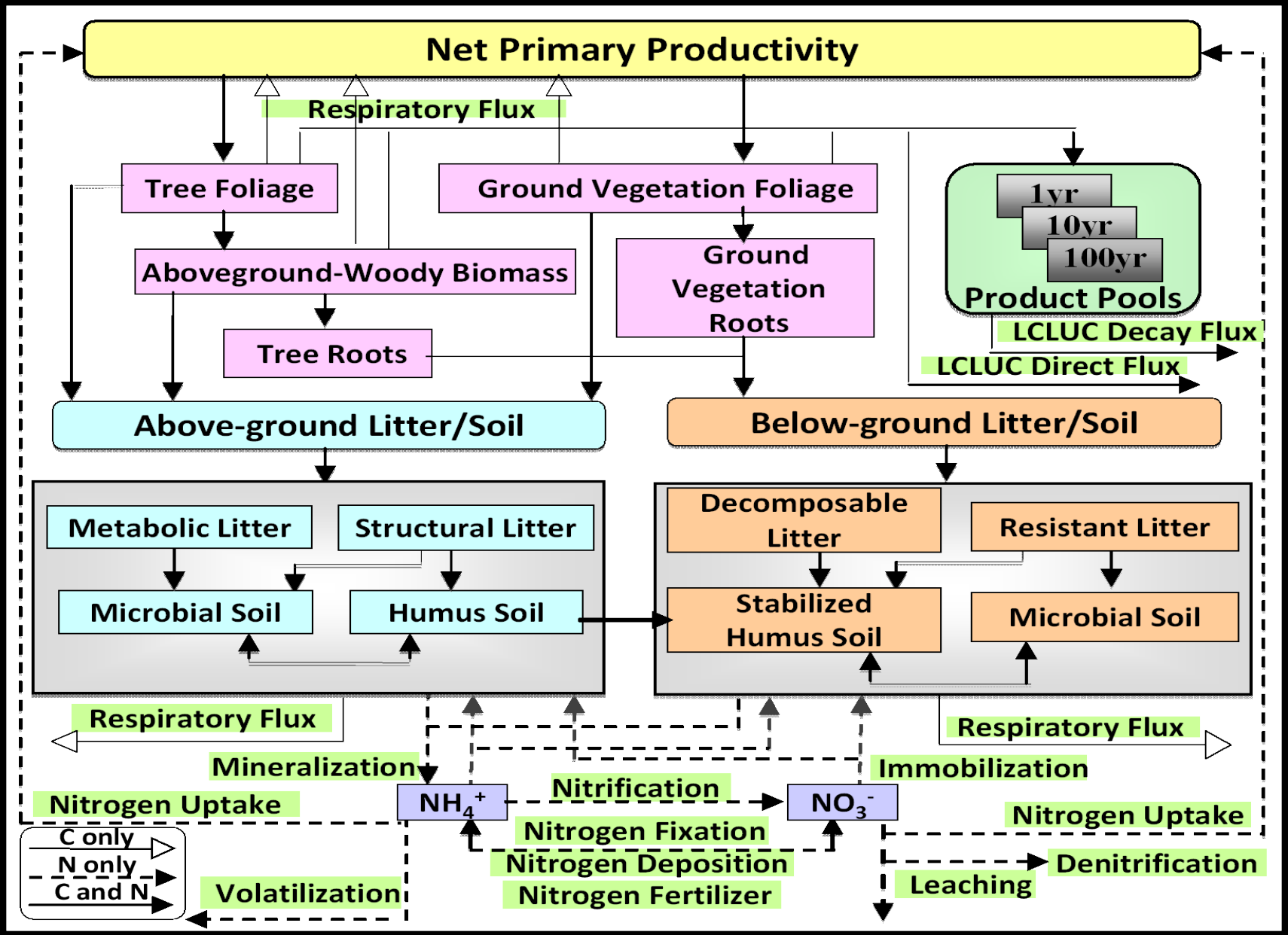


Biome Types

- Tropical Evergreen
- Tropical Deciduous
- Temperate Evergreen
- Temperate Deciduous
- Boreal Forest
- Savanna
- Grassland
- Shrubland
- Tundra
- Desert
- Polar Desert
- Cropland
- Pasture

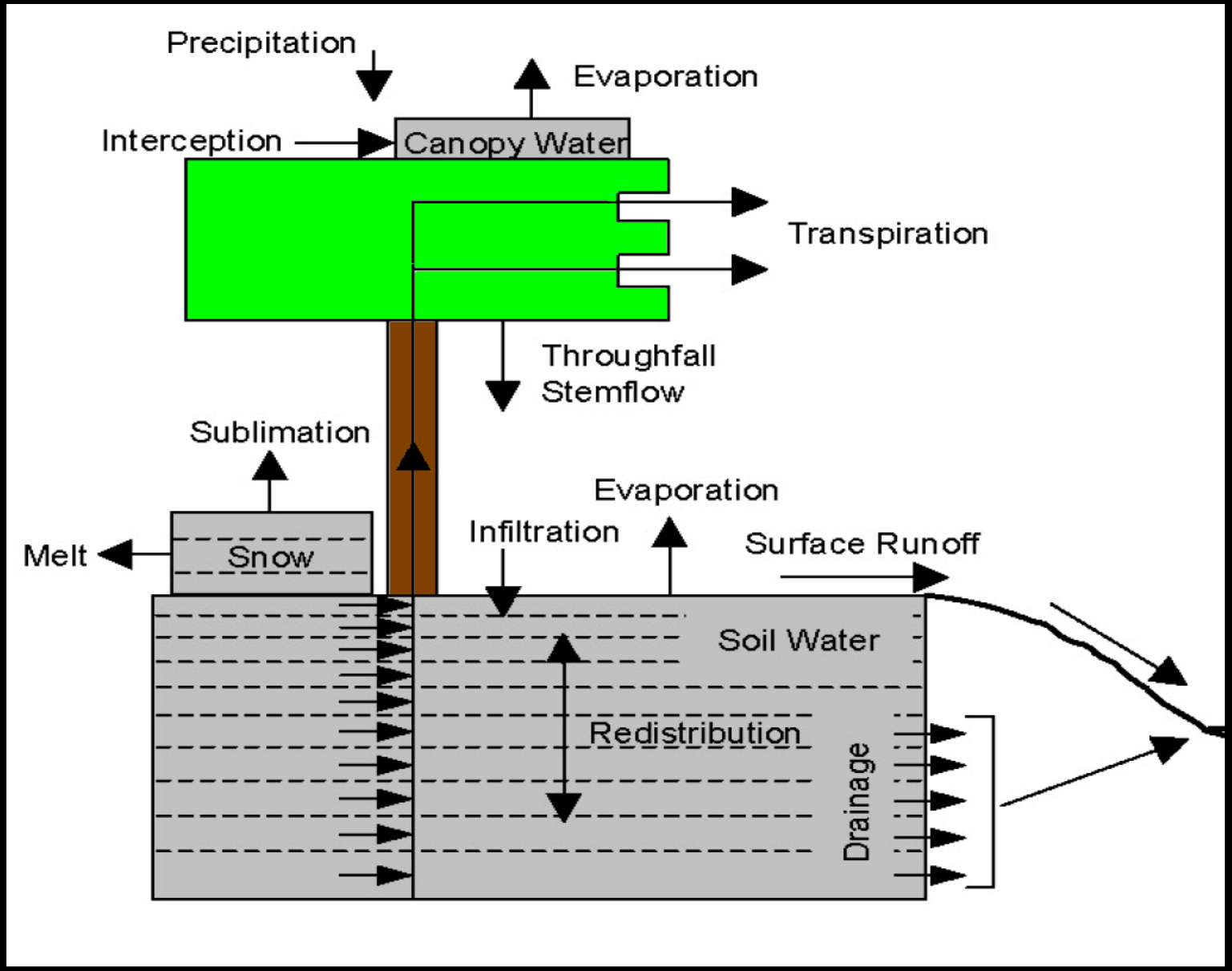
Jain and Yang (2005,*GBC*)

Global Terrestrial C-N ISAM



Yang *et al.* (2008)

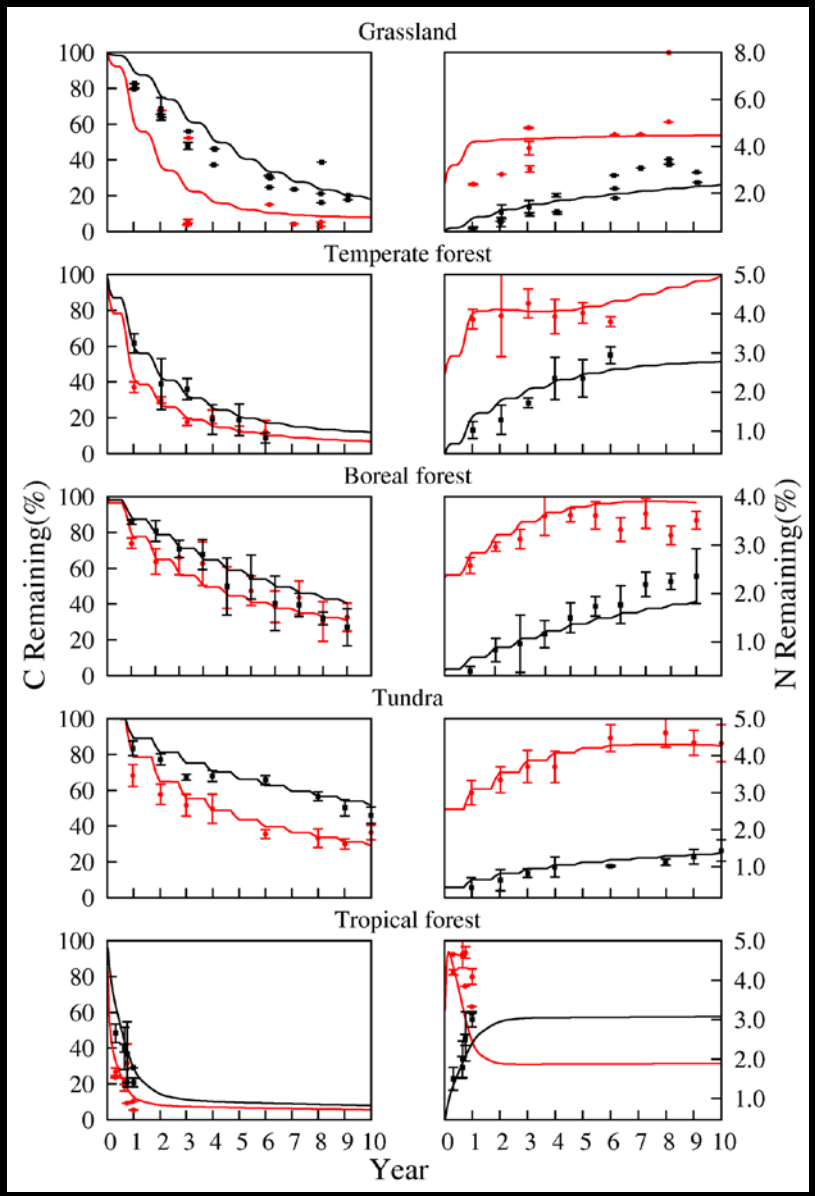
Hydrology in ISAM



Model Calibration

- Long-term Inter-site Decomposition ExperimenT (LIDET) and other site-specific data

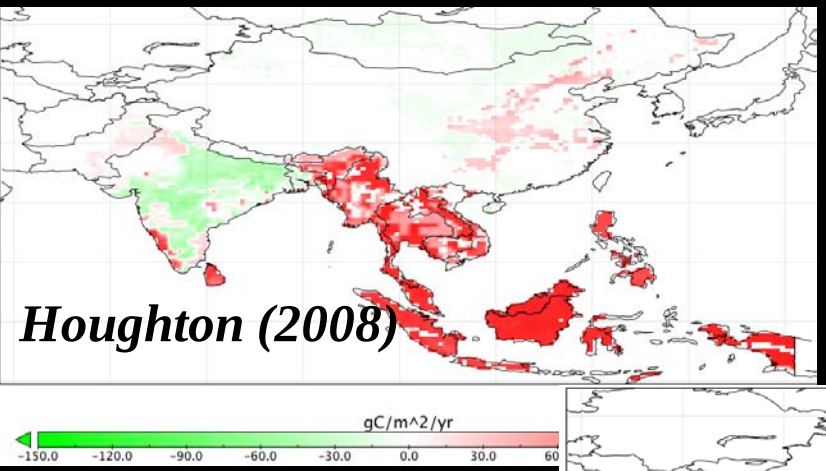
- Leaf, wood and root litter decomposition data
  - C:N
  - Lignin:N
  - Climate

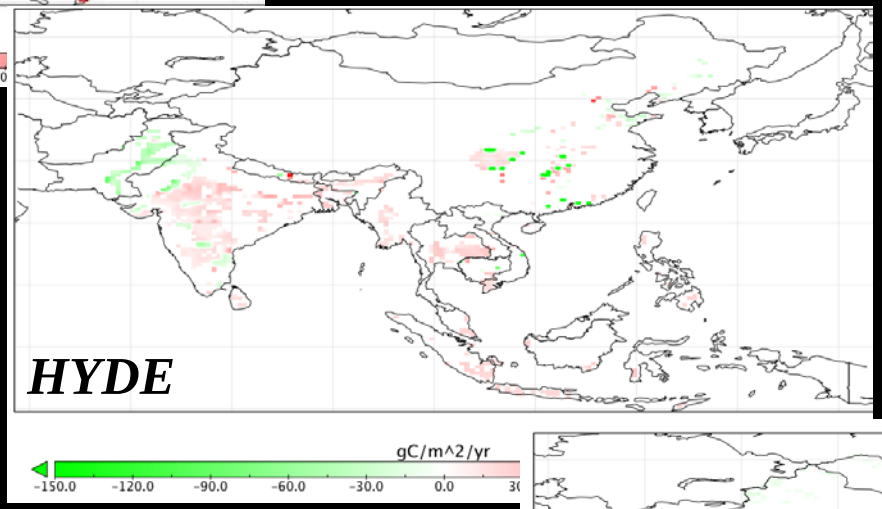


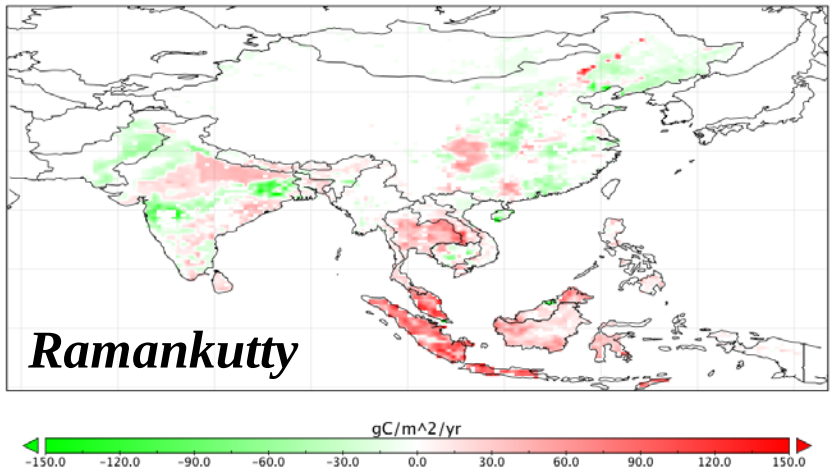
Yang *et al.* (2008)

Carbon Emissions from Land Use Changes

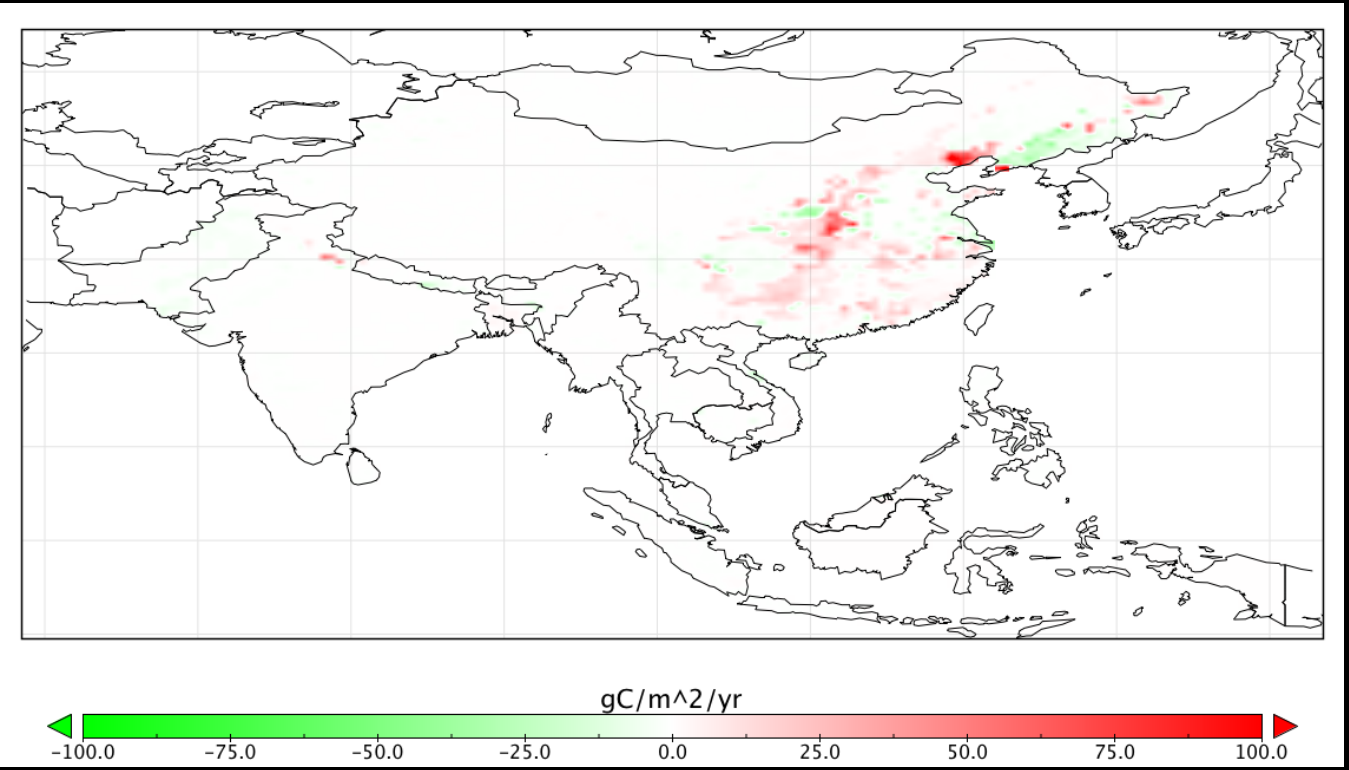
Emissions of C from Land Use Changes (1990s)





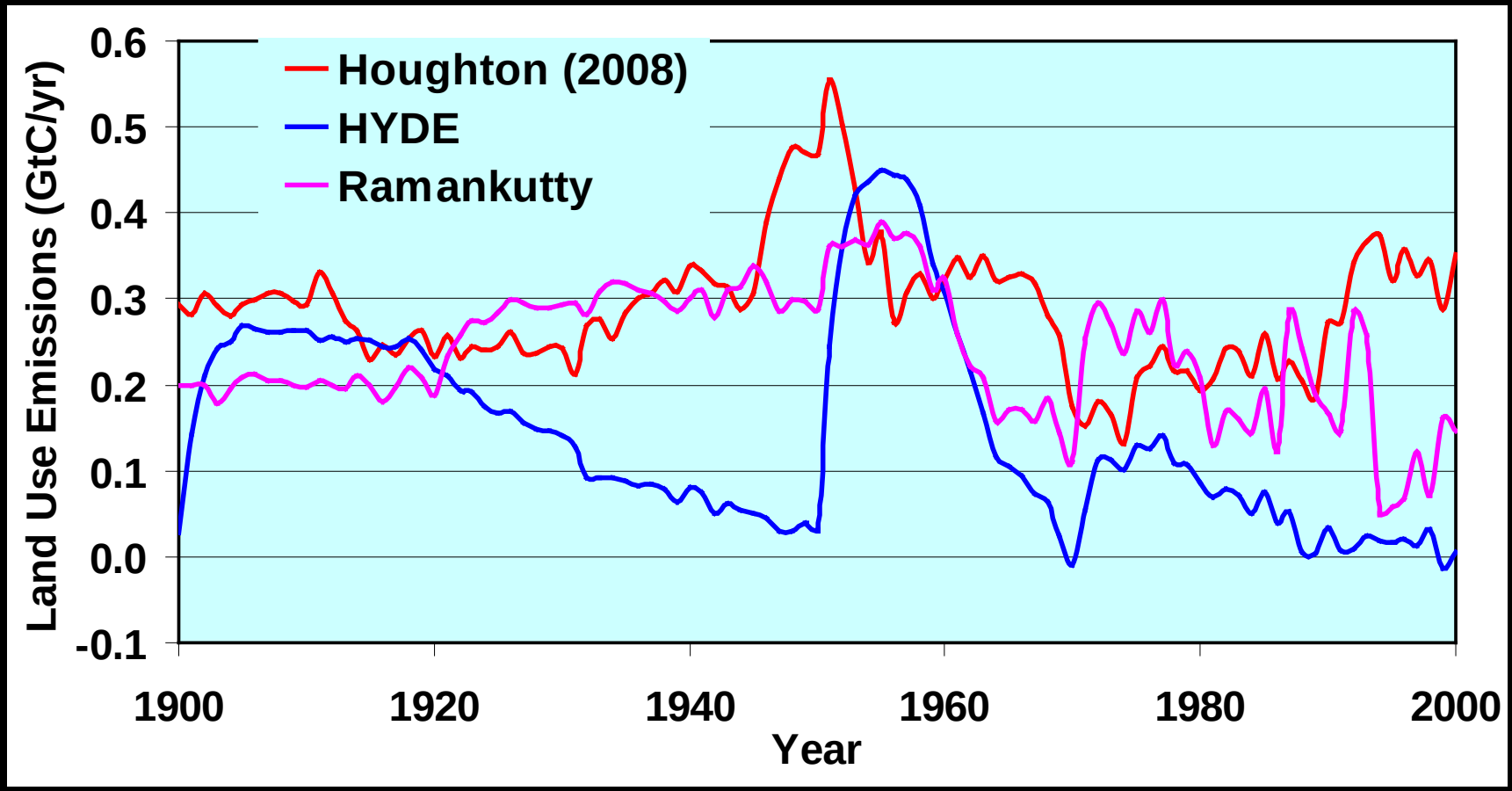


Effect of Nitrogen Limitation on Secondary Forest



N Limitation leads to additional terrestrial carbon source

Historical Land Use Emissions



Global Mean for 1990s

Houghton	**0.32 GtC**
HYDE	**0.02 GtC**
Ramankutty	**0.14 GtC**

Other Estimates for Tropical Asia

- Estimates of Deforestation Rates and C Emissions (1990s)

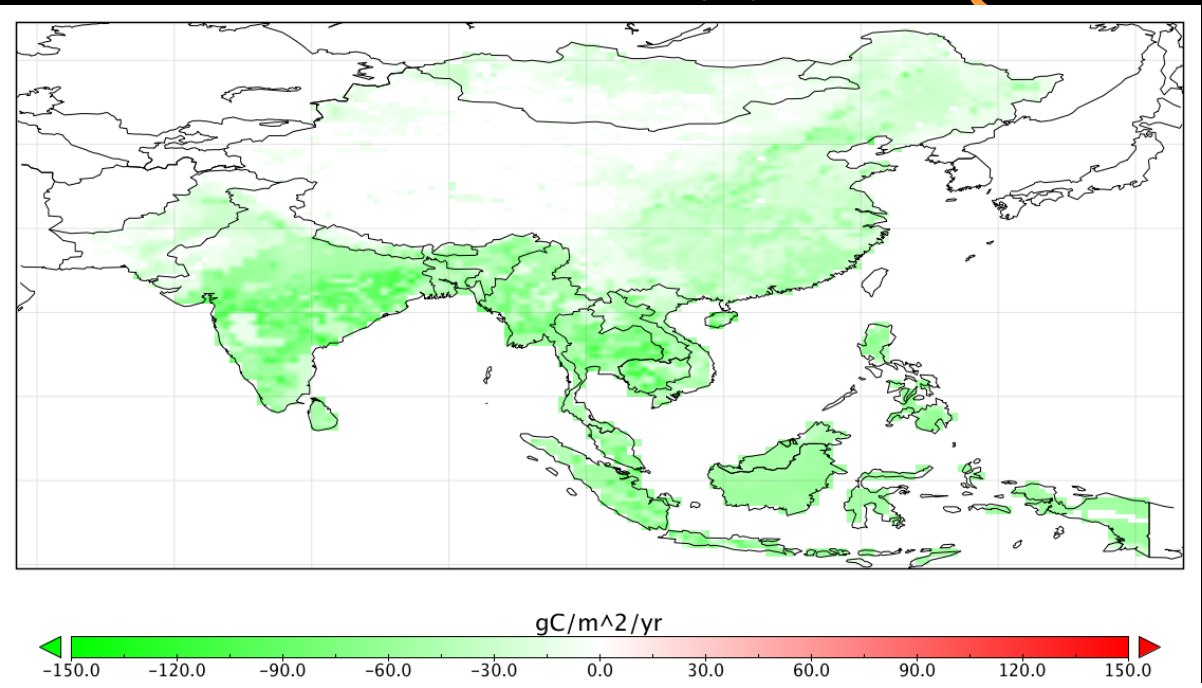
(10^6 ha/yr)	(PgC/yr)	
8.9	0.4 (±0.5)	Achard et al. 2004
8.0	0.4 (±0.4)	DeFries et al 2002
10.8	1.1 (±0.5)	FAO 2001, Houghton 2003
	0.8 (±0.5)	IPCC (2007)

Uncertainties in LU Emissions….

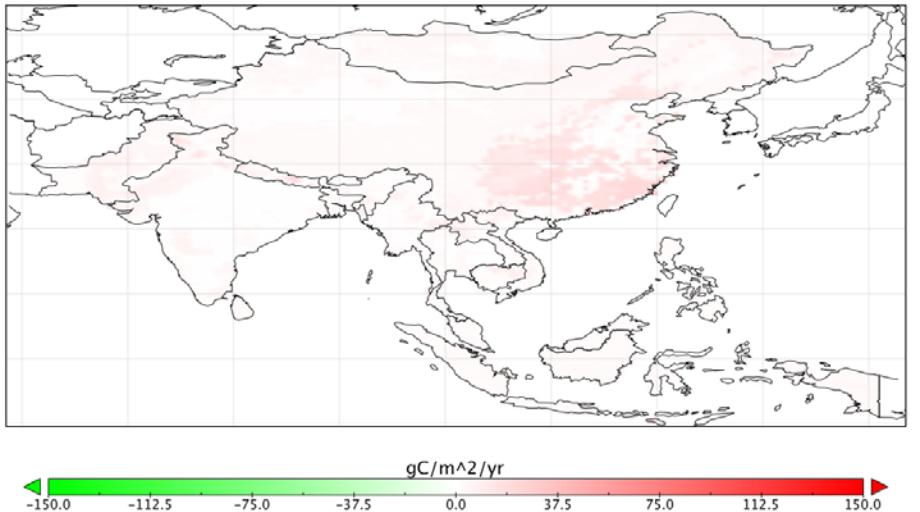
- Rates of land-use change
  - Deforestation, afforestation, abandonment
  - Other changes in land use
- Carbon biomass
  - …of the ecosystems converted
  - Degradation and growth
- Interactions
  - Biophysical feedbacks

Factors Contribution to the Net Carbon Storage/Release Across Monsoon Asian Region

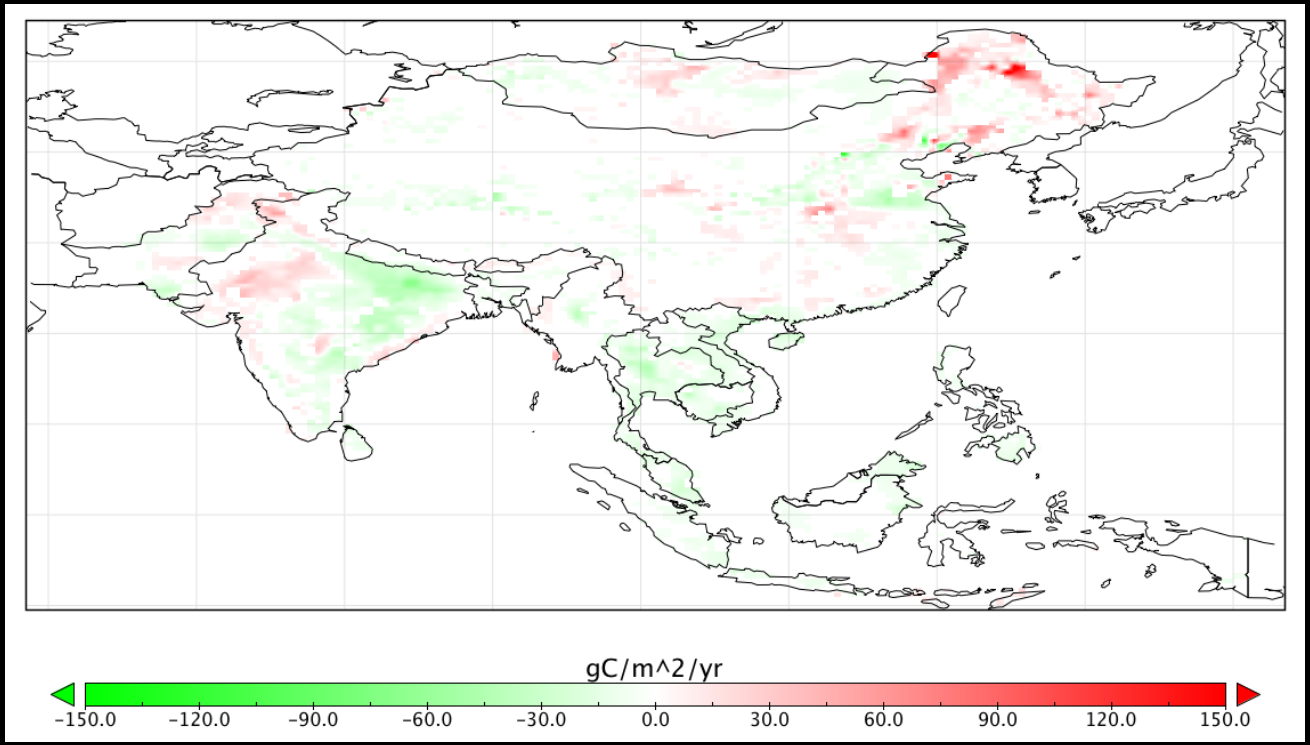
C Storage due to CO2 Fertilization Effect (1990s)



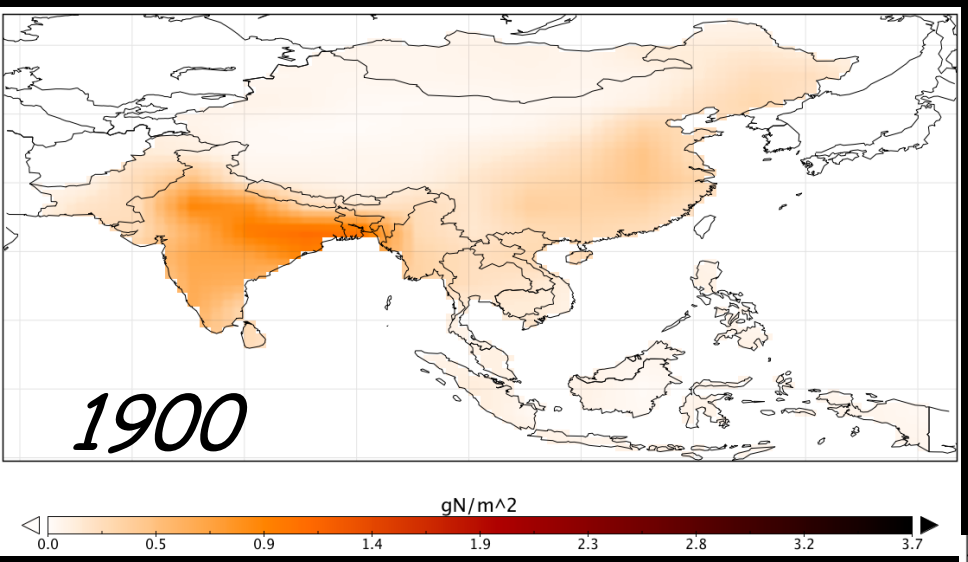
Inclusion of N dynamics reduces CO2 fertilization effect

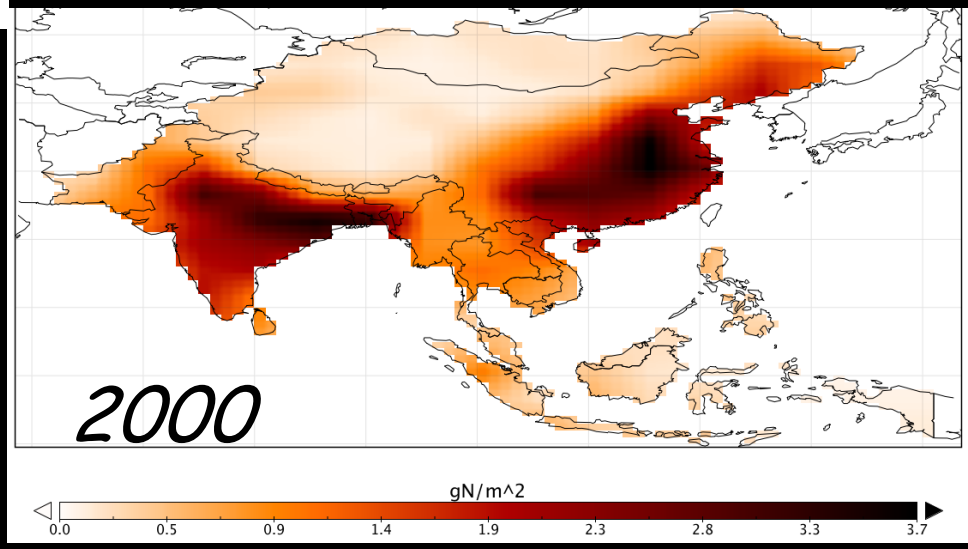


C Storage/Release due to Climate Change (1990s)



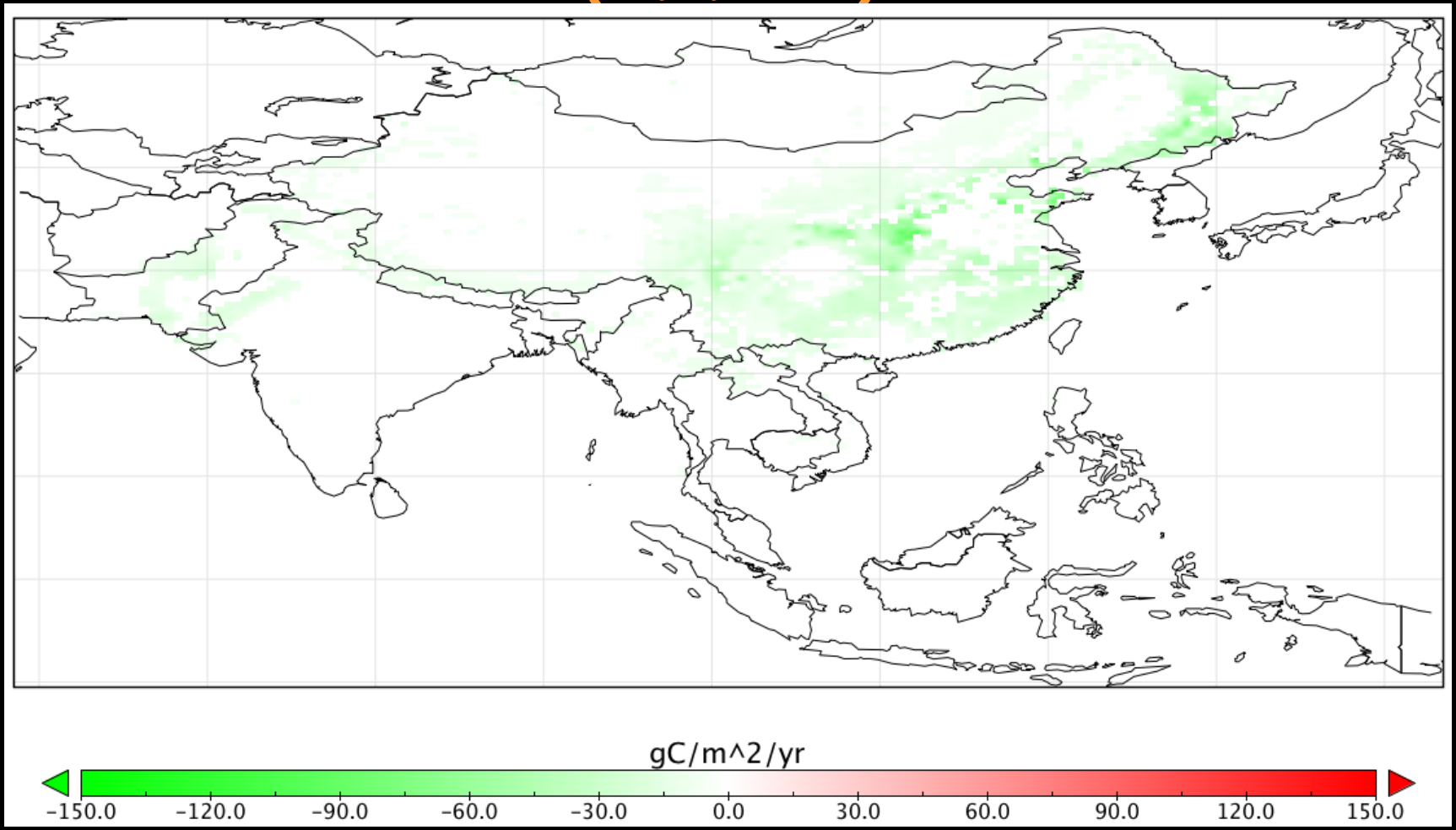
Nitrogen Deposition - Fossil Fuel Burning & N Fertilizer





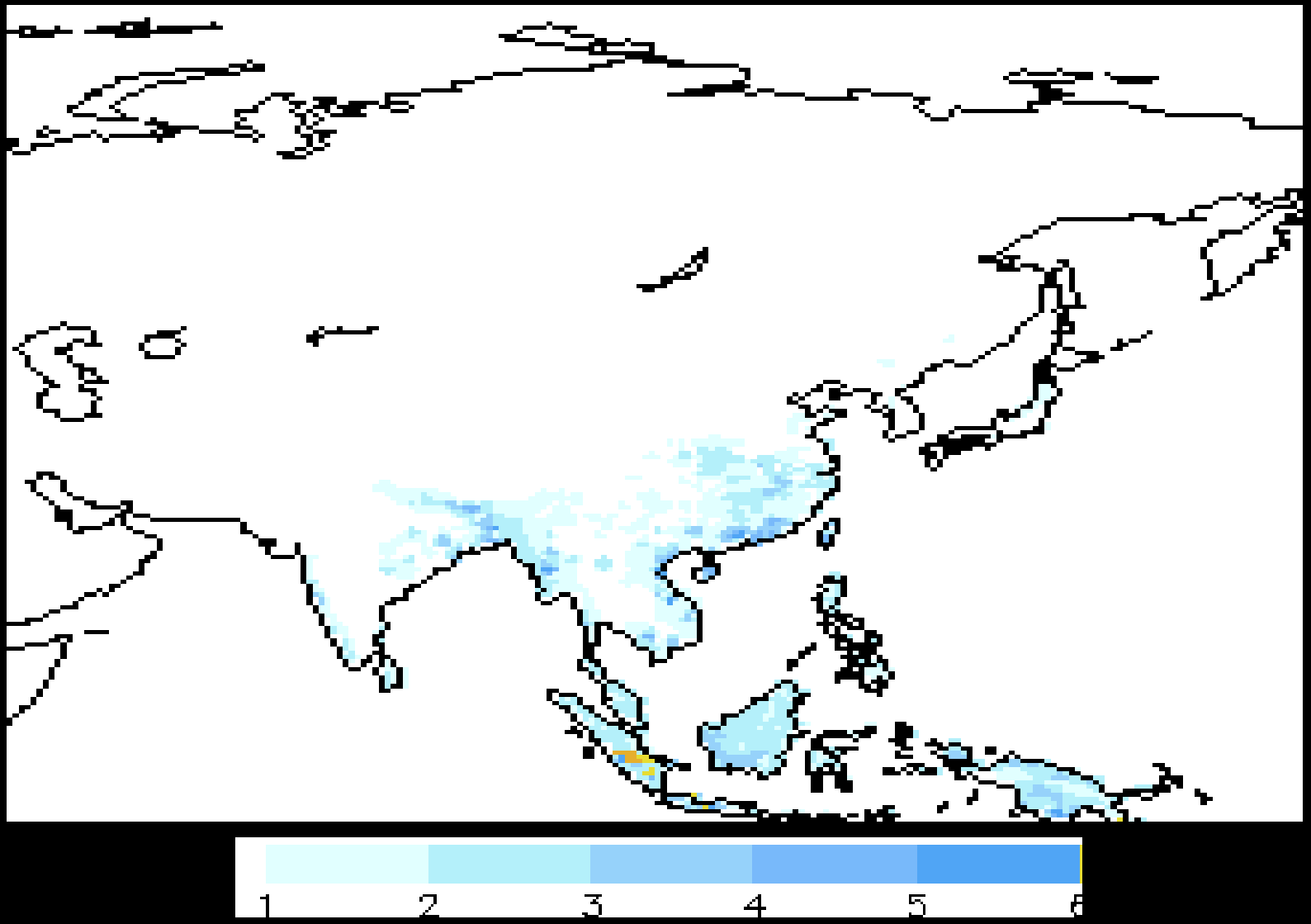
Galloway et al. (2004)

N Deposition Effect on C Storage (1990s)

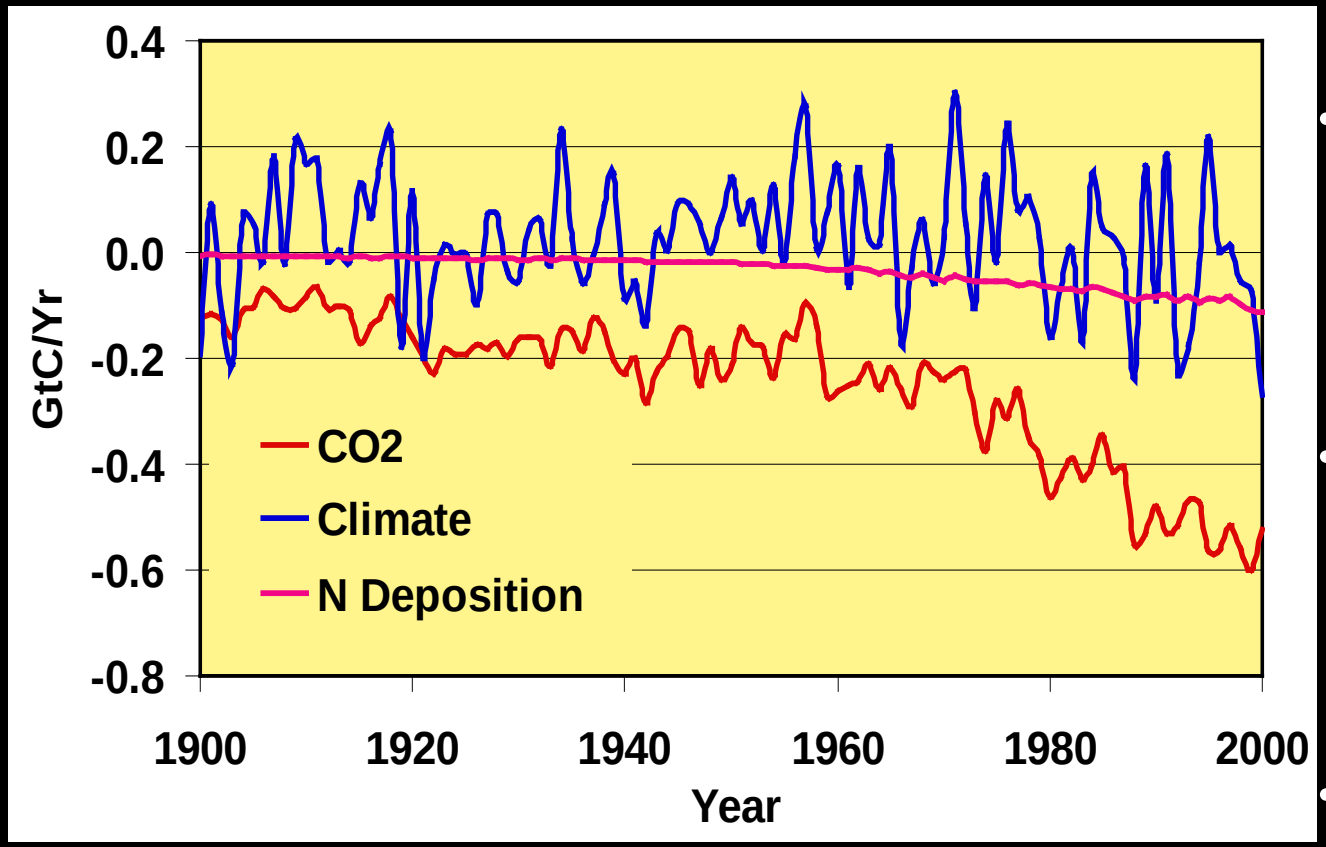


N deposition leads to additional terrestrial carbon sink

N Leaching (gN/m^2)

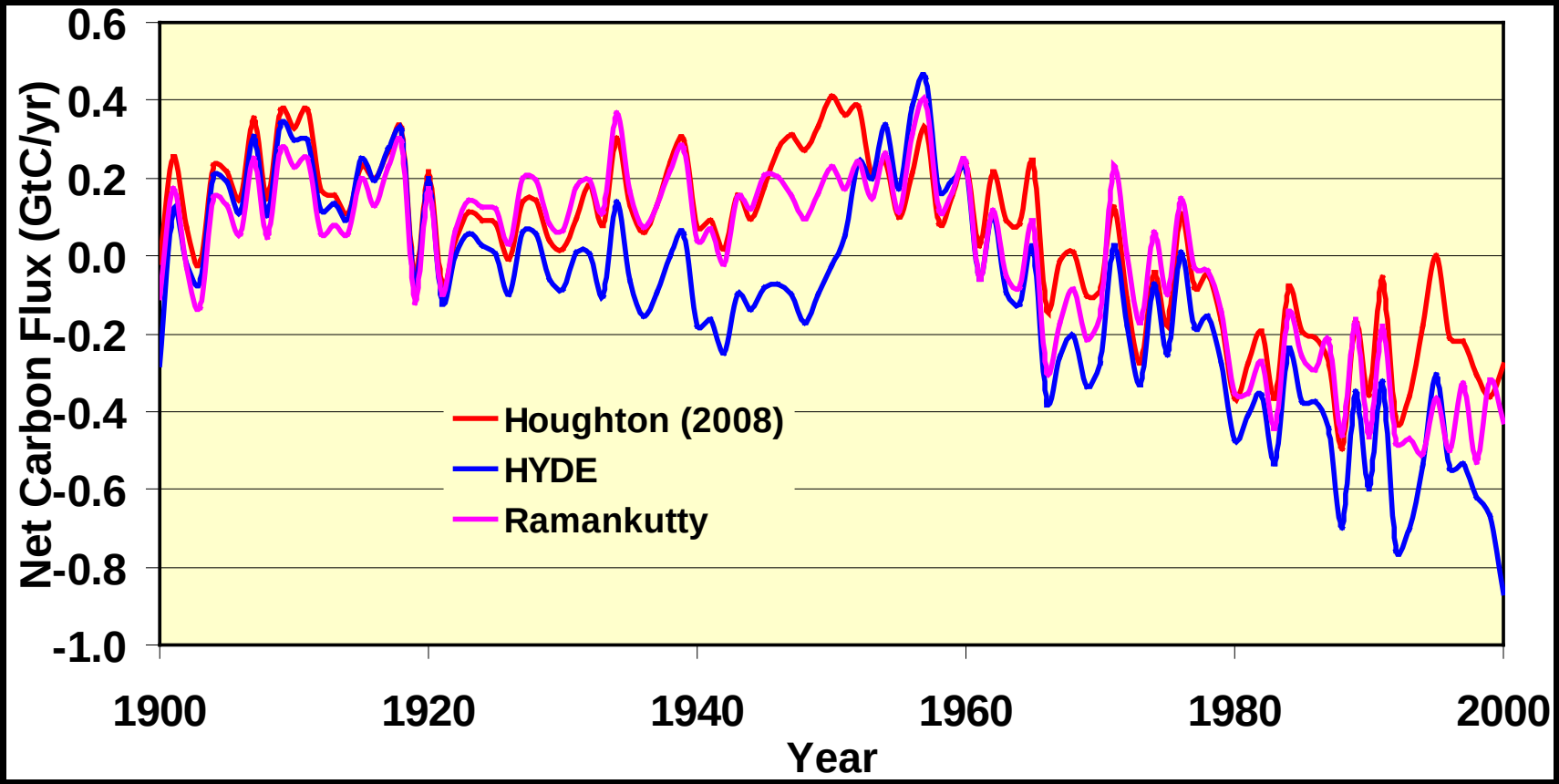


Terrestrial Response to Changes in CO2, Climate, N Deposition



- Climate introduces interannual variability
- CO_2 effect drives directional trend: net sink
- N deposition contributes small amount of C storage

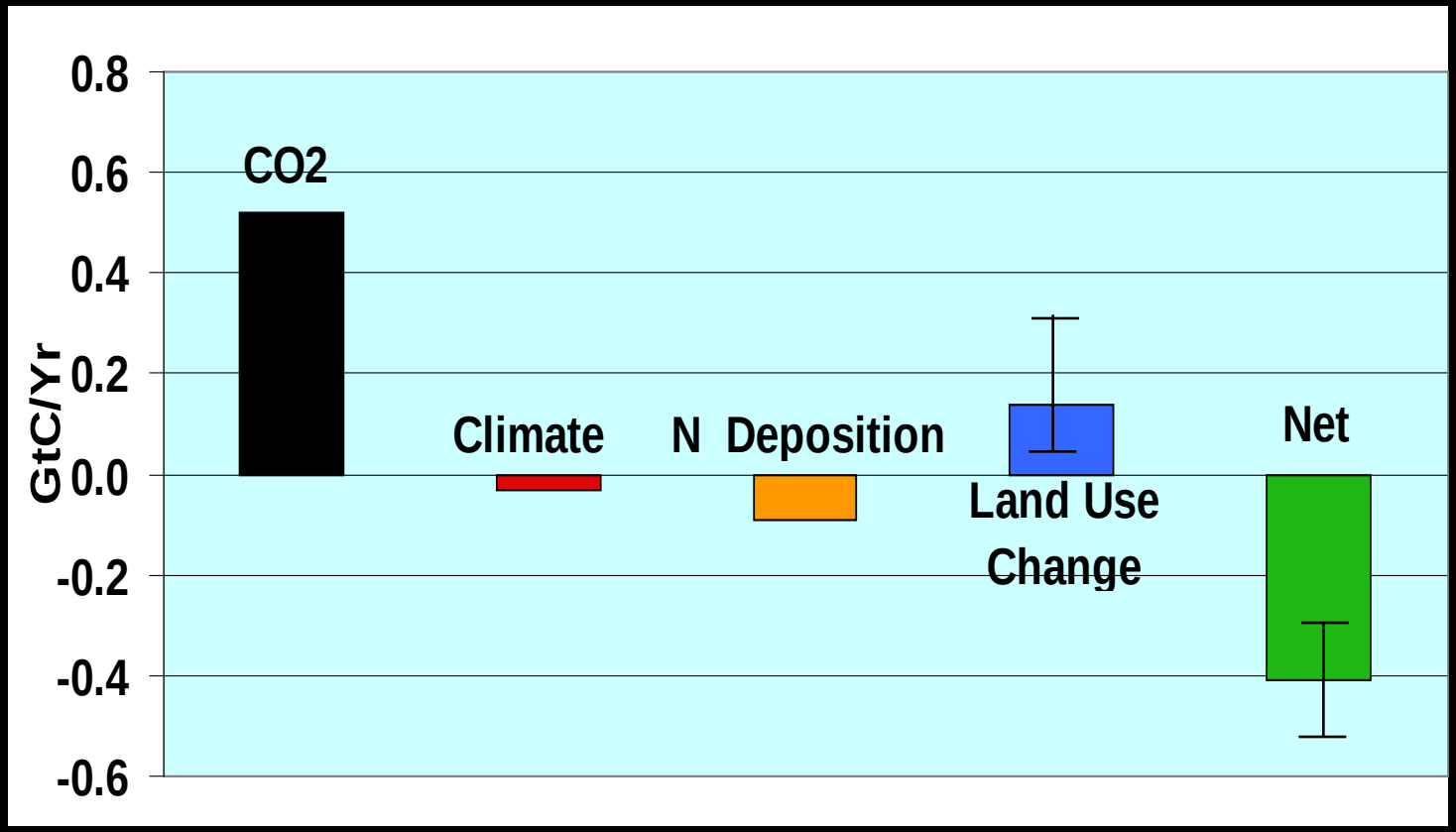
Historical Net Carbon Flux



Global Mean for 1990s

Houghton	**- 0.25 GtC**
HYDE	**- 0.56 GtC**
Ramankutty	**- 0.51 GtC**

Terrestrial Response to Changes in CO2, Climate, LUC, N Deposition



Combined effect leads to a C sink for the 1990s

A Final Question (or two)

- *Are we biased in our observation of sources relative to sinks?*
  - Satellites see deforestation better than they see growth
  - Are changes due feedback processes contribute more to sinks than sources?

Conclusions

- Changes in land use and management play a dominant role in determining sources and sinks of carbon.
- CO2 fertilization accounts for a major portion of today's carbon sink in monsoon Asian region …

  ….perhaps all of it if we could measure it

Work in Progress…

- Model past, present and future carbon dynamics in the region
- Conduct remote sensing derived analyses of LCLUC and carbon dynamics

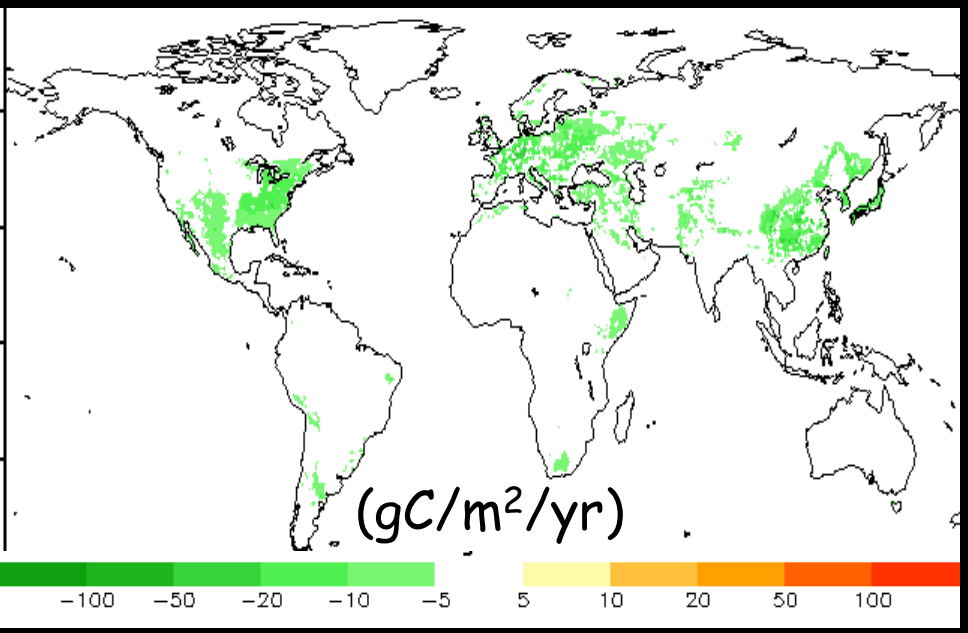
  ……our collaboration with Dave Skole, Rama Nemanai and others
- Input field and remote sensing derived data into the ISAM
- Evaluate the impact of LCLCU on C dynamics in the future using socio-economic model coupled with the ISAM

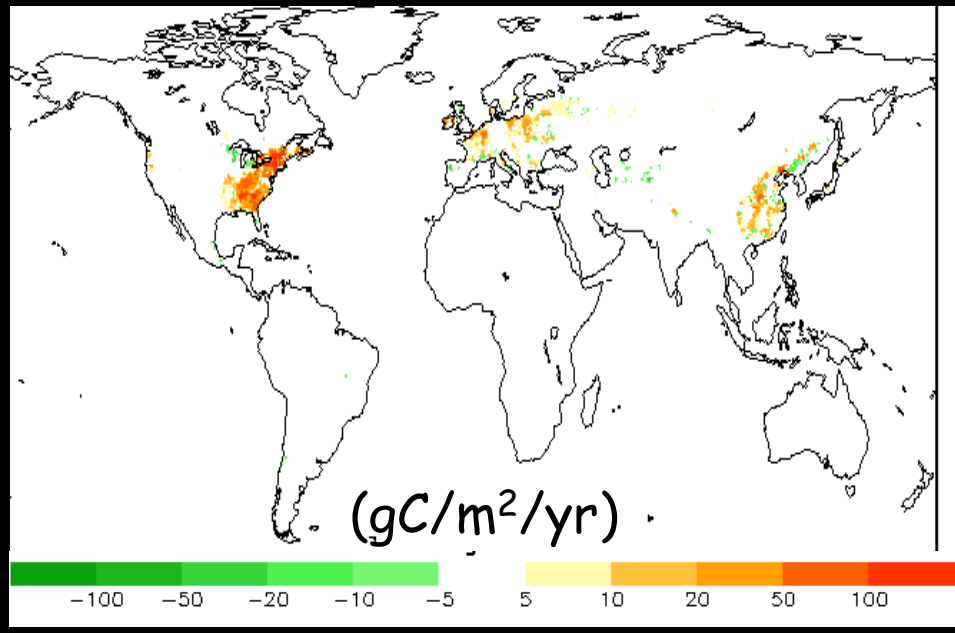
  ……our collaboration with Brian O'Neill of NCAR

Thank you..

The End

N dynamics – N unchanged:
N Deposition and LUC effect on C flux (1990s)

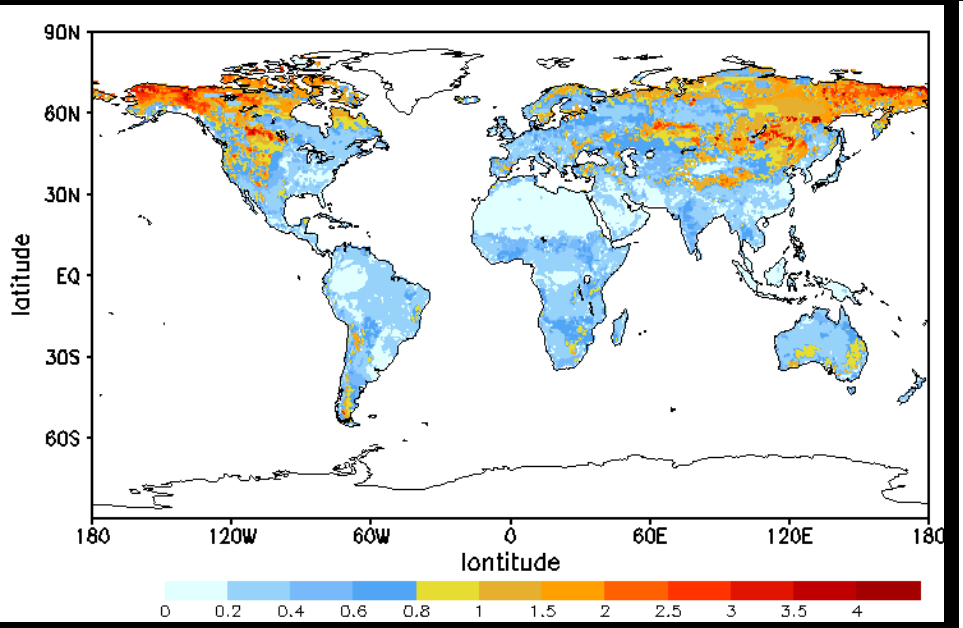




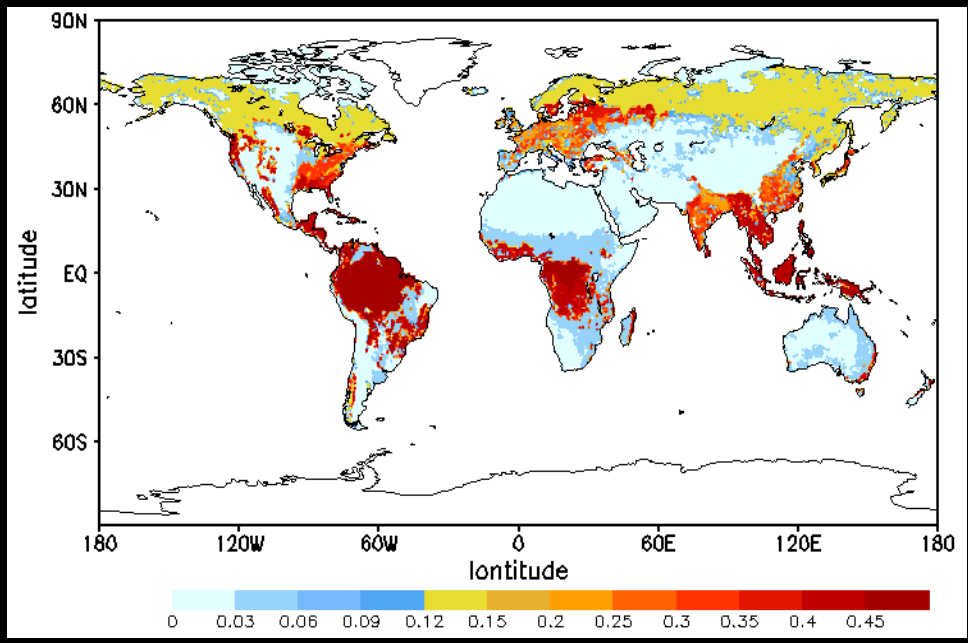
N deposition leads to additional terrestrial carbon sink

Land cove changes for cropland leads to additional terrestrial carbon source

N Storage in Soils and Vegetation



N in soils (kg N/m2)



N in vegetation (kg N/m2)

Terrestrial Nitrogen Cycle

- Inputs:
  - Nitrification
  - N deposition
- Outputs:
  - Leaching
  - Denitrification
    - N_2O, N_2, NOx
- Plant availability:
  - Supply v. demand
- Litter decomposition

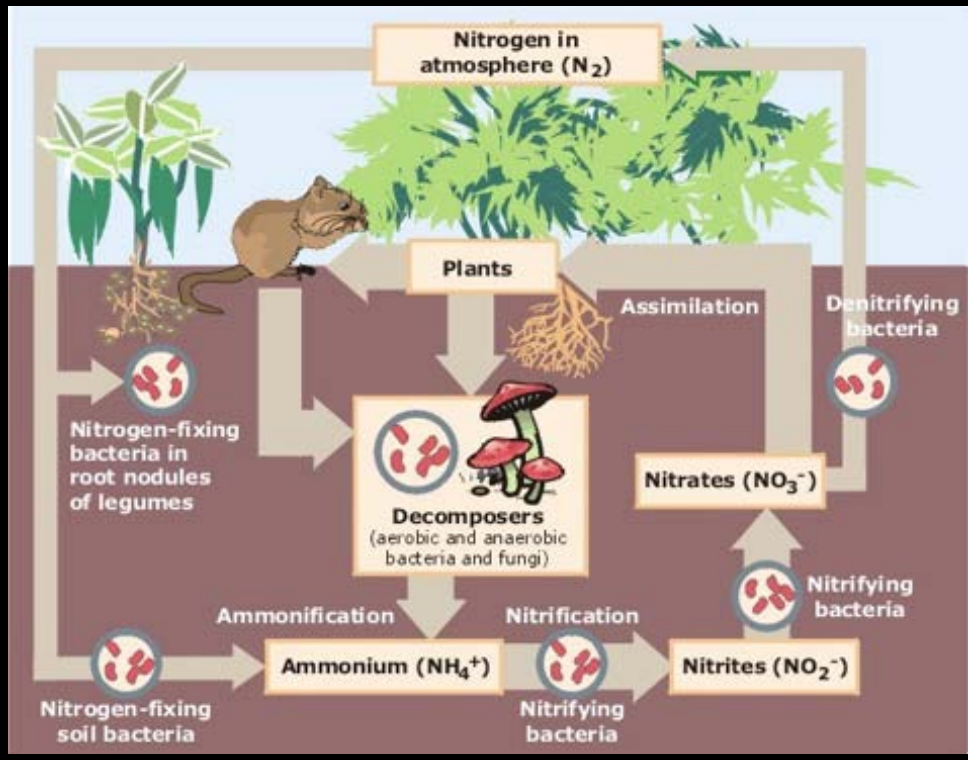
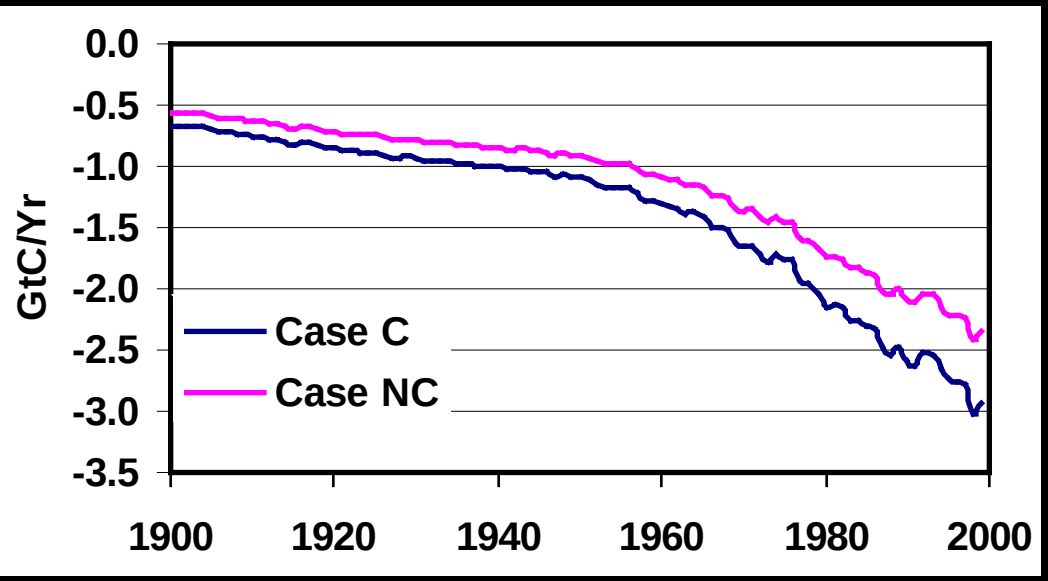


Image source: US EPA

Response to Increasing CO2



- Terrestrial ecosystems are a net sink in both cases
- Inclusion of N dynamics reduces CO_2 fertilization effect
- Without new N inputs mineral N available for plants declines

ISAM Simulations

- ISAM run to equilibrium with [CO_2] ~ 280 ppm and climate for early 1900s

- Five scenarios examined with and without N dynamics (1765-2000):
  1. Increasing CO_2 (~370 ppm by 2000)
  2. Climate variability (Temp. and Precip.)
  3. Increasing CO_2 + Climate variability
  4. Changes in N deposition
  5. Changes in land cover and land use

Land Use Emissions

ISAM Simulations

- Without N dynamics (Case C):
  - N availability held constant at preindustrial levels

- With N dynamics (Case NC):
  - N allowed to vary according to fully dynamic N cycle

    Model accounts for the effect of available mineral N on NPP and soil decompositions

- Two time periods: 1900-2000, 1990's

Results