# Agriculture's Role in Mitigation of Greenhouse Gases

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CASMGS
Consortium for Agricultural Soils Mitigation of Greenhouse Gases

***K-State Research and Extension***

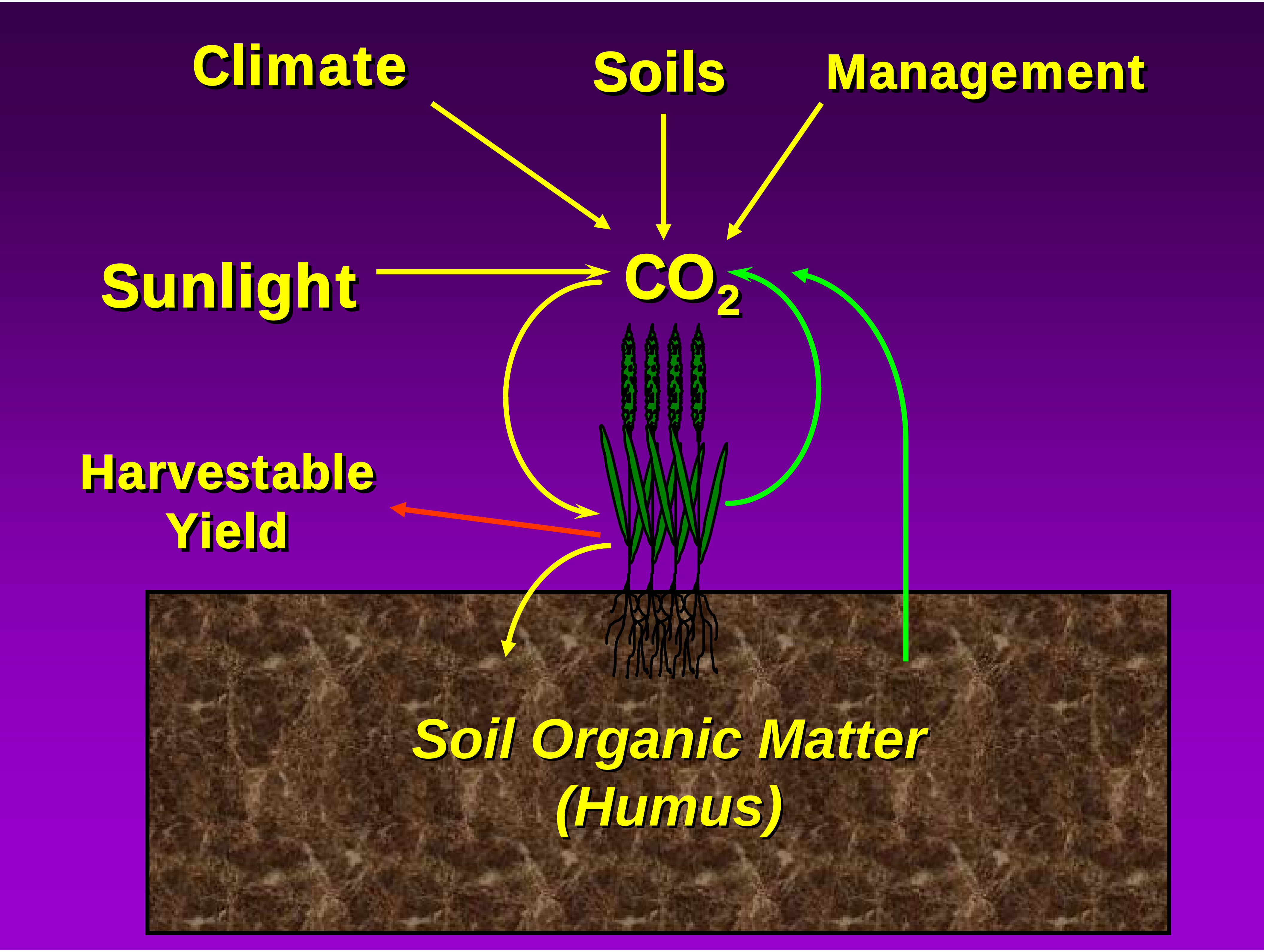
# Strategies to Reduce Atmospheric $CO_2$

- Strategies
  - Reduce fossil fuel consumption
    - Improve efficiency
    - Renewable energy sources
  - Identify sinks and sequestration rate
    - Terrestrial
      - Soils
      - Plants
    - Aquatic
    - Geologic

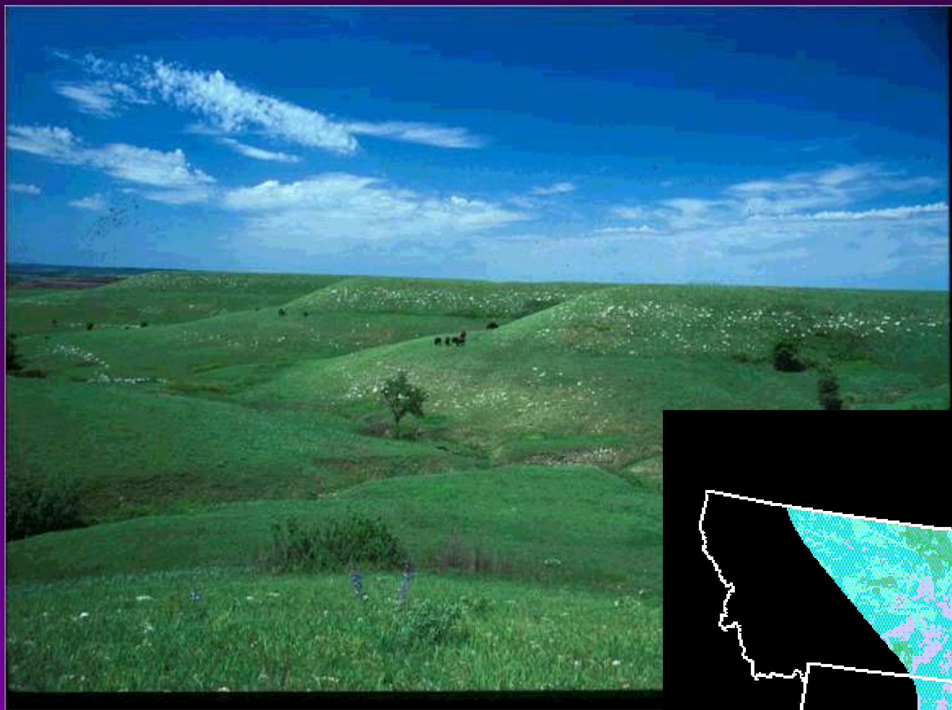
# Potential $CO_2$ Stabilization Options

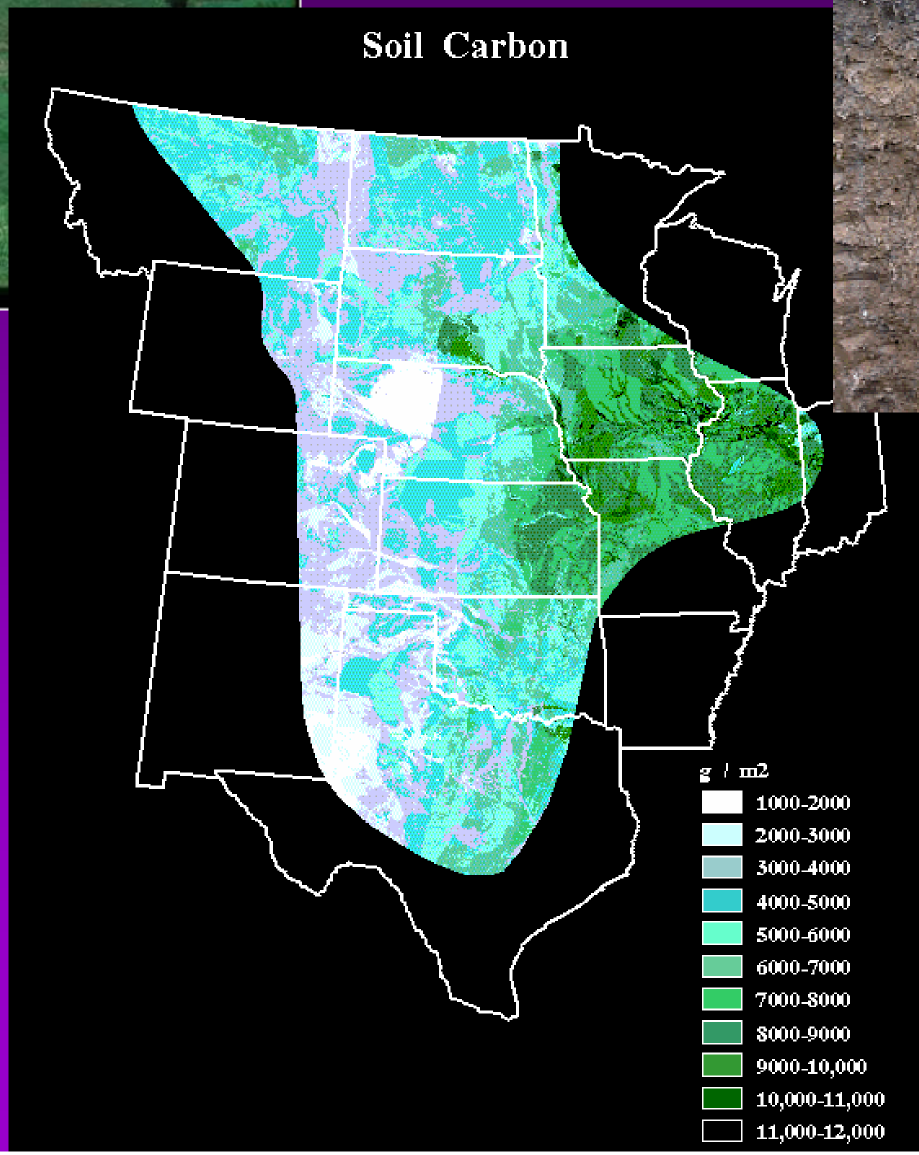
| | Rapidly Deployable | Not Rapidly Deployable |
|---|---|---|
| Minor Contributors <0.2 PgC/y | • **Biomass co-fire electric generation**<br>• Cogeneration (small scale)<br>• Hydropower<br>• Natural Gas Combined cycle<br>• Niche options (geothermal, solar) | • Integrated photovoltaics<br>• Forest management (fire suppression)<br>• Ocean fertilization |
| Major Contributors >0.2 PgC/y | • **C sequestration in ag. soils**<br>• Improved appliance efficiency<br>• Improved buildings<br>• Improved vehicle efficiency<br>• Non-$CO_2$ gas abatement from industry<br>• **Non-$CO_2$ gas abatement from agriculture**<br>• Reforestation<br>• Stratospheric sulfates | • **Biomass to hydrogen**<br>• **Biomass to fuel**<br>• Cessation of deforestation<br>• Energy-efficient urban and transportation systems<br>• Fossil-fuel C separation with geologic or ocean storage<br>• High efficiency coal technology<br>• Large-scale solar<br>• Next generation nuclear fission<br>• Wind with $H_2$ storage<br>• Speculative technologies |

Caldeira et al. 2004. A portfolio of carbon management options, p. 103-130, *In* C. B. Field and M. R. Raupach, eds. The Global Carbon Cycle. Island Press, Washington, DC.

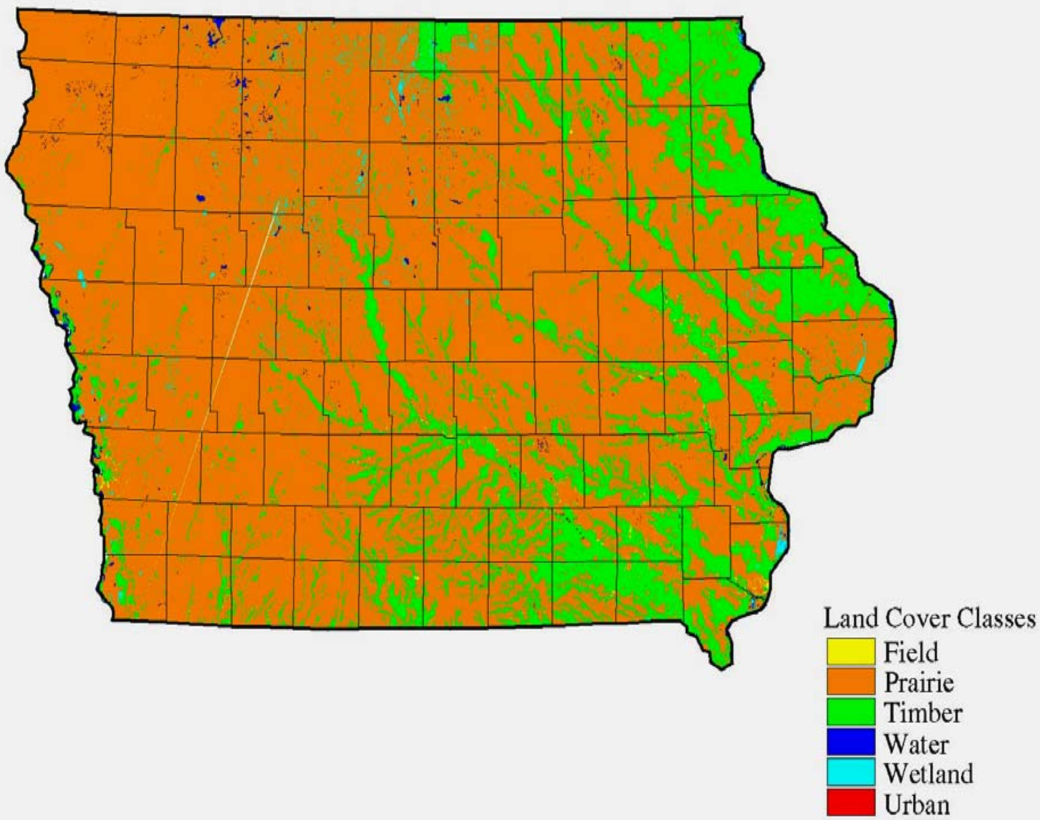


Climate
Soils
Management
Sunlight
$CO_2$
Harvestable Yield
Soil Organic Matter
(Humus)

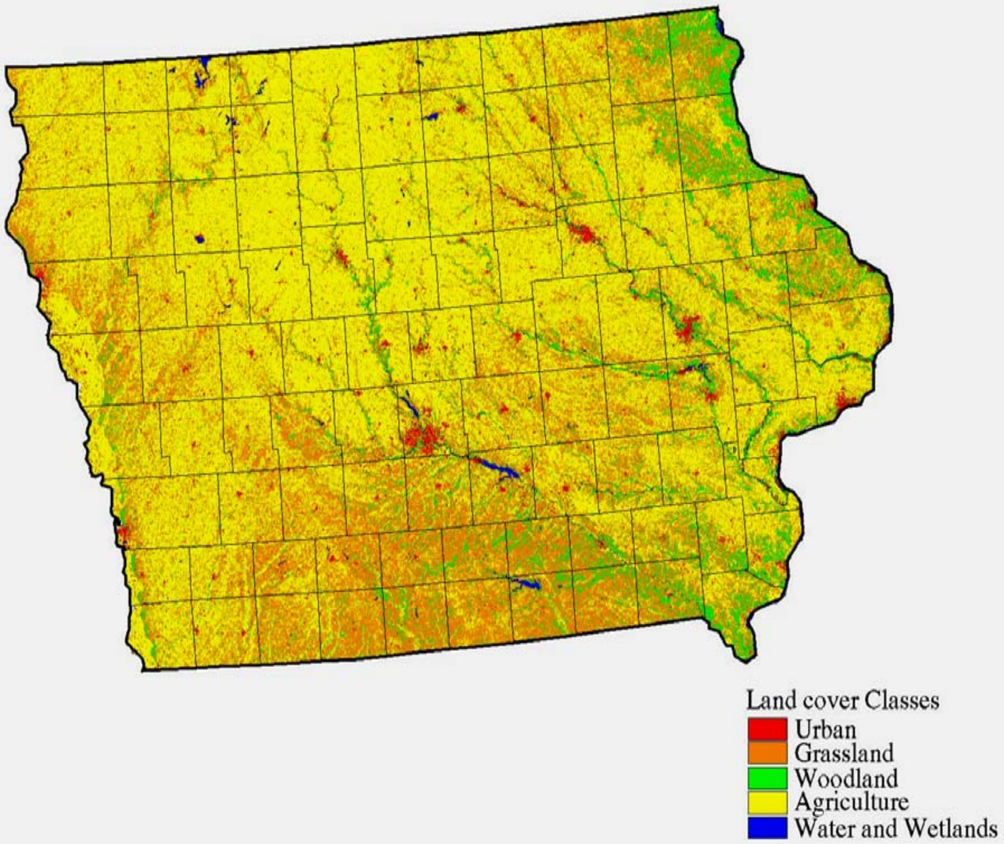


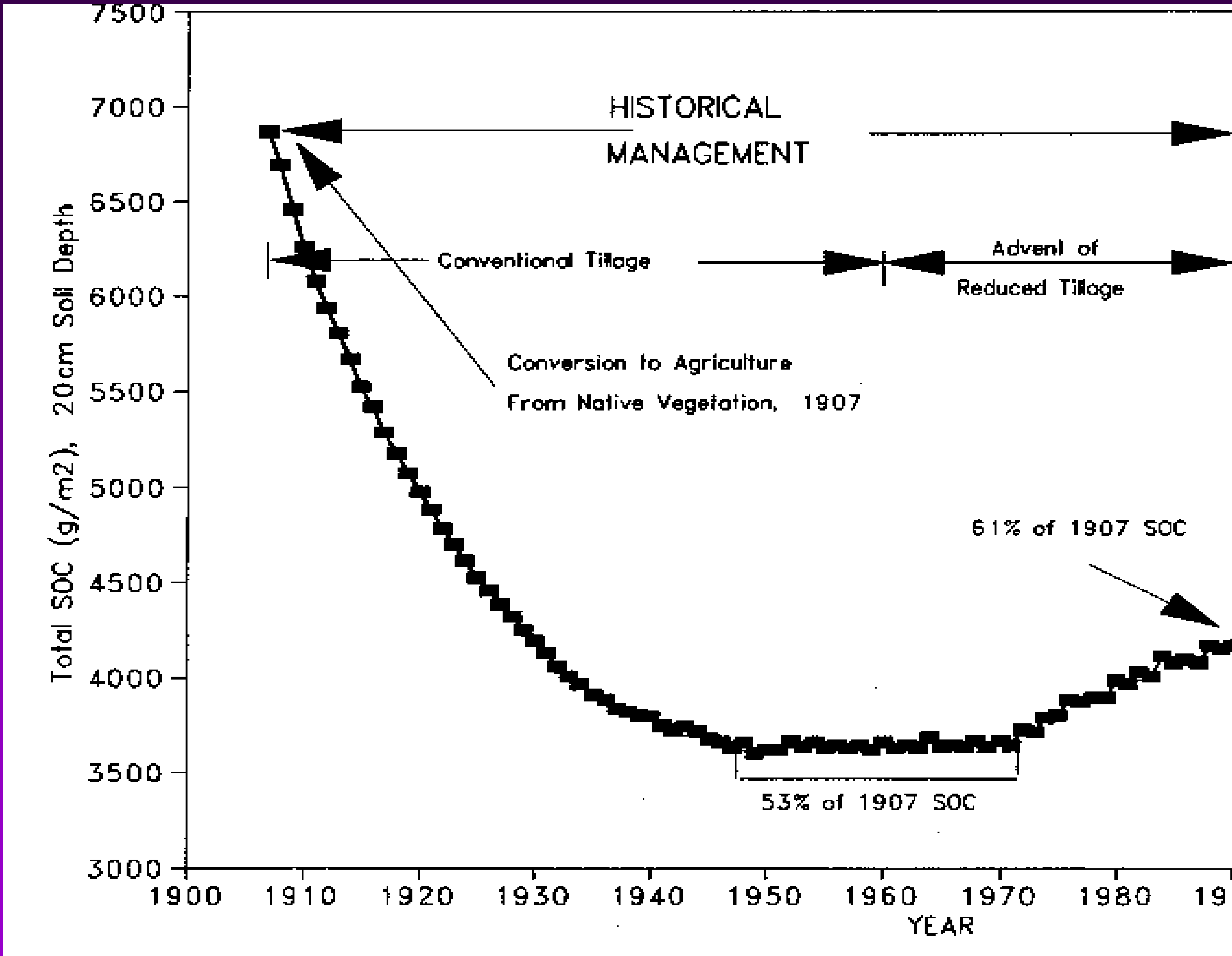

Soil Carbon
g / m2
1000-2000
2000-3000
3000-4000
4000-5000
5000-6000
6000-7000
7000-8000
8000-9000
9000-10,000
10,000-11,000
11,000-12,000

# Historic landcover 1840’s




# Current landcover 1990’s





HISTORICAL
MANAGEMENT
Conventional Tillage
Advent of
Reduced Tillage
Conversion to Agriculture
From Native Vegetation, 1907
61% of 1907 SOC
53% of 1907 SOC
Total SOC (g/m2), 20cm Soil Depth
YEAR
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
1900
1910
1920
1930
1940
1950
1960
1970
1980

# Crop Management Strategies for C Sequestration

Develop Crop Management Programs that:

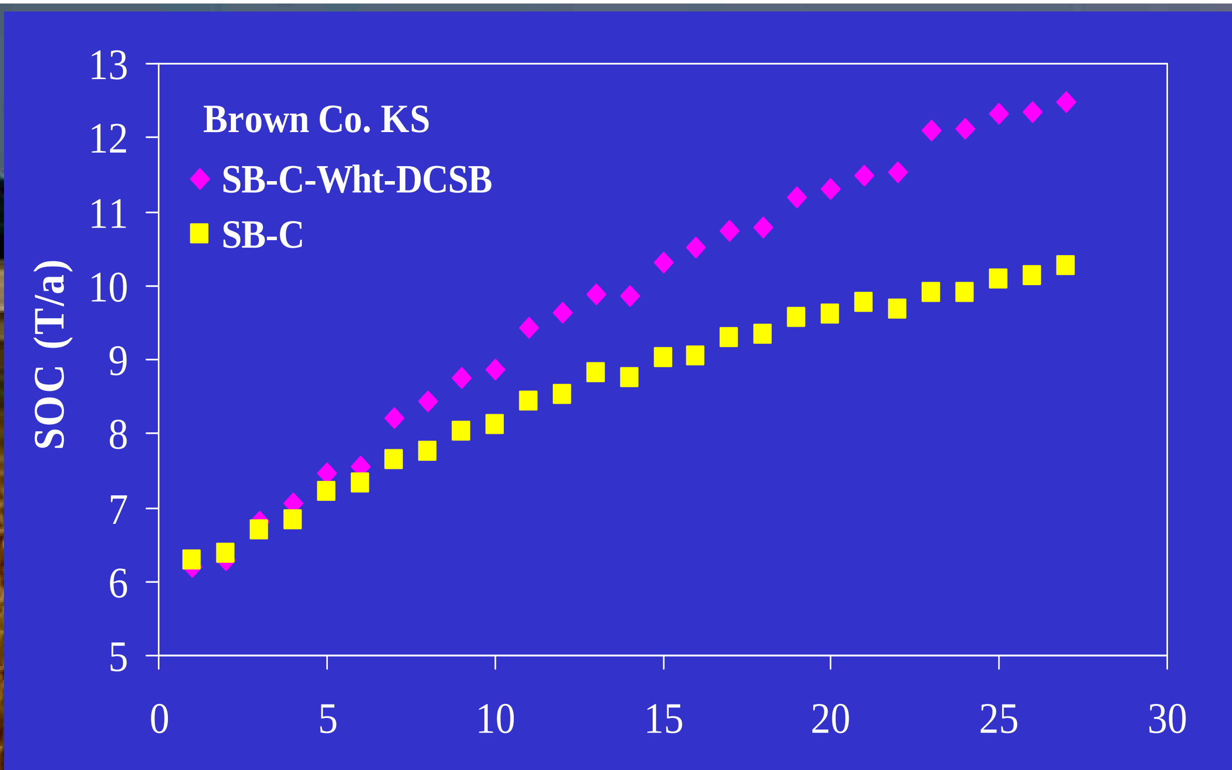
**Enhance C Inputs**

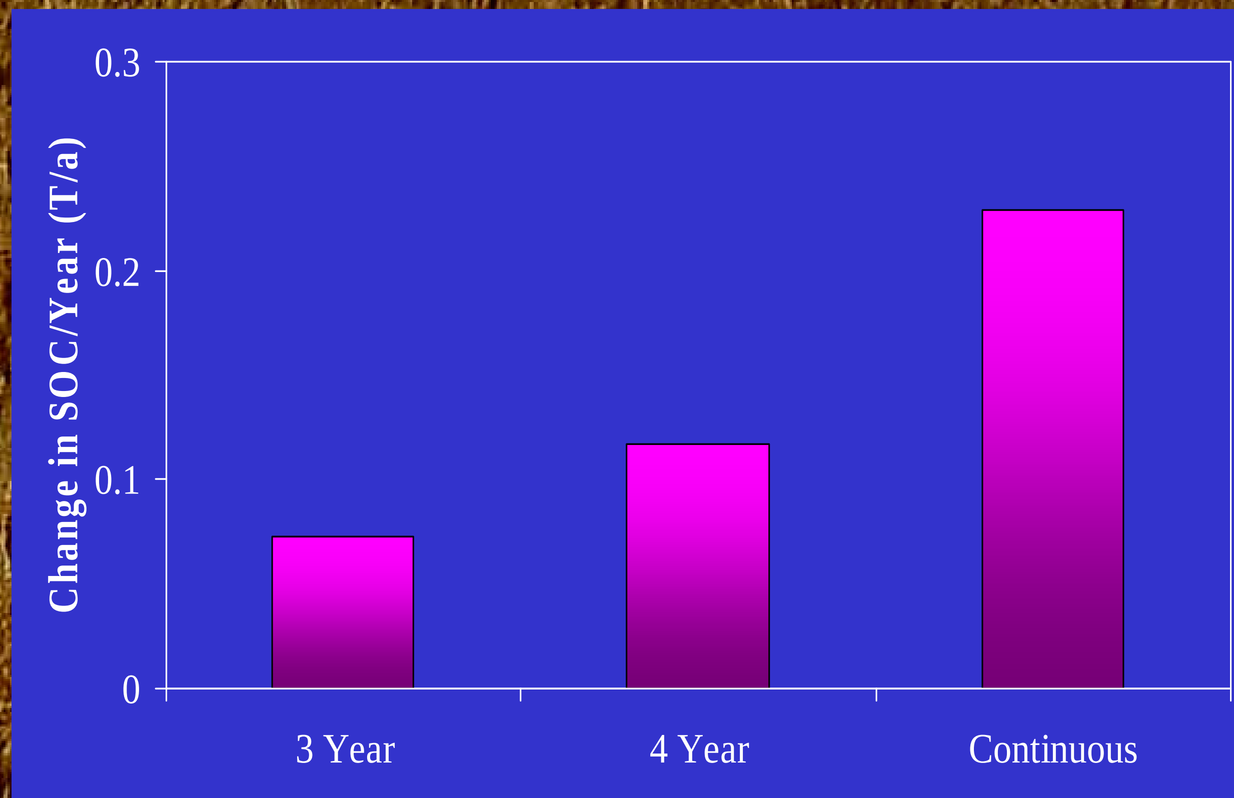
- **Crop Management**
- **Crop Selection**
- **Crop Rotations**

**Reduce C losses**

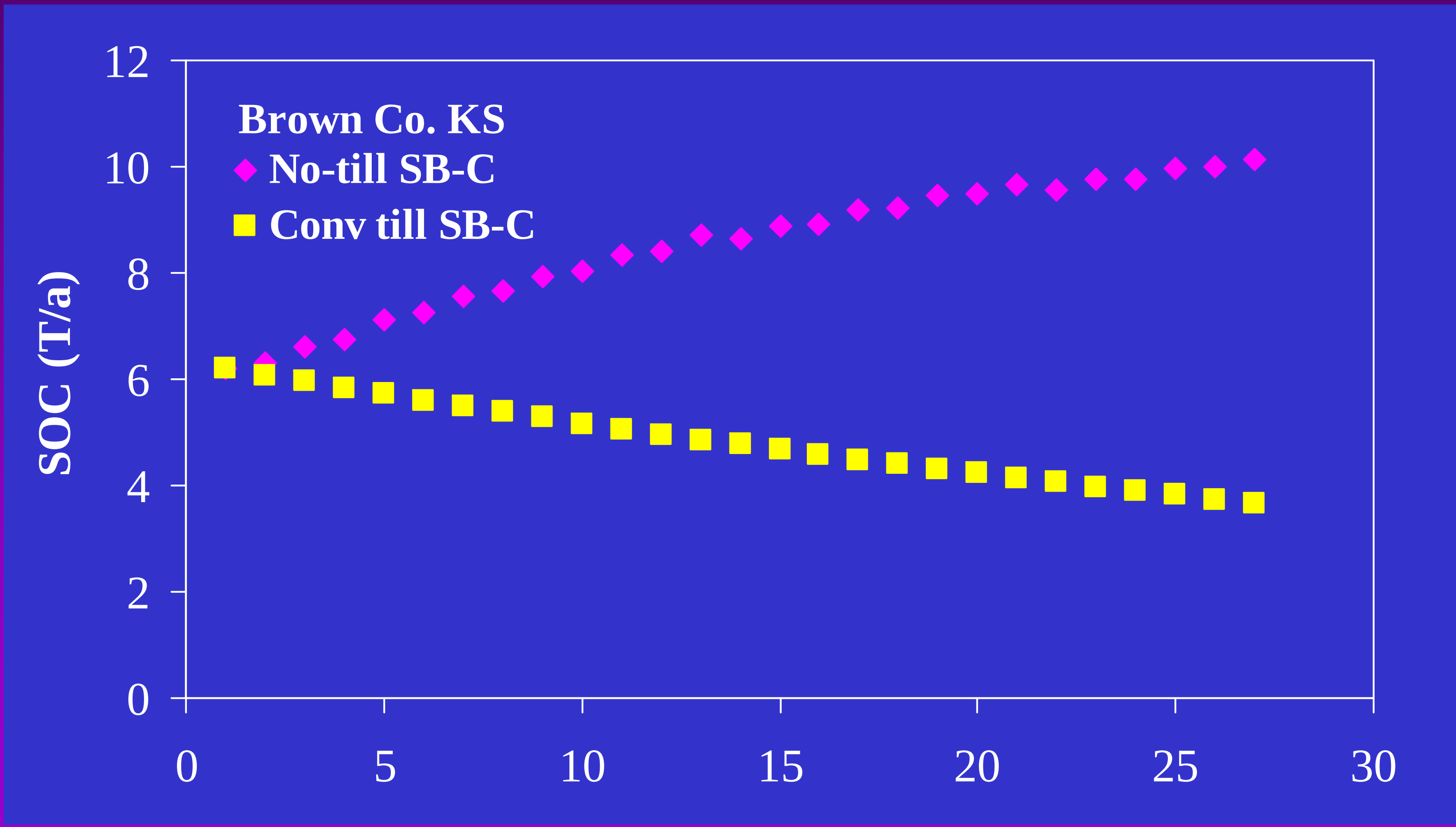
- **Tillage**
- **Fallow Management**

# Enhancing C Input – Intensifying Rotations



# Reducing Loss – Reducing tillage



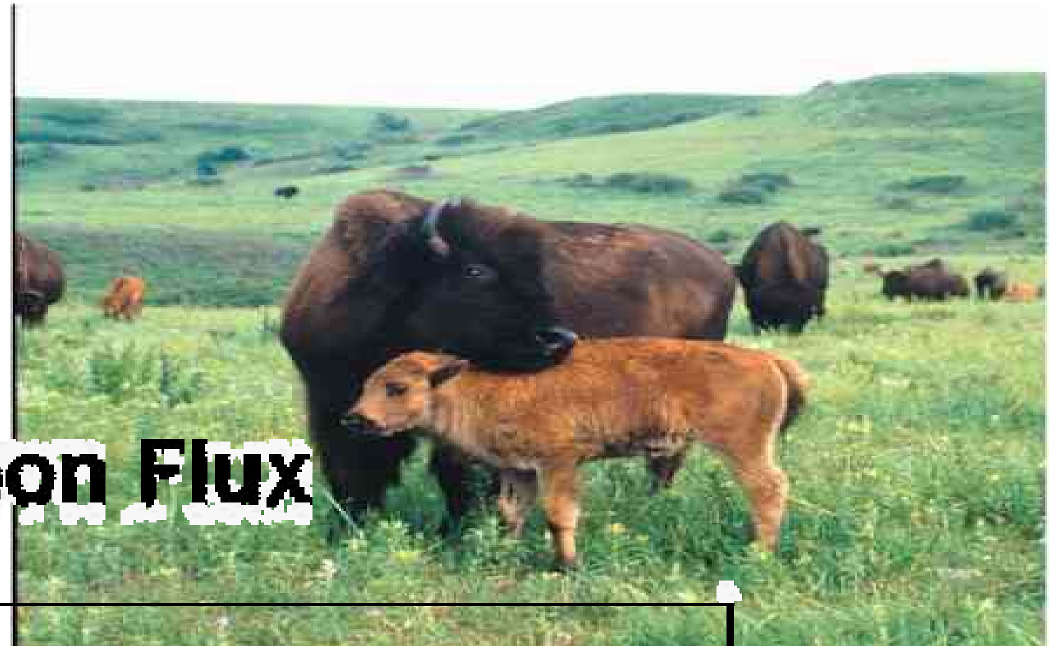
# Global potential and rates of soil organic C sequestration

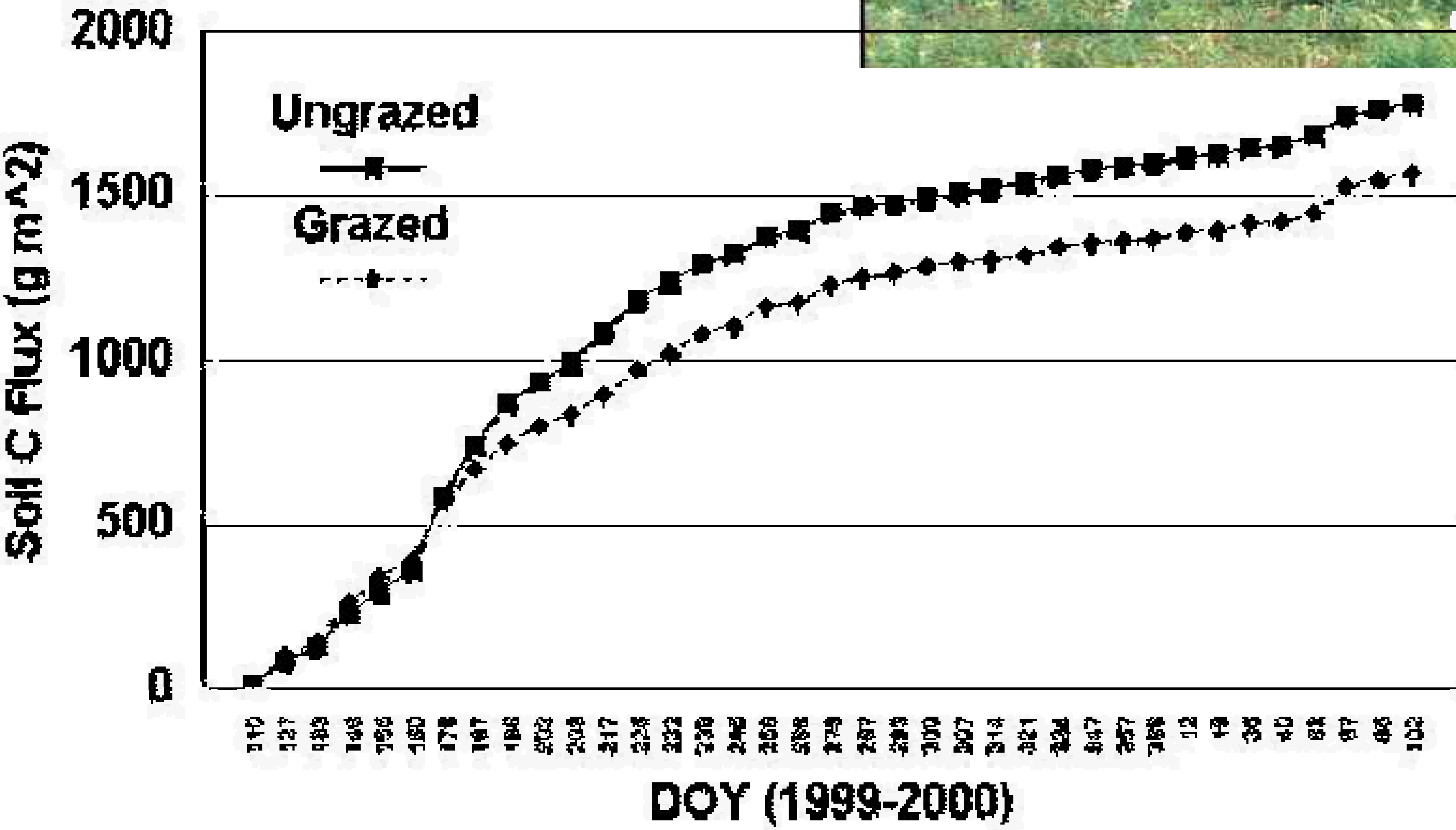
| | Mean | SD | Activities |
|---|---|---|---|
| | ***Global potential*, Pg C yr$^{-1}$** | | |
| IPCC (1996) | 0.663 | 0.218 | Ag. soils, set aside, wetland, degraded land |
| Lal & Bruce (1999) | 0.163 | 0.018 | Bio offset, crop syst., CT, erosion, degraded land |
| | ***Global historical rates*, Mg C ha$^{-1}$ yr$^{-1}$** | | |
| West & Post (2002) | 0.57 | 0.14 | No till |

# Grasslands

| | Soil C (Mg ha$^{-1}$) | Soil N (Mg ha$^{-1}$) |
|---|---|---|
| Control | 36.0 | 3.3 |
| N fertilized | 40.7* | 3.8* |
| Control | 41.5* | 3.7 |
| Mowed | 34.5 | 3.4 |
| Burned | 41.2* | 3.2 |
| Unburned | 34.6 | 3.7* |

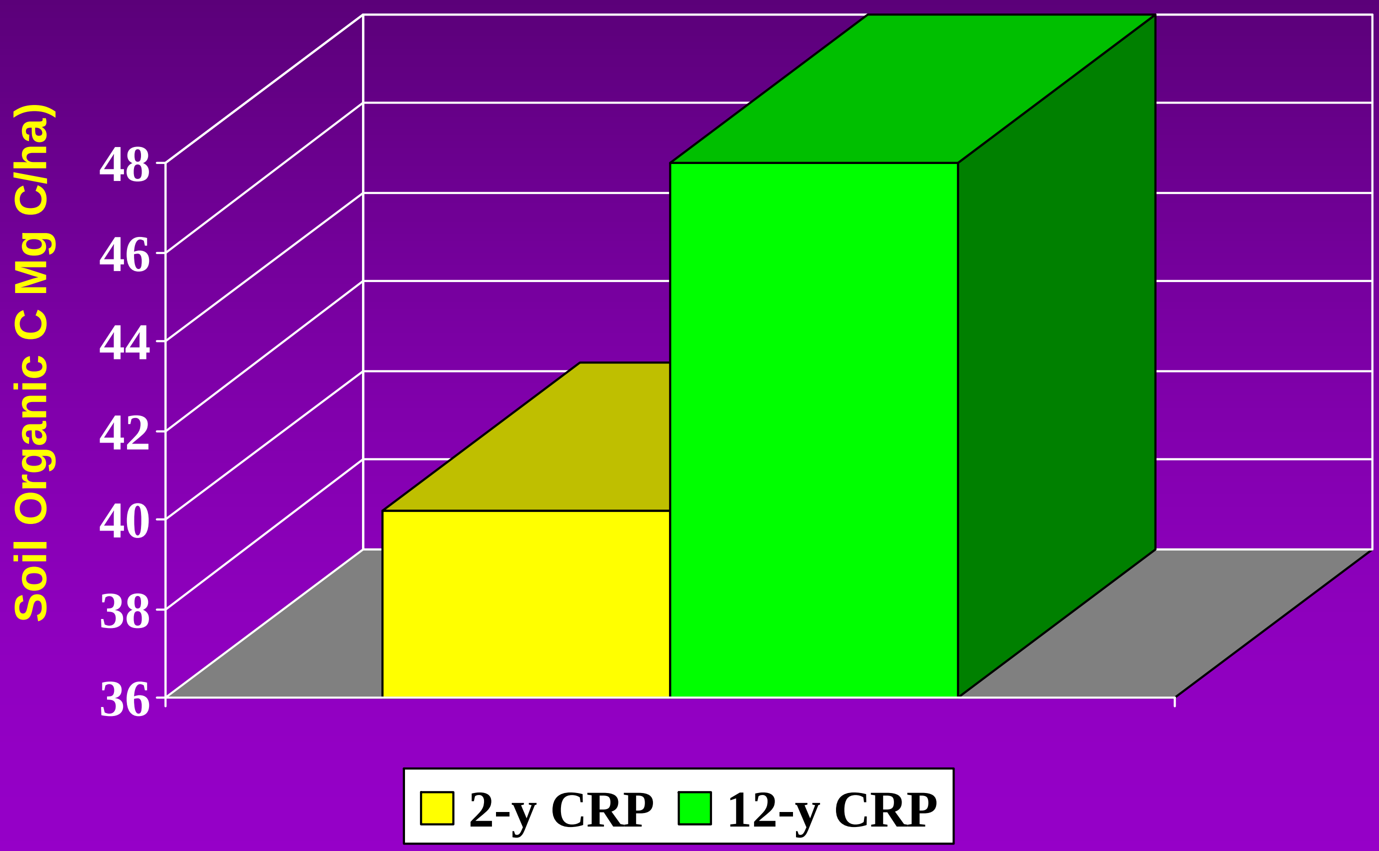
# Soil Carbon Flux





# Soil organic C after 2 and 12 y of CRP in Nebraska (Baer, Kitchen, Blair, and Rice)

0.8 MT/ha/y



# Potential of U.S. Agriculture for Mitigation

| Scenario | MMTC/yr |
|---|---|
| C sequestration in cropland | 132 (69-195) |
| C sequestration in CRP | 13 |
| C sequestration in rangelands | 58 (30-110) |
| Biofuel production (C offset) | ~50 |
| Saving in fuel consumption | 1-2 |
| Reduction of C emission from eroded sediments | ~15 |
| Total | 270 |

US emissions: ~1800 MMTC/yr

Lal et al., 1999, 2003

## Two Key Factors in Assessing the Terrestrial Carbon Sequestration Potential in the US:

BIOPHYSICAL HETEROGENEITY:

Carbon rates vary due to bio-physical conditions (soils, climate, etc)

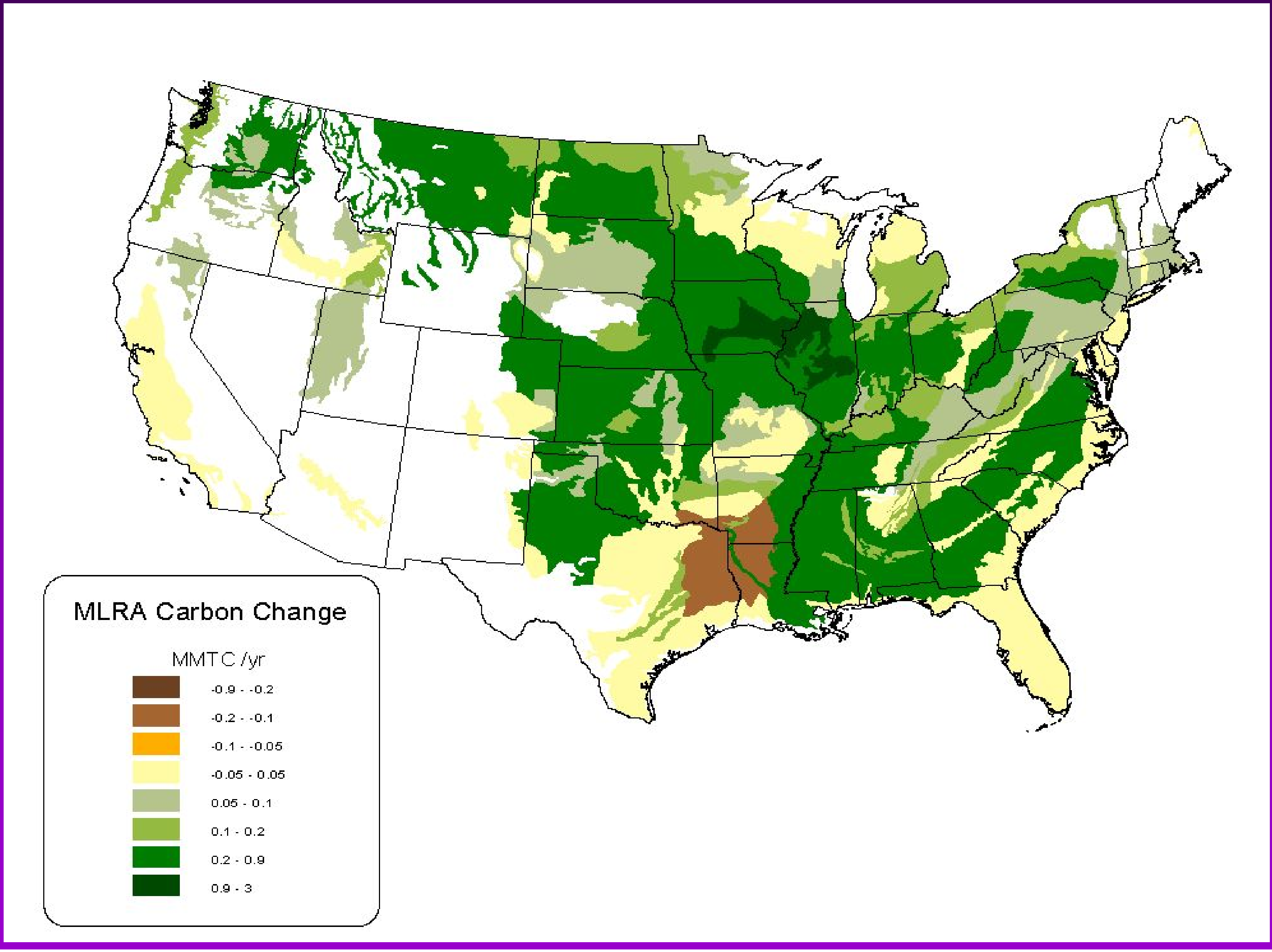
ECONOMIC HETEROGENEITY:

Opportunity costs vary spatially due to factors affecting productivity and profitability

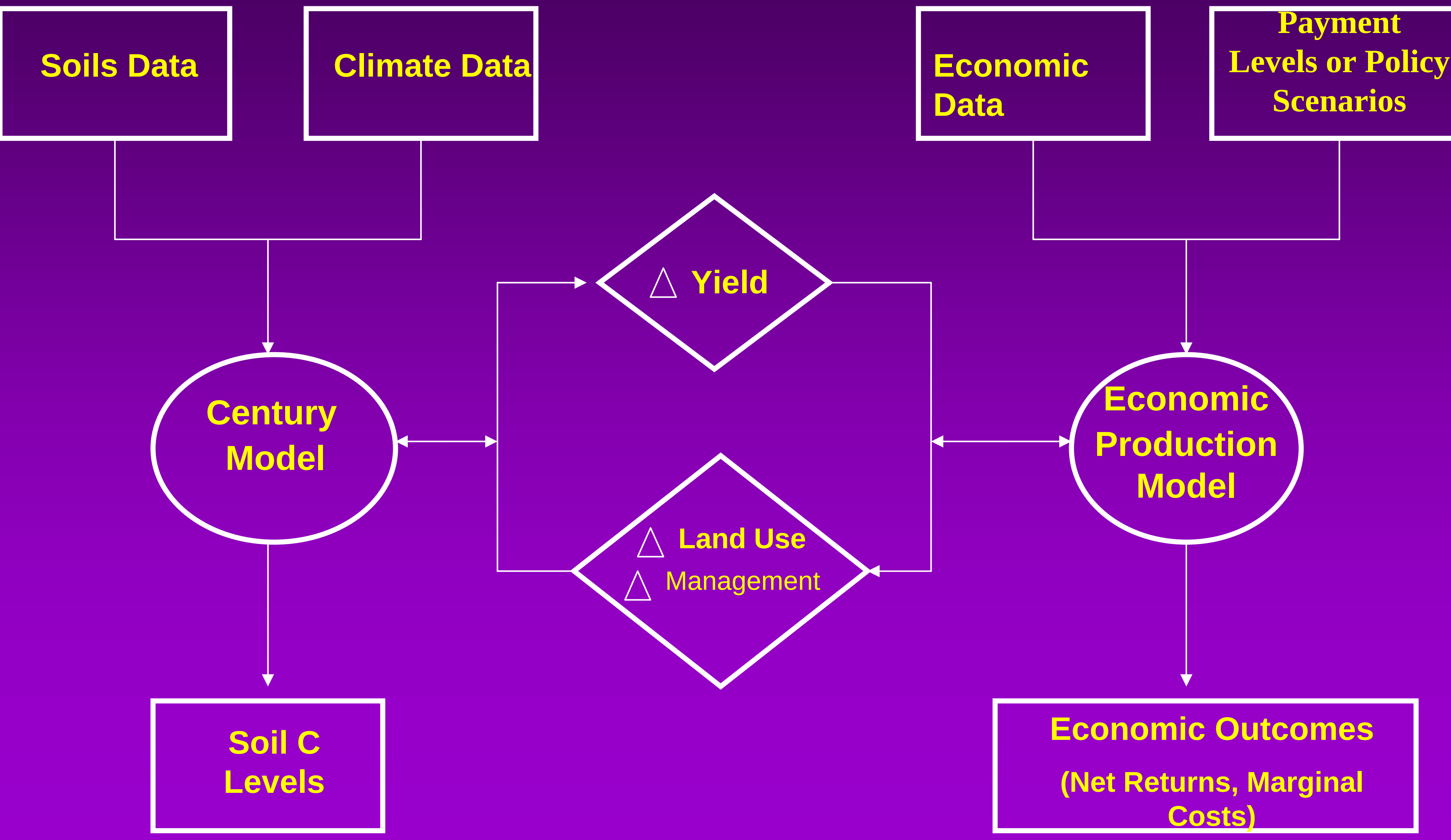
- production practices
- farm-specific management factors (experience, education, attitudes, etc.)
- prices (location)

# Century

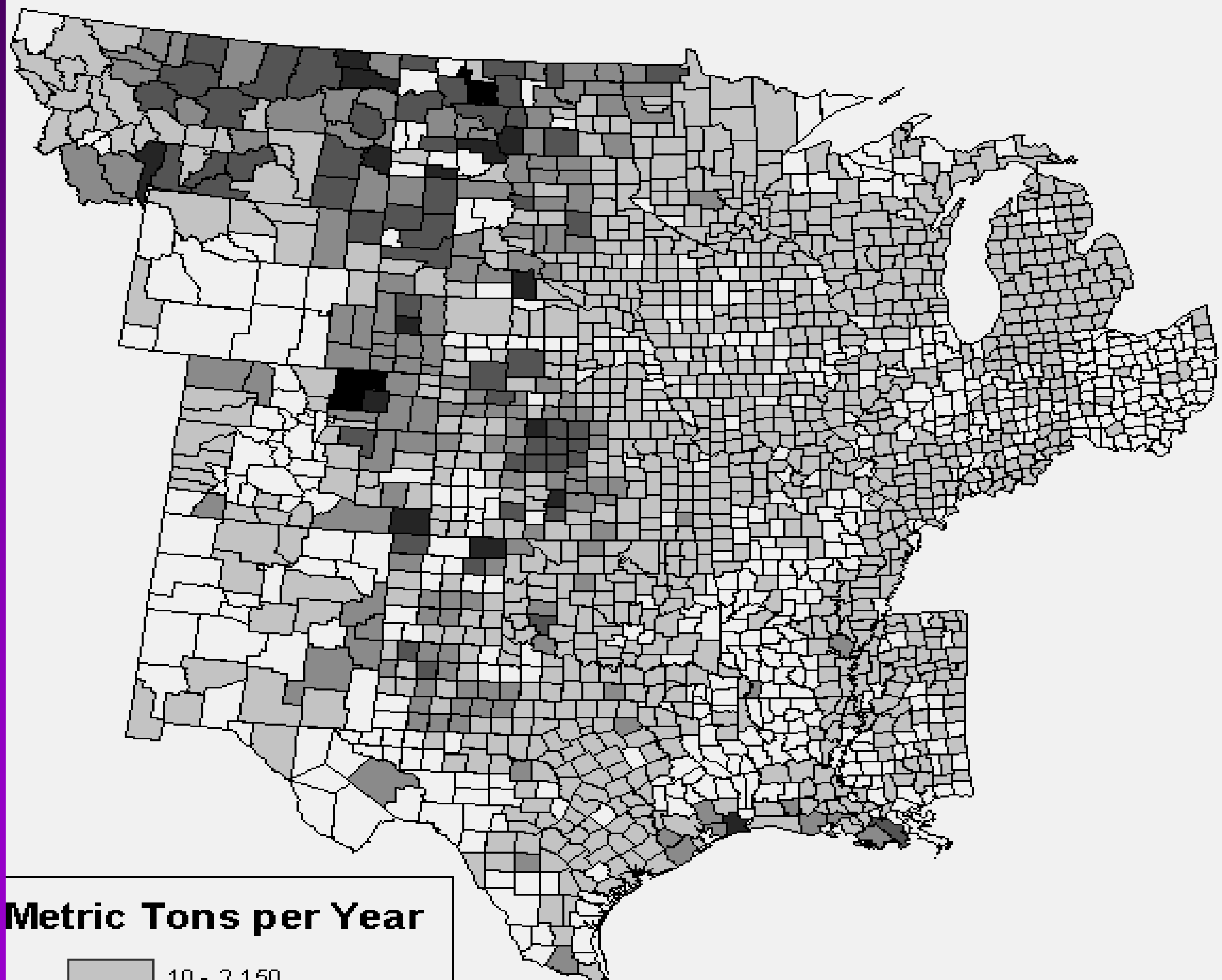
## 21.2 MMTC $yr^{-1}$ on 149 Mha cropland



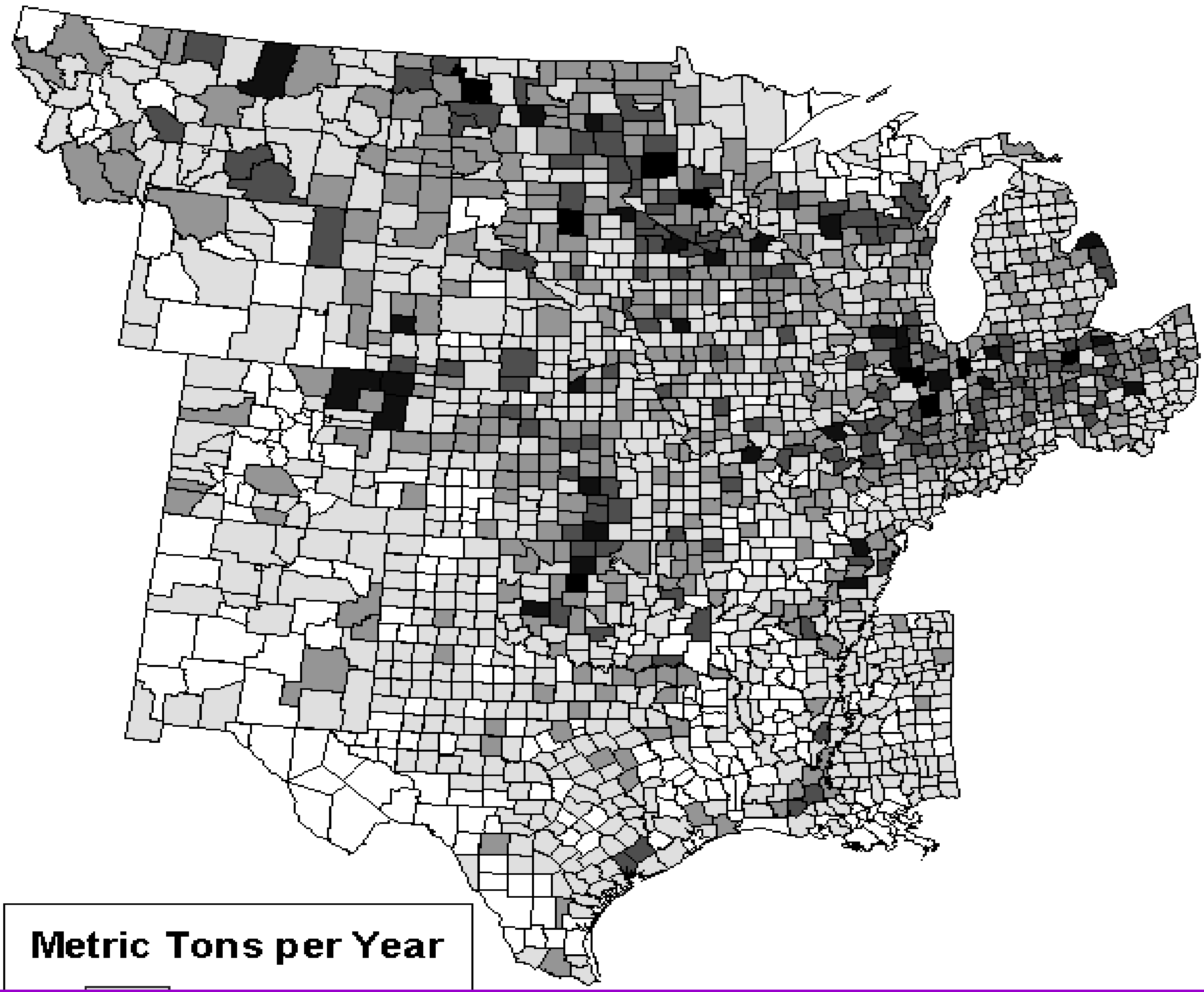
# INTEGRATED ECONOMIC AND BIOPHYSICAL MODEL: Century Model and Production Economic Model

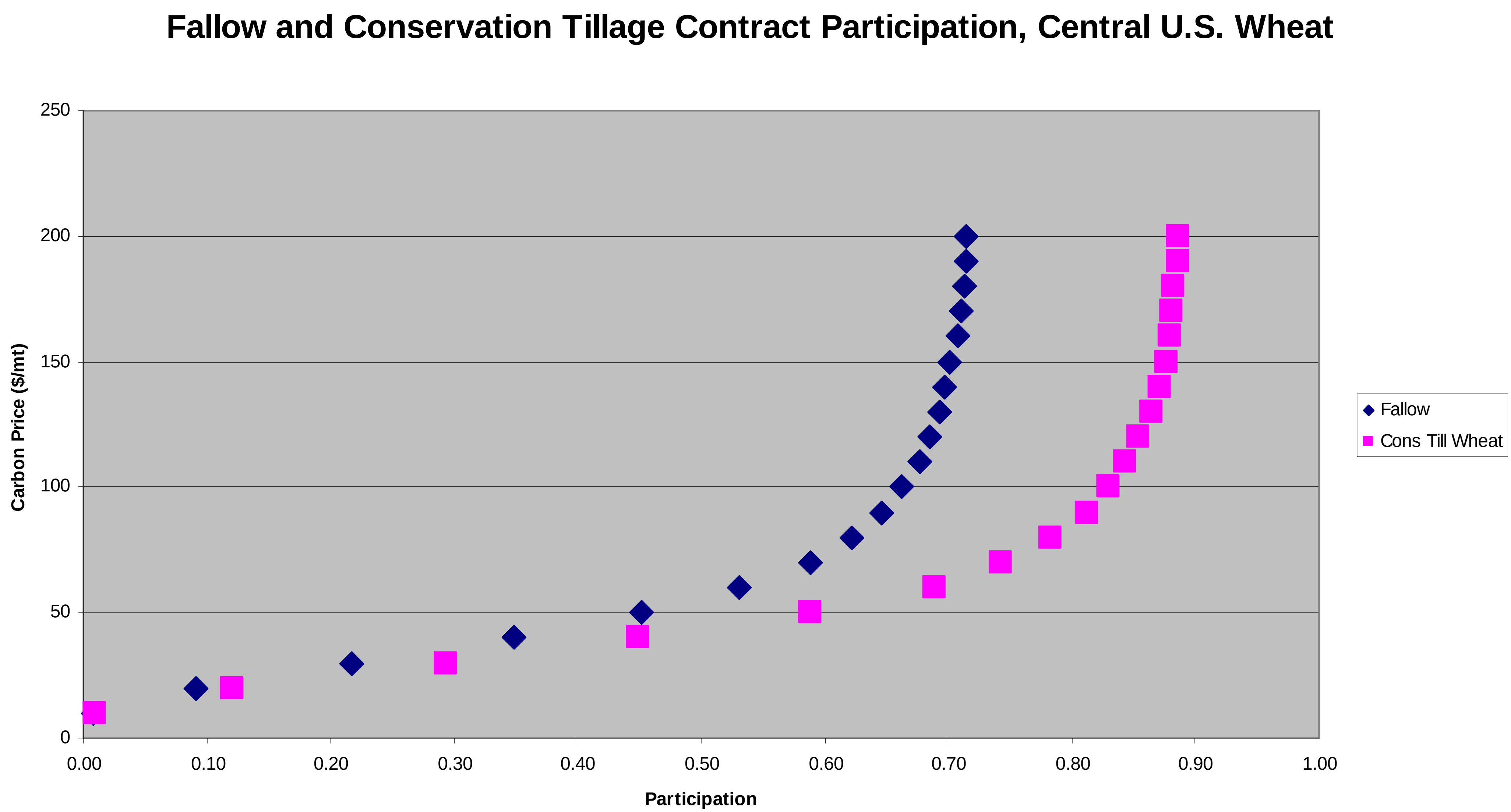


# Simulated Soil Carbon Sequestration from Fallow Reduction with a $50 per metric ton Carbon Price



# Simulated Soil Carbon Sequestration from Conservation Tillage with a $50 per metric ton Carbon Price





Fallow and Conservation Tillage Contract Participation, Central U.S. Wheat
Carbon Price ($/mt)
250
200
150
100
50
0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Participation
Fallow
Cons Till Wheat

# Measuring and monitoring soil C sequestration: a challenge?

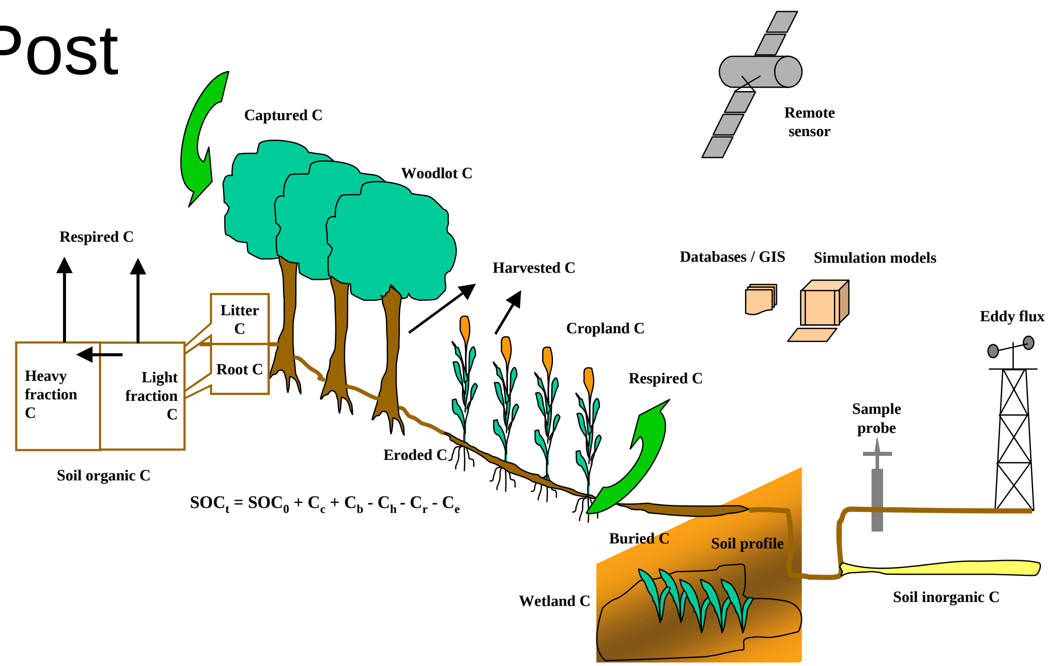
Long term experiments have been essential tools to understand the temporal dynamics of soil C

Soil survey maps can be used to estimate the spatial distribution of soil organic C stocks

The challenge consists in developing cost-effective methods for detecting changes in soil organic C that occur in fields as a result of changes in management

# Detecting and scaling changes in soil carbon

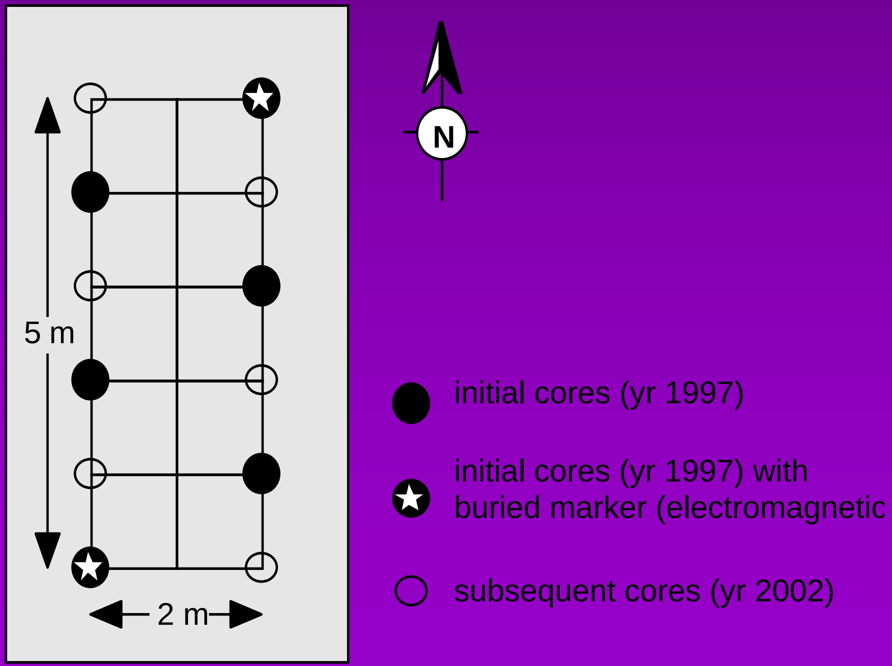
- Detecting soil C changes
  - Difficult on short time scales
  - Amount of change small compared to total C
- Methods for detecting and projecting soil C changes (Post et al. 2001)
  - Direct methods
    - Field and laboratory measurements
    - Eddy covariance
  - Indirect methods
    - Accounting
      - Stratified accounting
      - Remote sensing
      - Models




Post et al. (2001)

# Sampling protocol used in the Prairie Soil Carbon Balance (PSCB) project

- Use "microsites" (4 x 7 m) to reduce spatial variability
- Three to six microsites per field
- Calculate SOC storage on an equivalent mass basis
- Analyze samples taken at different times together
- Soil C changes detected in 3 yr
  - 0.71 Mg C $ha^{-1}$ – semiarid
  - 1.25 Mg C $ha^{-1}$ – subhumid




Ellert et al. (2001)

# Emerging technologies for measuring soil C

- Laser Induced Breakdown Spectroscopy (LIBS)
- Neutron Inelastic Scattering (NIS)
- Infrared (NIR)

  - Minimal sampling volume
  - Analysis time < 1 min
  - Daily throughput

# Full Cost Accounting: GWP of Field Crop Activities

| | Soil-C | N-Fert | Lime | Fuel | $N_2O$ | $CH_4$ | Net |
|---|---|---|---|---|---|---|---|
| | *g $CO_2$ -equiv / $m^2$ / y* | | | | | | |
| *Annual Crops* | | | | | | | |
| Conv. tillage | 0 | 27 | 23 | 16 | 52 | -4 | 114 |
| No-till | -110 | 27 | 34 | 12 | 56 | -5 | 14 |
| Low Input | -40 | 9 | 19 | 20 | 60 | -5 | 63 |
| Organic | -29 | 0 | 0 | 19 | 56 | -5 | 41 |
| *Perennial Crops* | | | | | | | |
| Alfalfa | -161 | 0 | 80 | 8 | 59 | -6 | -20 |

Robertson et al. *Science* 289:1922-1925 (2000)

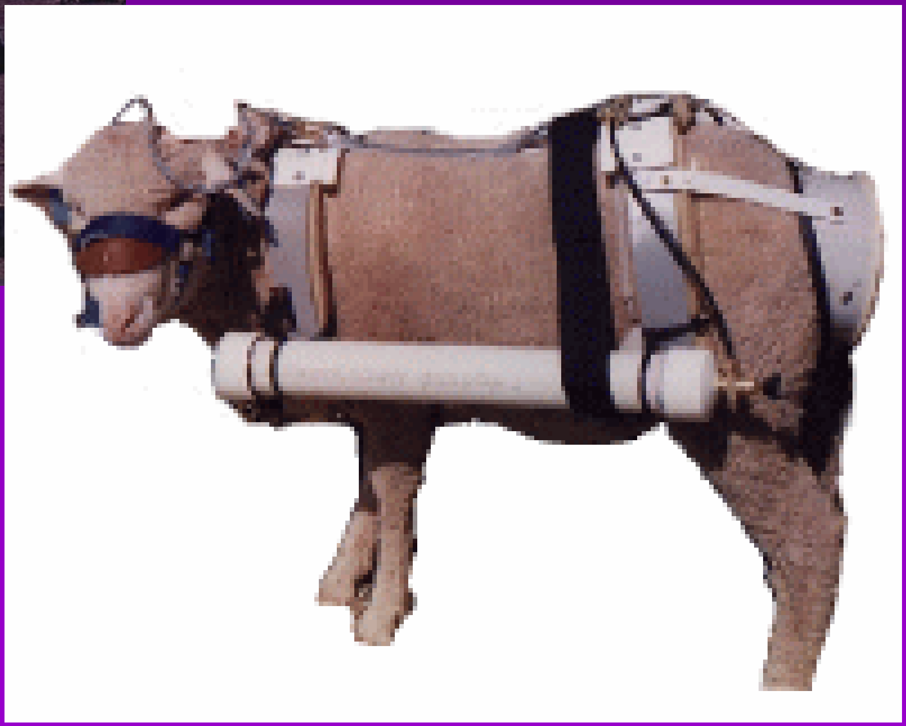
# N management to reduce $N_2O$

(reduce N availability when $N_2O$ production potential is greatest and plant needs are low)

- Timing
  - Split applications
  - Delayed applications
  - Use nitrification inhibitors
- Placement
  - Banded
  - Injected
- Rate
  - Utilized N from organic matter efficiently
    - Soil, crop residue, cover crops

# Methane

# Mitigation of $CH_4$ !!



# United States Efforts in Agriculture

- USDA is utilizing conservation programs to encourage carbon sequestration and GHG reductions
  - GHG offsets are factors in setting priorities under:
    - The Environmental Quality Incentives Program
    - The Conservation Reserve Program
  - Methane to Markets
  - Conservation Innovation Grants
- Federal government challenged the private sector to take action
  - USDA is working with the Department of Energy to improve the voluntary GHG reduction registry
  - USDA is negotiating voluntary agreements with businesses and sectors
  - Several corporations are undertaking projects in partnership with farmers and land owners

# Examples of feasibility and pilot projects on soil carbon sequestration

| Region | Land Use | Land management change |
|---|---|---|
| Saskatchewan, Canada | Cropland | Direct seeding / cropping intensification |
| **Pacific Northwest, USA** | **Cropland** | **Direct seeding / cropping intensification** |
| **Midwest**<br>**Iowa, Kansas, Nebraska** | **Cropland**<br>**Grass planting** | **No-till**<br>**New grass plantings** |
| Oaxaca, Mexico | Crop / natural fallow secondary forest | Fruit tree intercrops with annual crops / Conservation tillage |
| Pampas, Argentina | Cropland | Direct seeding |
| Kazakhstan | Cropland | Agriculture to grassland |

**Izaurralde (2004), Rice**

# Carbon Accounting System

- Verifiable and transparent for reporting changes in soil carbon stocks
  - (i.e., withstand reasonable scrutiny by an independent third party as to completeness, consistency, and correctness)
- Cost efficient if soil C will be competitive with other C offsets
- Based on best science possible
- Provide accounts and associated uncertainties for soil C measurements

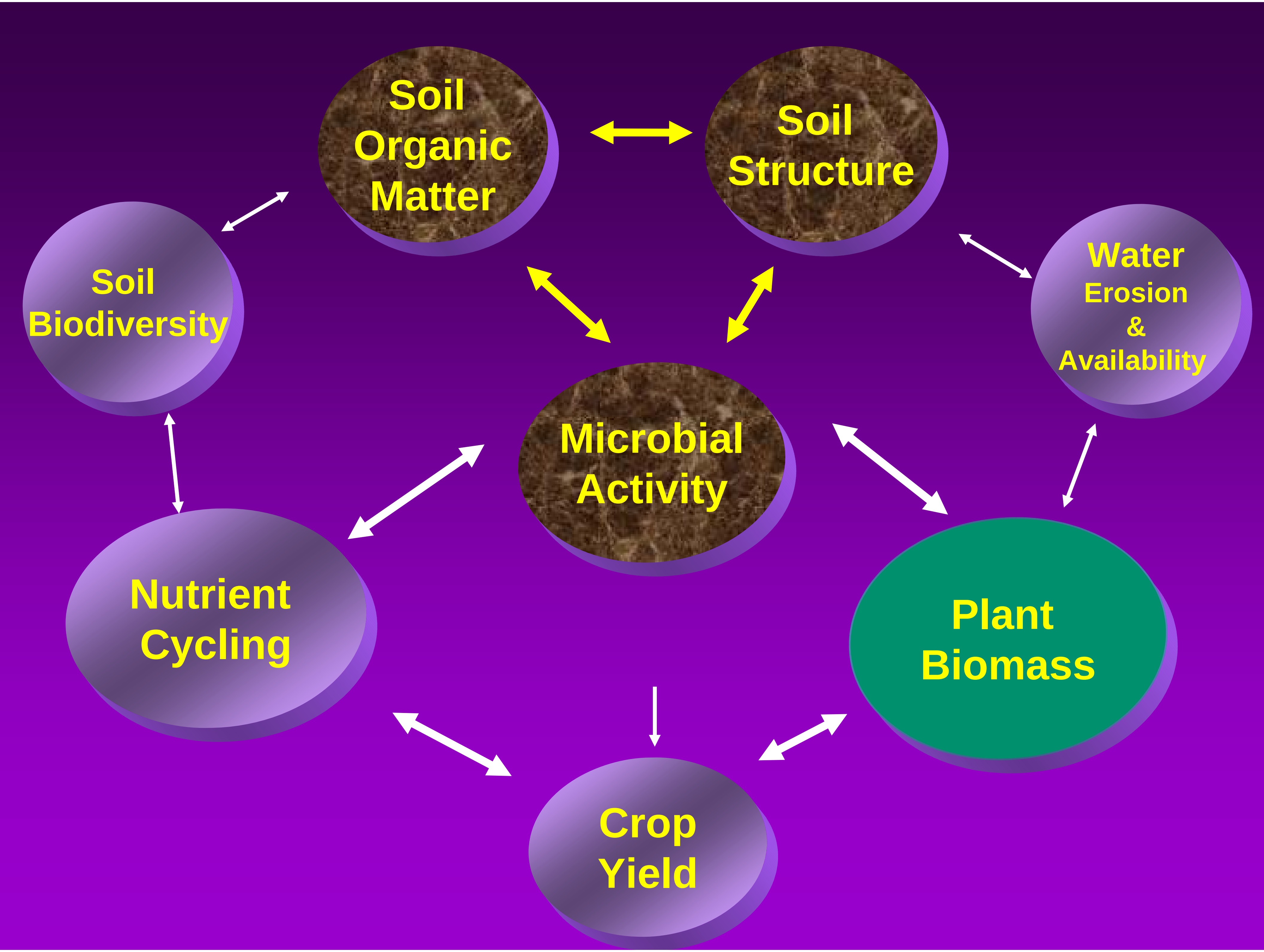
# Research and Education Needs

- Continued validation of models
- Full cost accounting
- Synthesis of USDA and LG universities information
  - Maintain long-term sites
- $N_2O$ and N management
- $CH_4$
- Measurement and monitoring at multiple scales
- Standards/guidelines for measurement and accounting

# Research and Education Needs

- Demonstration projects
- New technologies
  - May increase soil C
  - Measurements

- Multiple agencies and programs
  - Better coordination
  - Make use of university partners
  - Multi-institutional and multi-disciplinary


Soil Organic Matter
Soil Structure
Soil Biodiversity
Water Erosion & Availability
Microbial Activity
Nutrient Cycling
Plant Biomass
Crop Yield

# Soil Organic Matter


**Keep your sense of humus**

M. Sarrantonio (1994)