



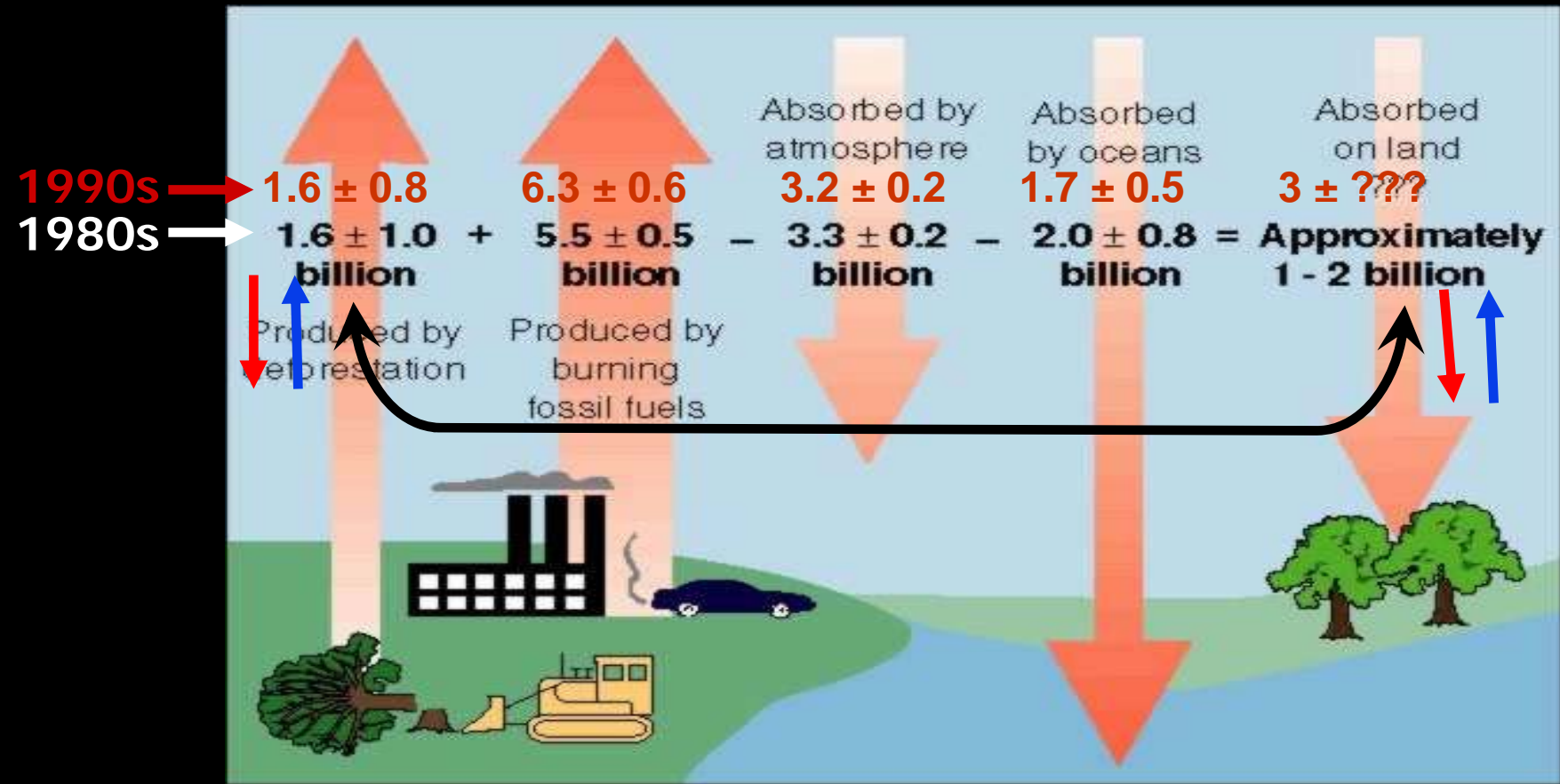
# **Land Use, Carbon Cycle, and Climate Change**

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# Global CO<sub>2</sub> Budget (GtC/yr) & 'Missing' Carbon Sink



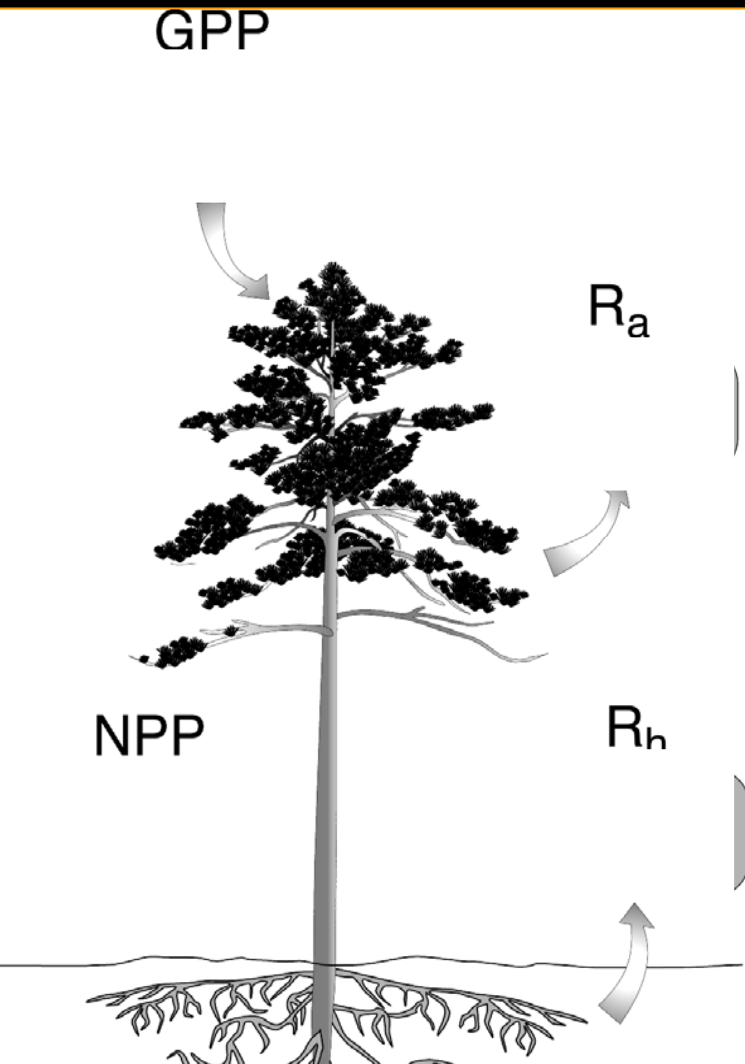
- The global CO<sub>2</sub> budget is usually defined as the mass balance among sources and sinks of CO<sub>2</sub> produced by human activities.
- Balancing the global CO<sub>2</sub> budget requires a large unidentified ("missing") carbon sink on land.

# Introduction



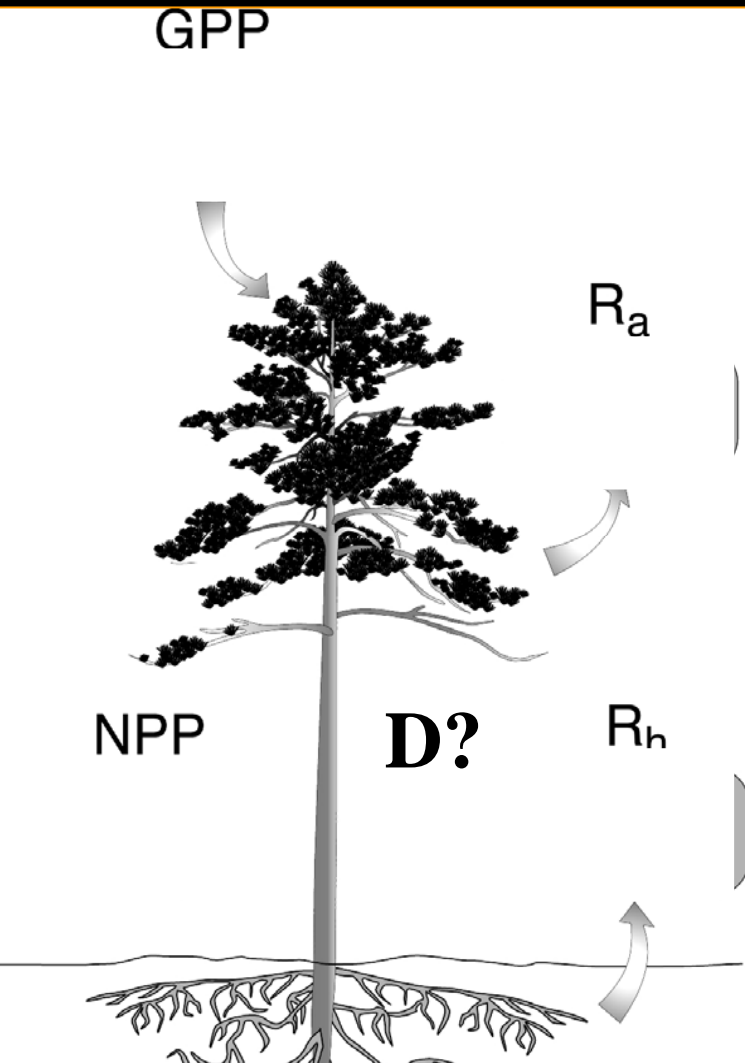
- What are the processes responsible for the North America net carbon budget?
  - Annual mean North America patterns of changes in plant and soil carbon stocks examined using the terrestrial carbon cycle component of the Integrated Science Assessment Model (ISAM)
  - Simulations considered the effects of land cover change, observed atmospheric CO<sub>2</sub> concentration, climate and nitrogen deposition, as well as soil management practices
  - Effects of land cover changes and various ecosystem processes simultaneously considered.

# Processes Involved in Terrestrial Ecosystem Carbon Cycle



- ◆ **Net Primary Production (NPP)**
  - $NPP (60 \text{ GtC/yr}) = GPP - R_a$
  - Short term carbon uptake
- ◆ **Net Ecosystem production (NEP)**
  - $NEP (10 \text{ GtC/yr}) = NPP - R_h$
  - Medium term carbon uptake
- ◆ **Net Biome Production (NBP)**
  - $NBP (1-2 \text{ GtC/yr}) = NEP - D$
  - Long term carbon uptake

# Factors Effecting NPP, NEP, NBP: Disturbances



**Disturbances by fire and harvest (depends on disturbance history, stand type, forest age)**

- forest ecosystems become sources of carbon to the atmosphere immediately after disturbance

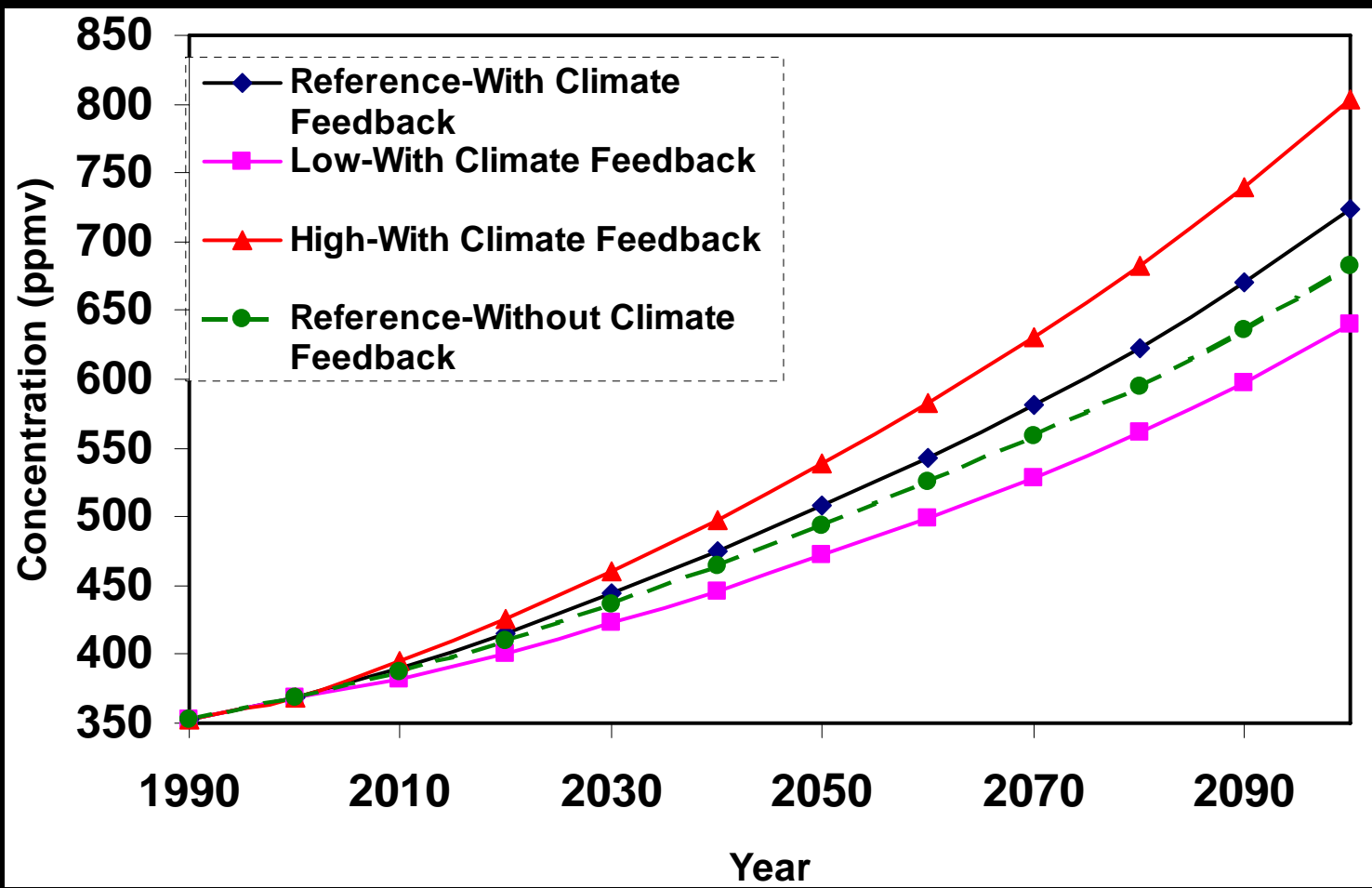
$$R_h > NPP$$

# Factors Effecting NPP, NEP, NBP: Fertilization and Climate Change

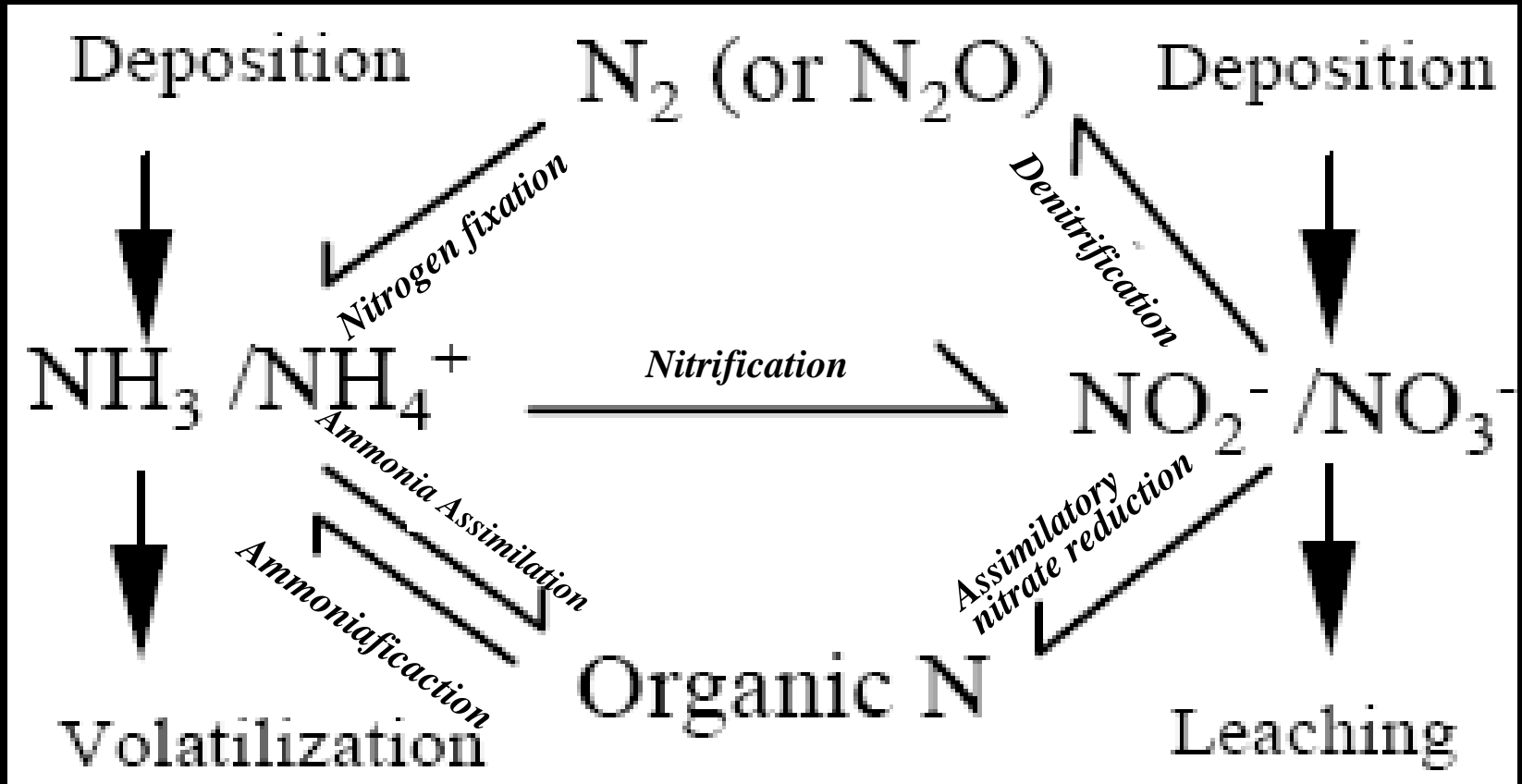


- ◆ **Fertilization Enhances photosynthesis**
  - Increase the reaction rate with CO<sub>2</sub>
  - Increase plant water-use efficiency
- ◆ **Warming may increase NPP**
  - Extend the length of the seasonal and daily growing cycles.
- ◆ **Warming may decrease NPP in water-stressed ecosystems and increase Ra and Rh**

# ISAM Estimated CO<sub>2</sub> Concentrations for IS92a Scenario



# Nitrogen Storage in Terrestrial Vegetation



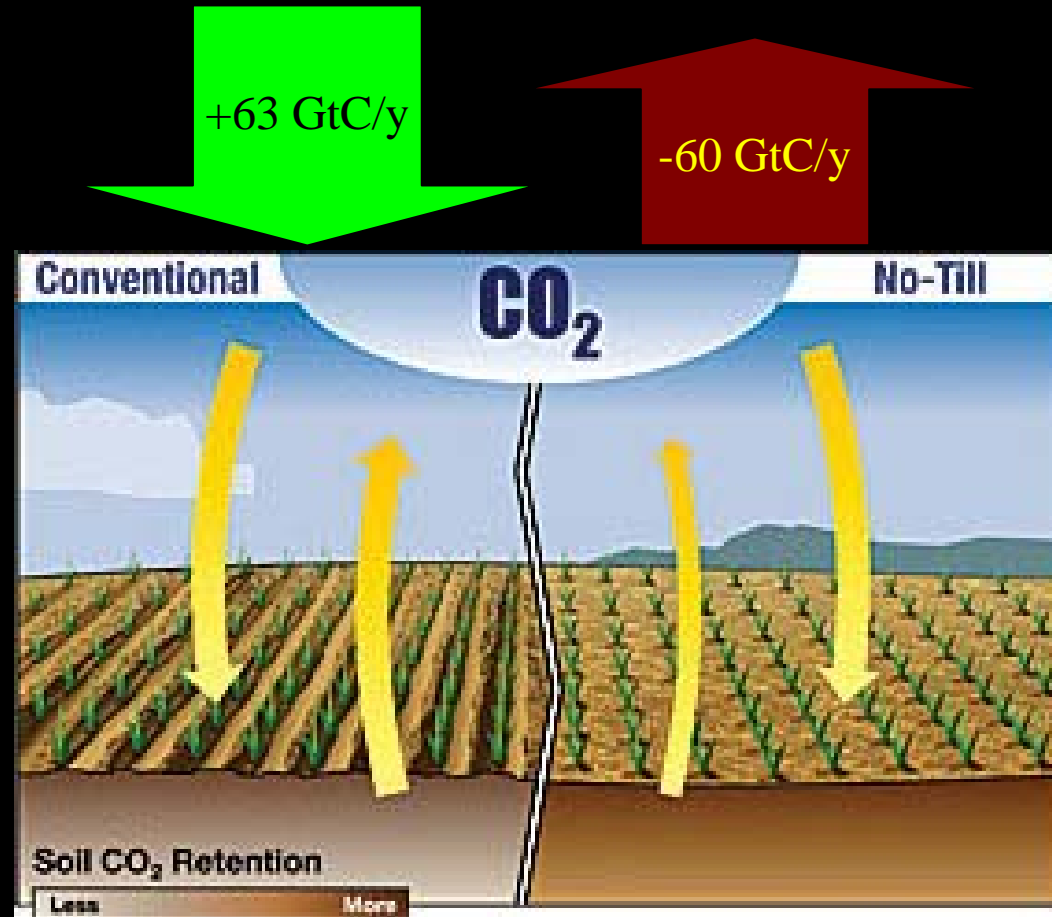
# Sequestering Carbon in Terrestrial Ecosystems: *No Tillage Agriculture Practices*



Small changes can lead to large benefit

- **Multiple benefits**

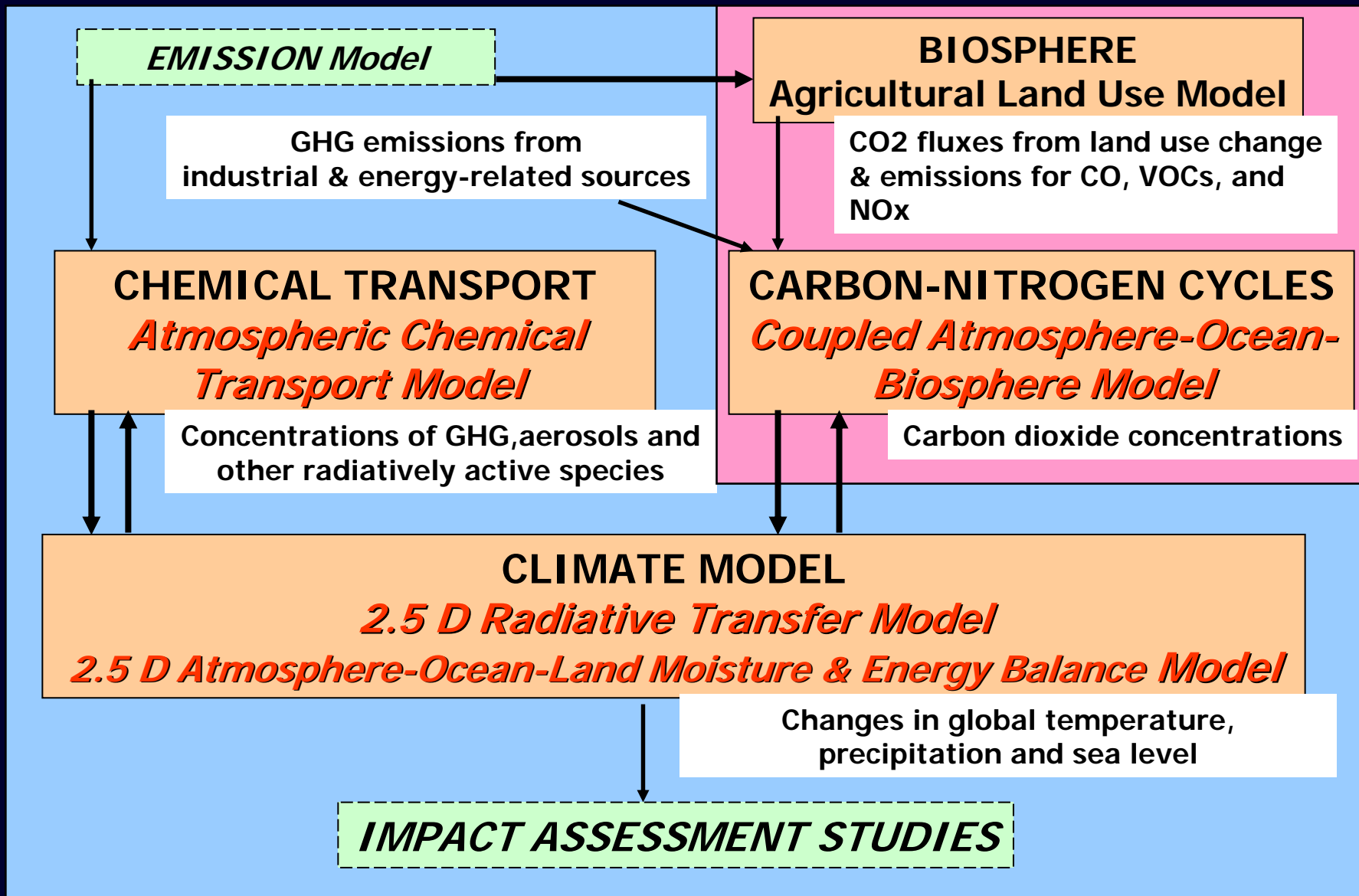
- Reduced erosion
- Improved soil fertility
- Increased water retention
- Conserved energy
- Increased crop yield
- Increased carbon storage





# Integrated Assessment Model (ISAM)

*Tool to Study Feedbacks Throughout The Earth System*



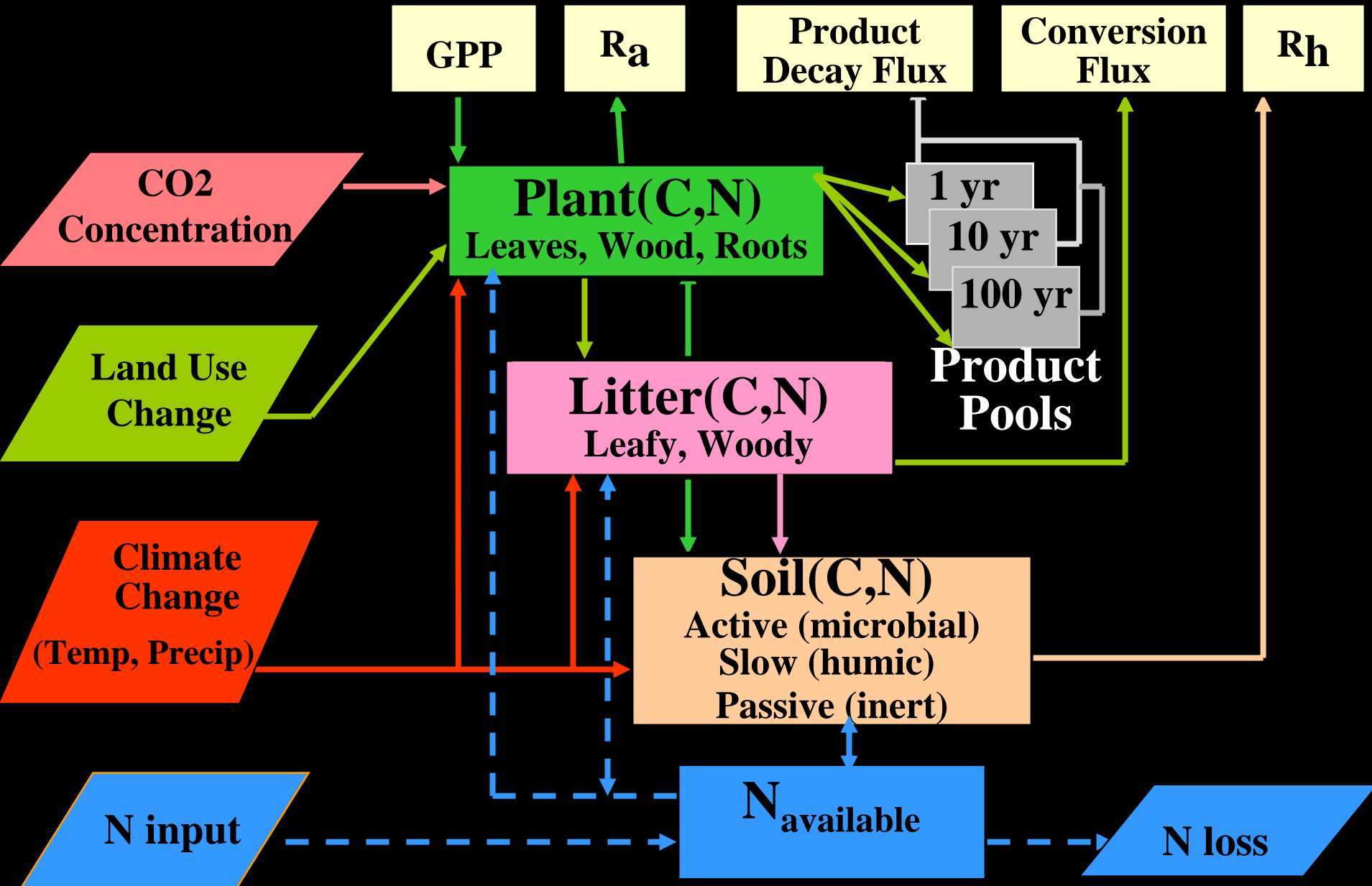
# ISAM Terrestrial Carbon Cycle Model



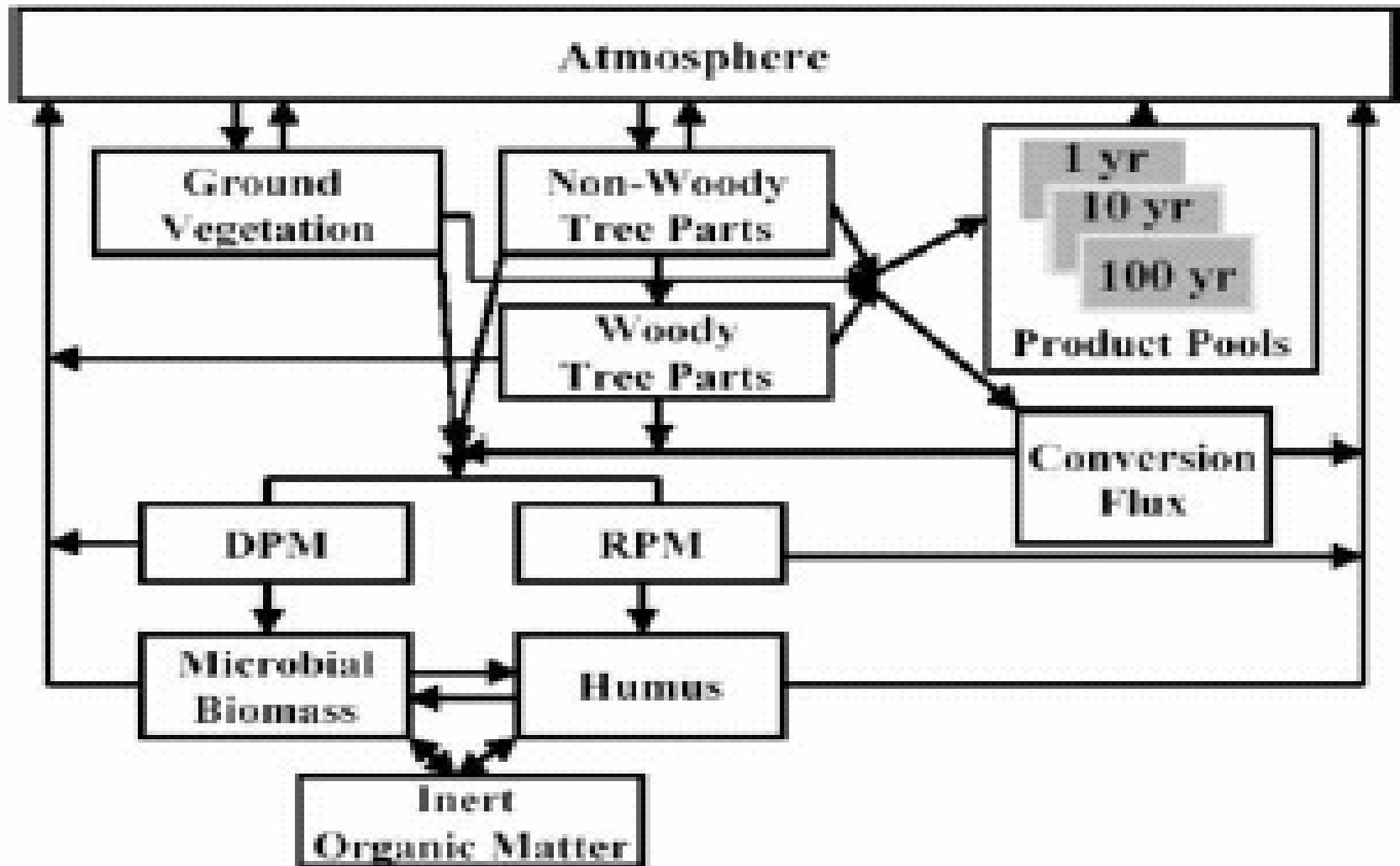
- ◆ **Spatial Resolution**: 0.5-by-0.5 degree
- ◆ **Land Cover Classifications**: Grid cells contain twelve land coverage classifications, which represent both highly managed land uses and less managed biomes
- ◆ **Changes in land cover classifications**: Driven by shifts in agriculture, afforestation, deforestation, reforestation, and pastureland
- ◆ **Processes**: Evapotranspiration, plant photosynthesis and respiration, litter production, and soil organic carbon decomposition
- ◆ **Feedbacks Mechanisms**: CO<sub>2</sub> and Nitrogen fertilization, and climate effects on photosynthesis, and respiration

In particular, the newly developed nitrogen cycle include all the major processes associated with nitrogen : immobilization, mineralization, nitrification, denitrification, leaching.

# Flow Chart of ISAM Terrestrial Carbon-Nitrogen Cycles Model

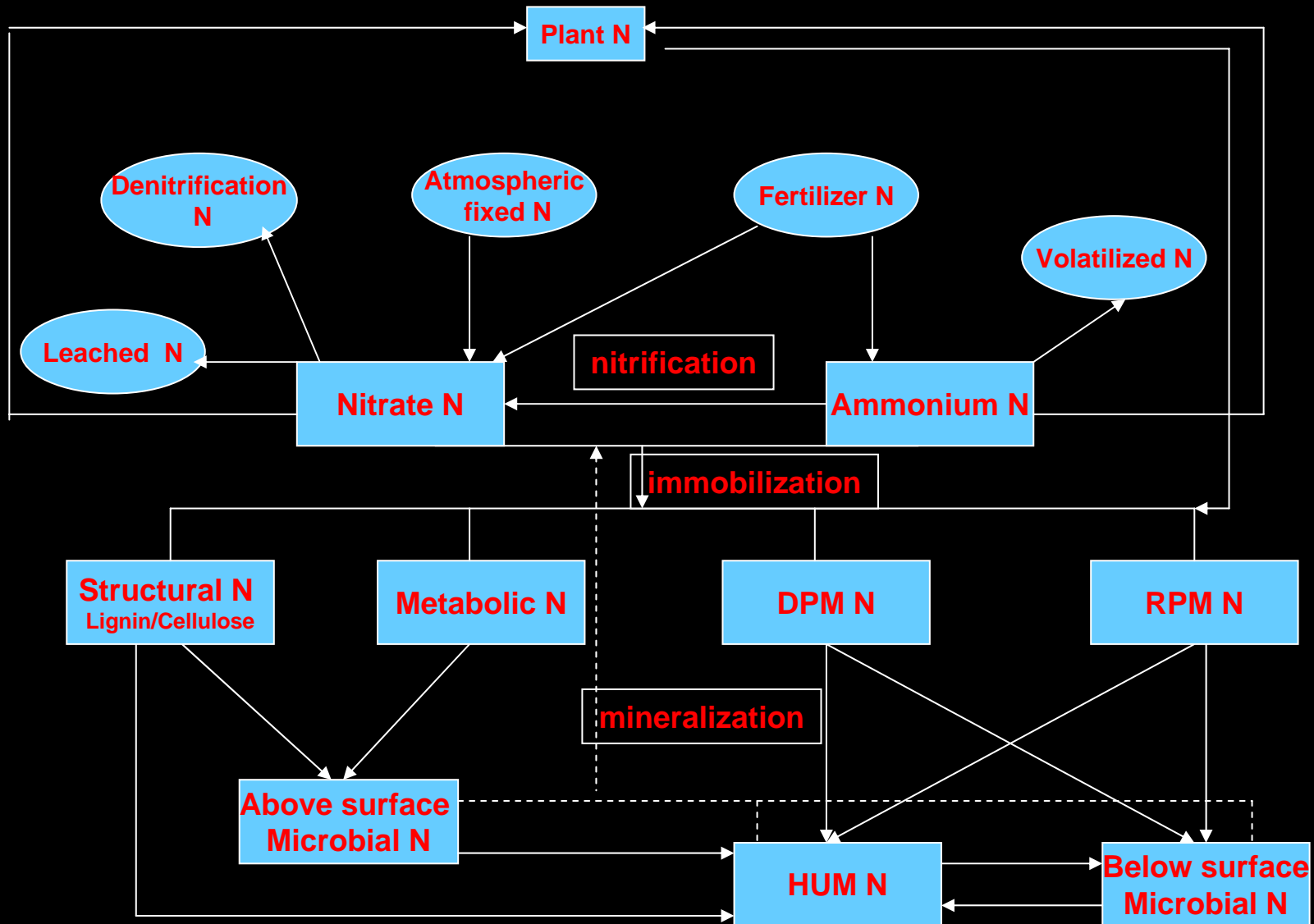


# Schematic Diagram of the Terrestrial Ecosystem Component of the ISAM

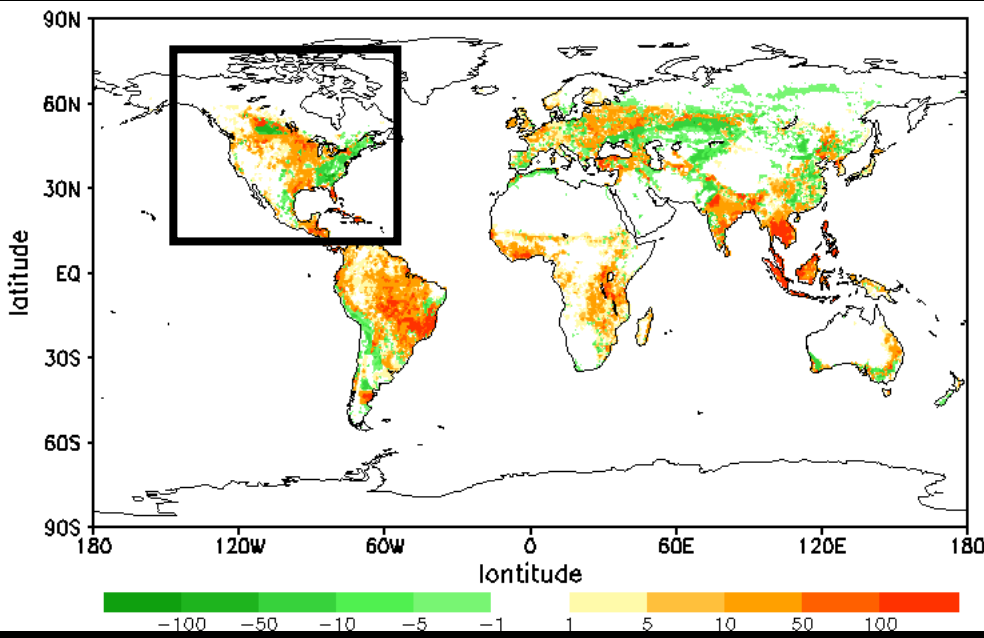




# Nitrogen Cycle

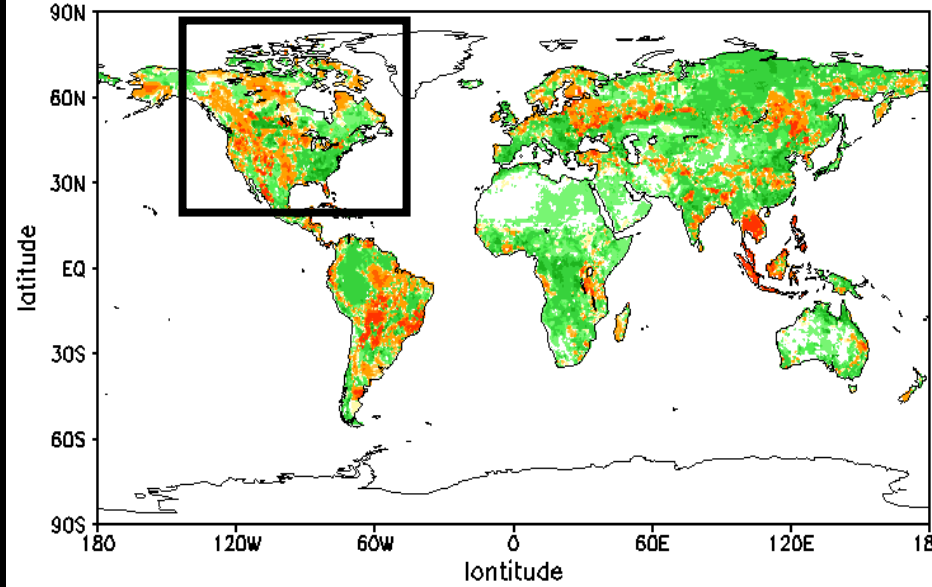


# ISAM Estimated Biospheric Fluxes for 1980s ( $\text{gC}\cdot\text{m}^{-2}\cdot\text{yr}^{-1}$ )

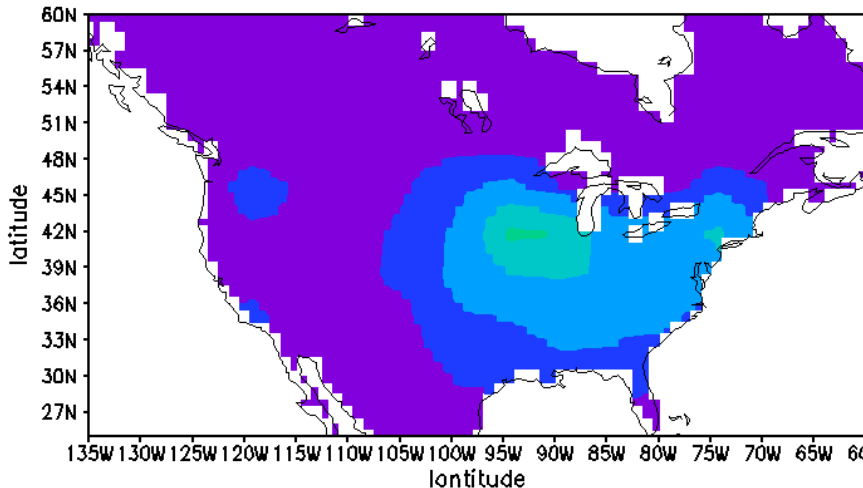


**Land Use Flux**

**Net Biospheric Flux**  
(= *land use + climate + CO<sub>2</sub>*)

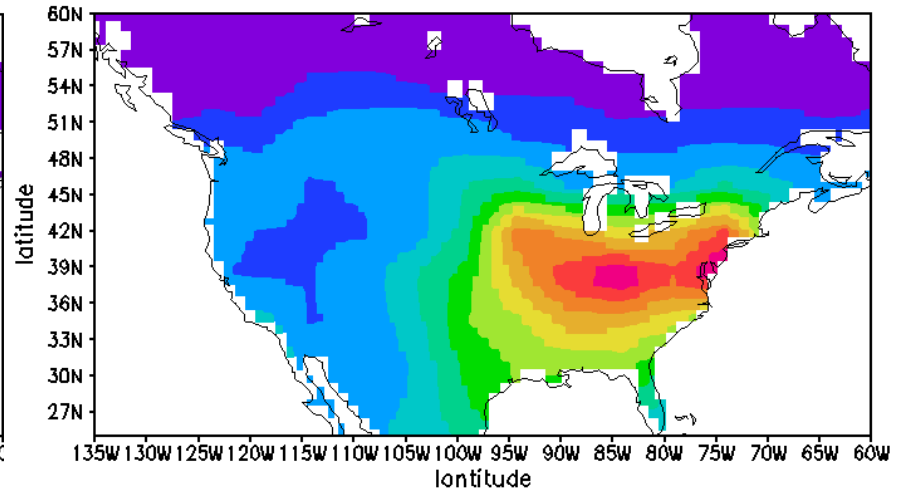


# Total Nitrogen Deposition in North America ( $mg\ N/m^2/yr$ )



1860

Total : 1.64 TgN/yr

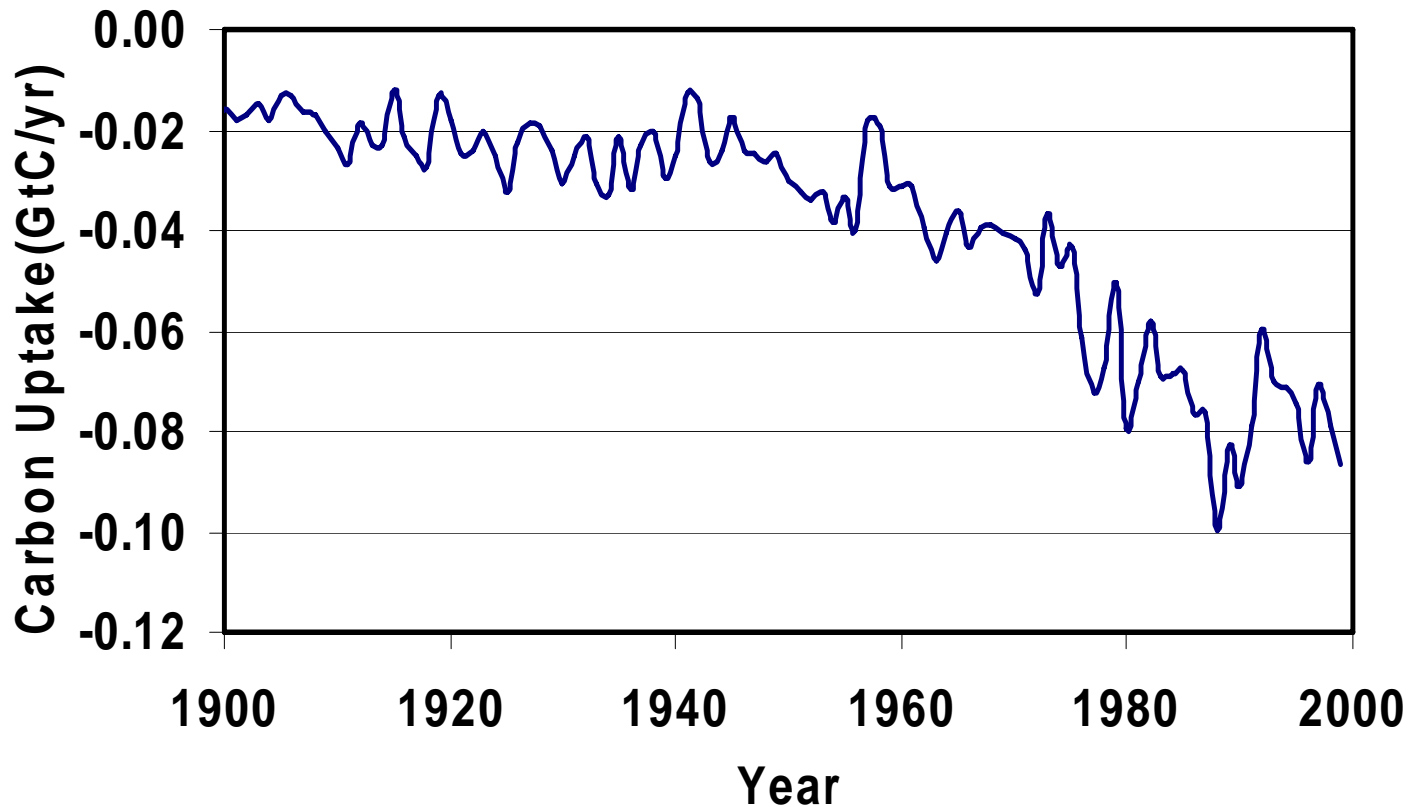


1990

Total : 7.4 TgN/yr

Calculated using global transport-chemistry model (Galloway et al., 2004).

# ISAM Estimated Influence of Nitrogen Deposition on North America Carbon Uptake



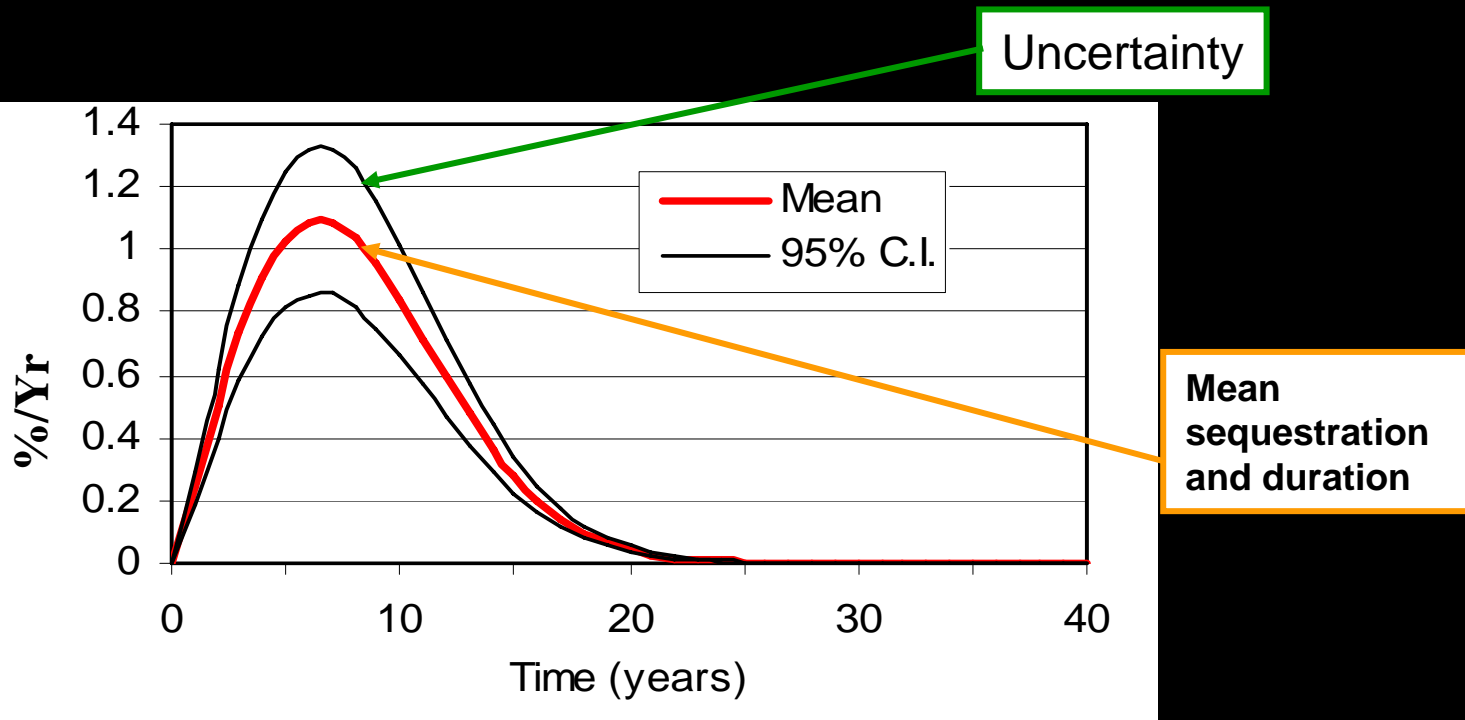
# Estimating Carbon Stocks Following Changes in Land Managements Using Averaged Measured Responses



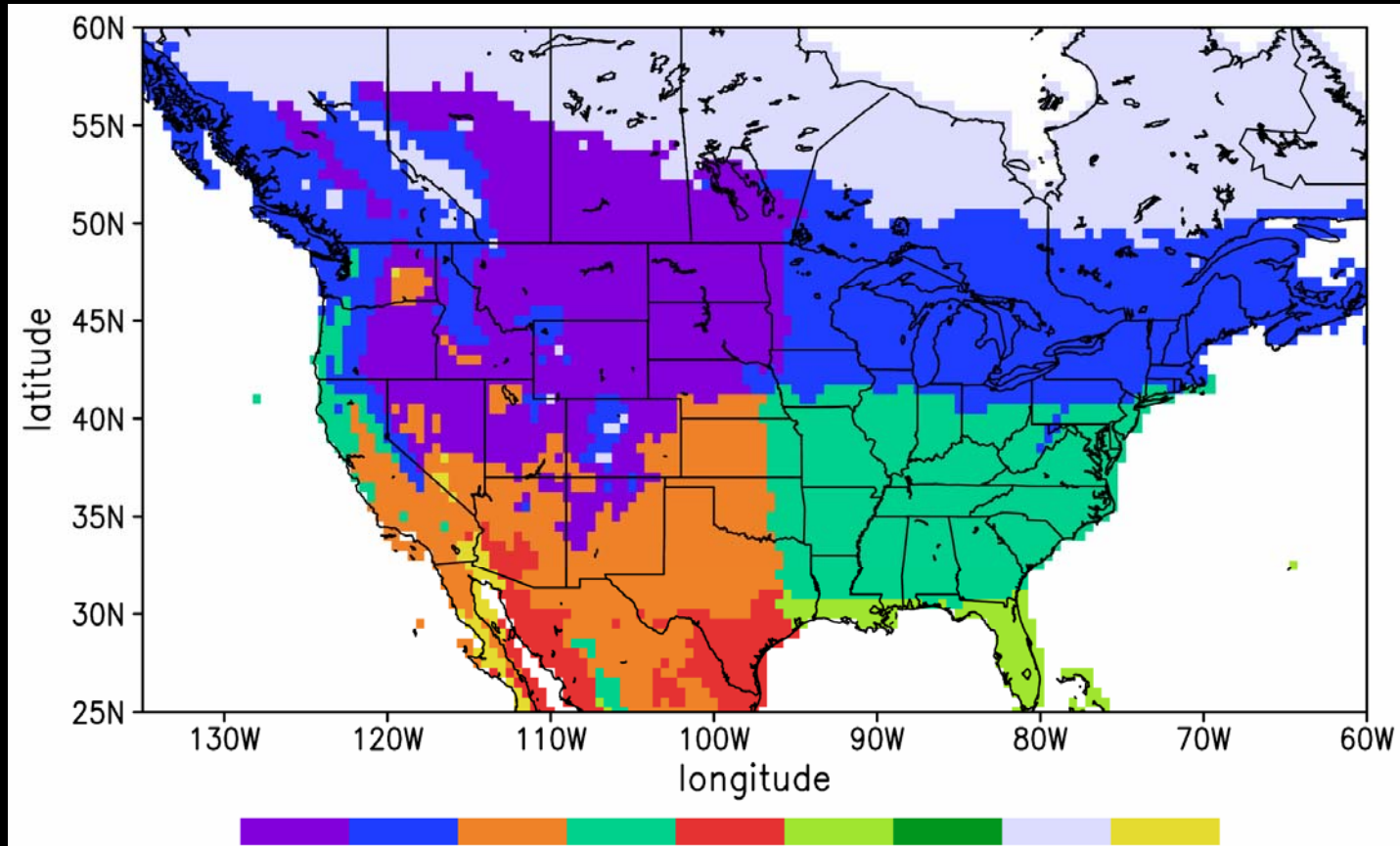
## Carbon Management Response Curves (CMRC):

Empirical relationships representing the effects of land management on carbon stocks

### Example: carbon accumulation under no-till



# Climate Regions



- Cold Temperate Dry (CTD)
  - Cold Temperate Moist (CTM)
  - Warm Temperate Dry (WTD)
  - Warm Temperate Moist (WTM)
  - Tropical Dry (TD)
  - Tropical Moist (TM)
  - Tropical Wet (CTD)
  - Polar (P)
  - Arid (A)
- Tropics (TROP)

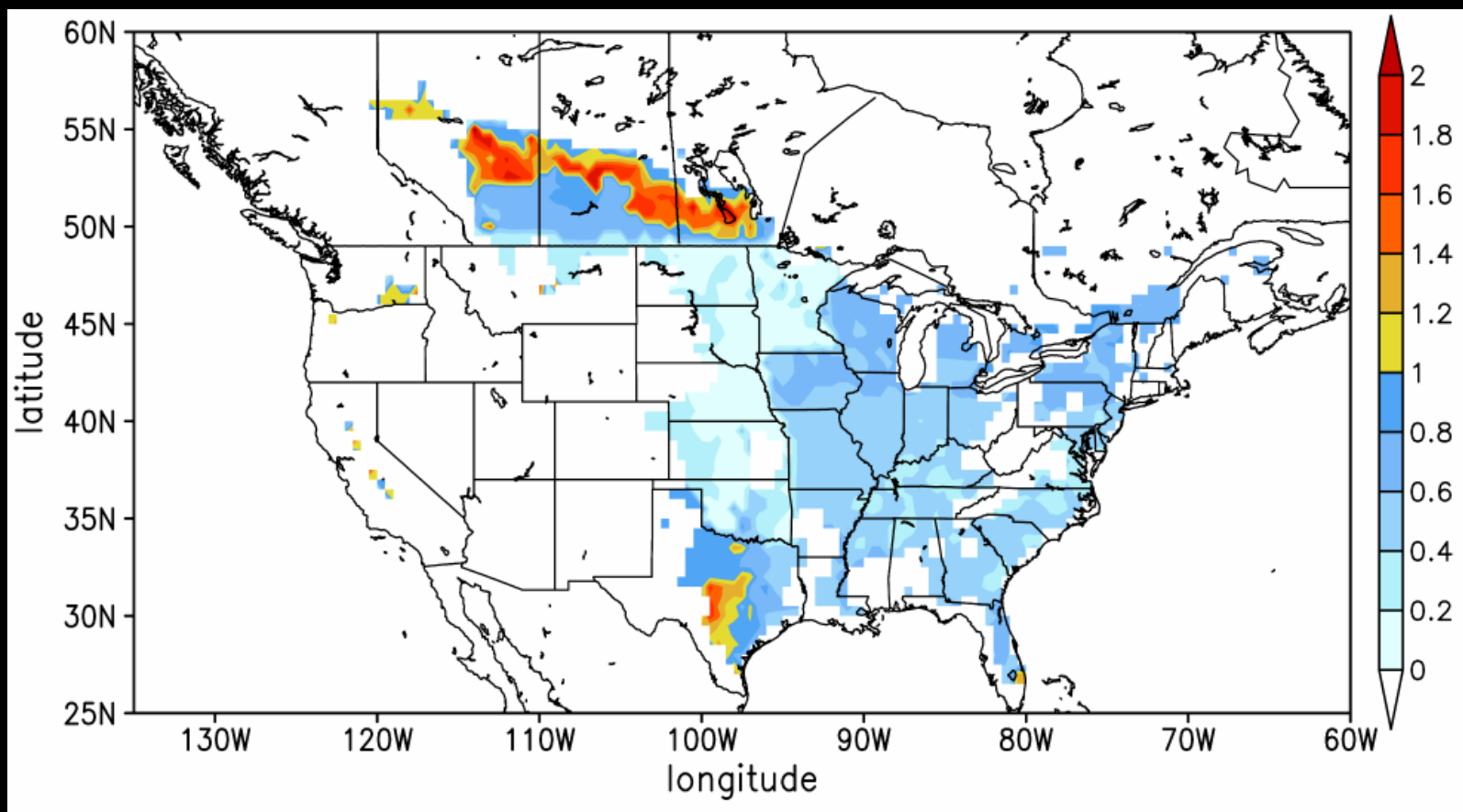
# Estimated Soil Carbon Sequestration Potential



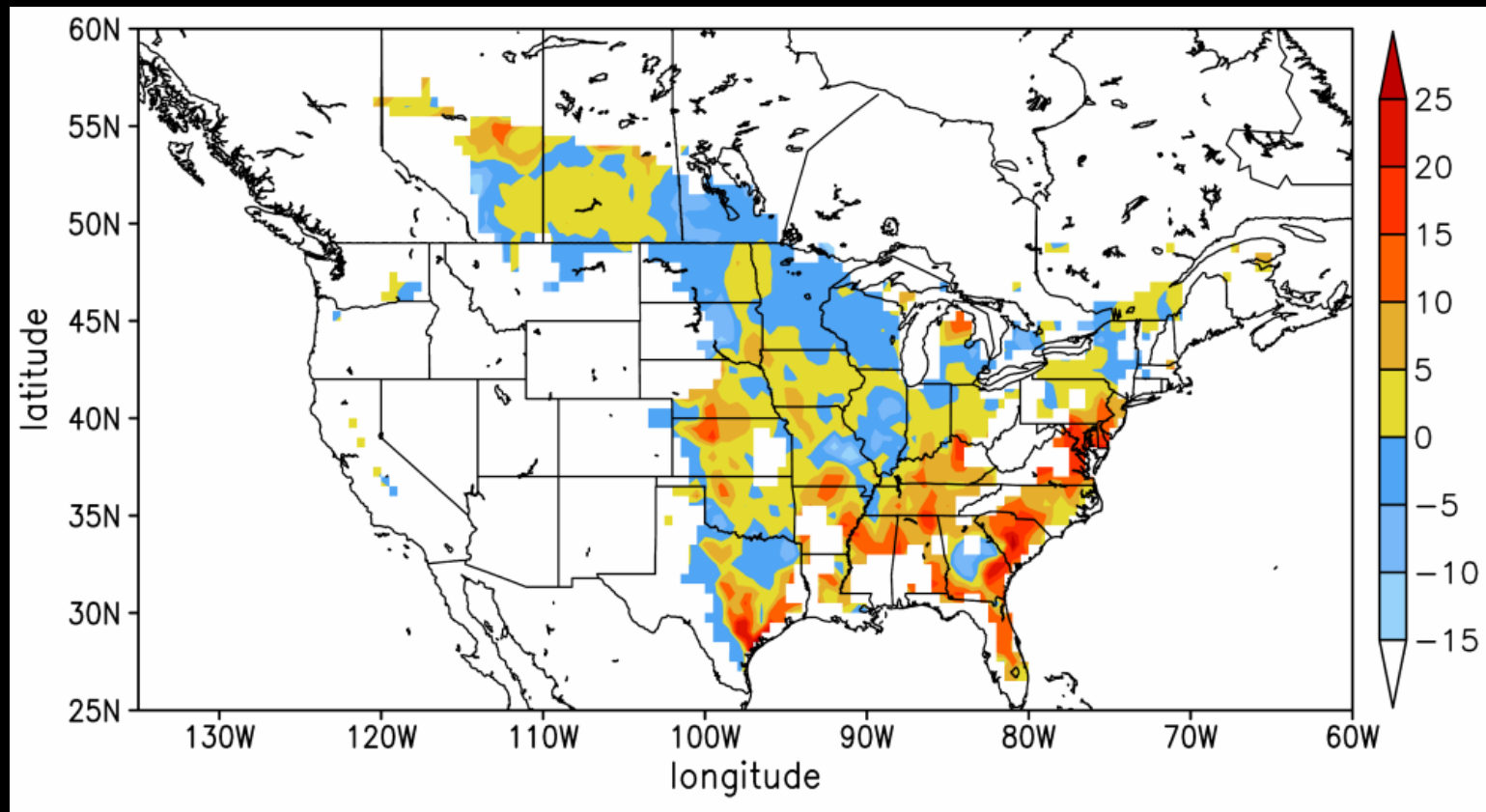
## CT to NT

*Averaged Over the Period 1981-2000*

*(MgC/ha/yr)*



# Percent Change Between With and Without Changes in Climate and CO<sub>2</sub>



**Positive (negative) values indicate an increase (decrease) in soil C sequestration potential due to changes in climate, land use and CO<sub>2</sub>.**

# Cropland Area, Cropland in NT, and Sequestration Rates



Climate Regions*	Cropland Area (Mha)*	NT Area (Mha)*	Sequestration Rates		
			(MgC ha <sup>-1</sup> yr <sup>-1</sup> )	Actual (TgC yr <sup>-1</sup> )**	Maximum (TgC yr <sup>-1</sup> )**
CTD	79.80	21.34	0.694	14.80	55.38
CTM	68.11	18.21	0.569	10.36	38.75
WTD	31.09	8.31	0.595	4.94	18.50
WTM	79.67	21.31	0.445	9.48	35.45
TROP	19.31	5.16	0.741	3.82	14.31
<b>Total</b>	<b>279.88</b>	<b>74.34</b>	<b>0.584</b>	<b>43.41</b>	<b>163.45</b>

\* For Year 2000

\*\* Averaged for the period 1981-2000

*NT area is based on soil tillage survey data at the U.S. State and Canadian Province levels (CTIC, 2000; Statistics Canada, 2001)*

*Jain et al. (2005)*



# ISAM Estimated North America Carbon Budget (Tg C/Year)

	1980s	1990s
Land Use	10.8	- 46.4
CO2	-177.0	-182.9
Climate	<u>190.6</u>	<u>246.7</u>
	24.4	16.7
Nitrogen	-74.9	-76.8
Management	<u>-26.4</u>	<u>- 60.3</u>
	-76.9	-120.4



**THE END**