



Carbon Sequestration in Agro-Ecosystems

Charles W. Rice
Soil Microbiologist

Department of Agronomy

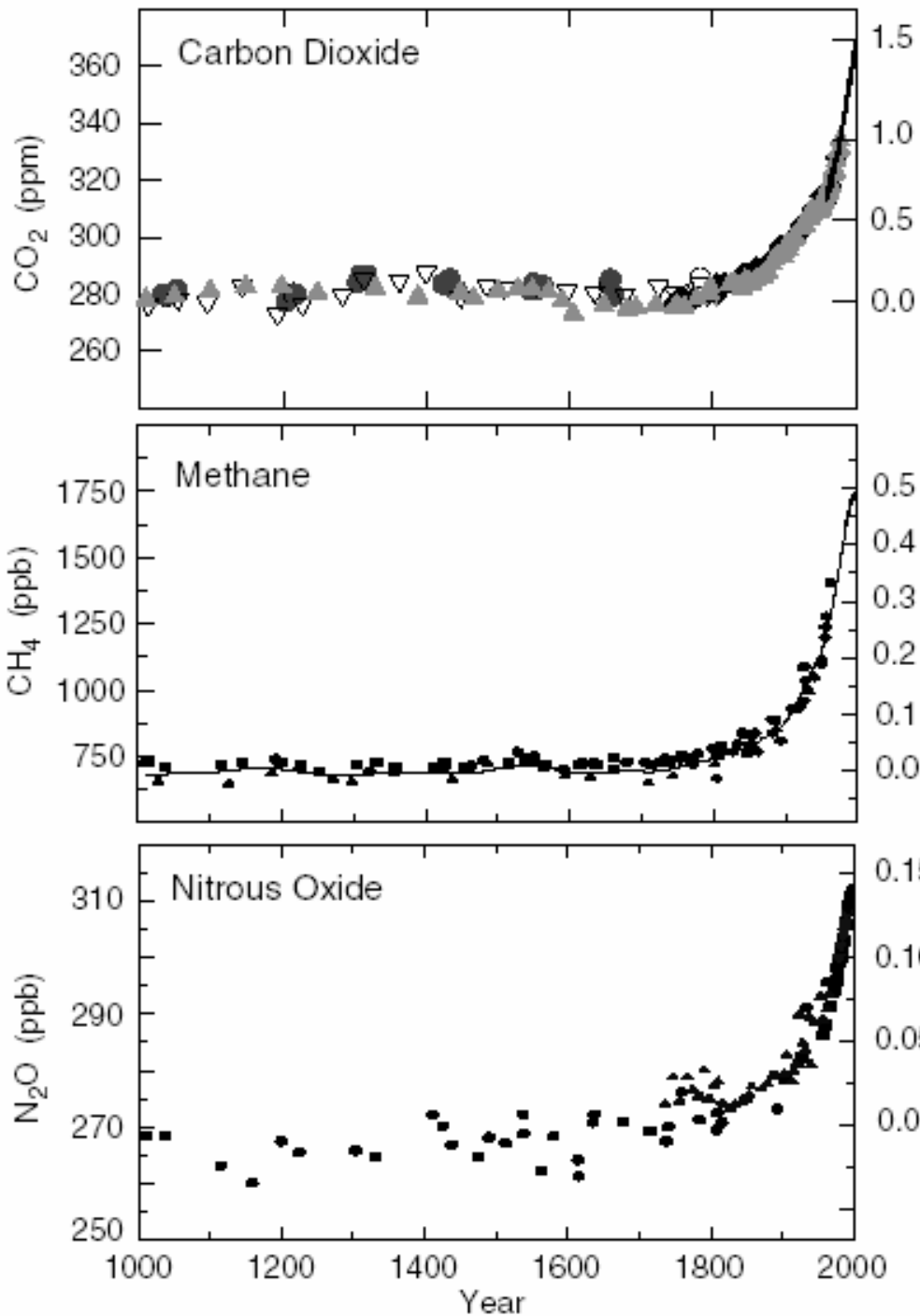


Consortium for Agricultural Soils Mitigation of Greenhouse Gases



K-State Research and Extension

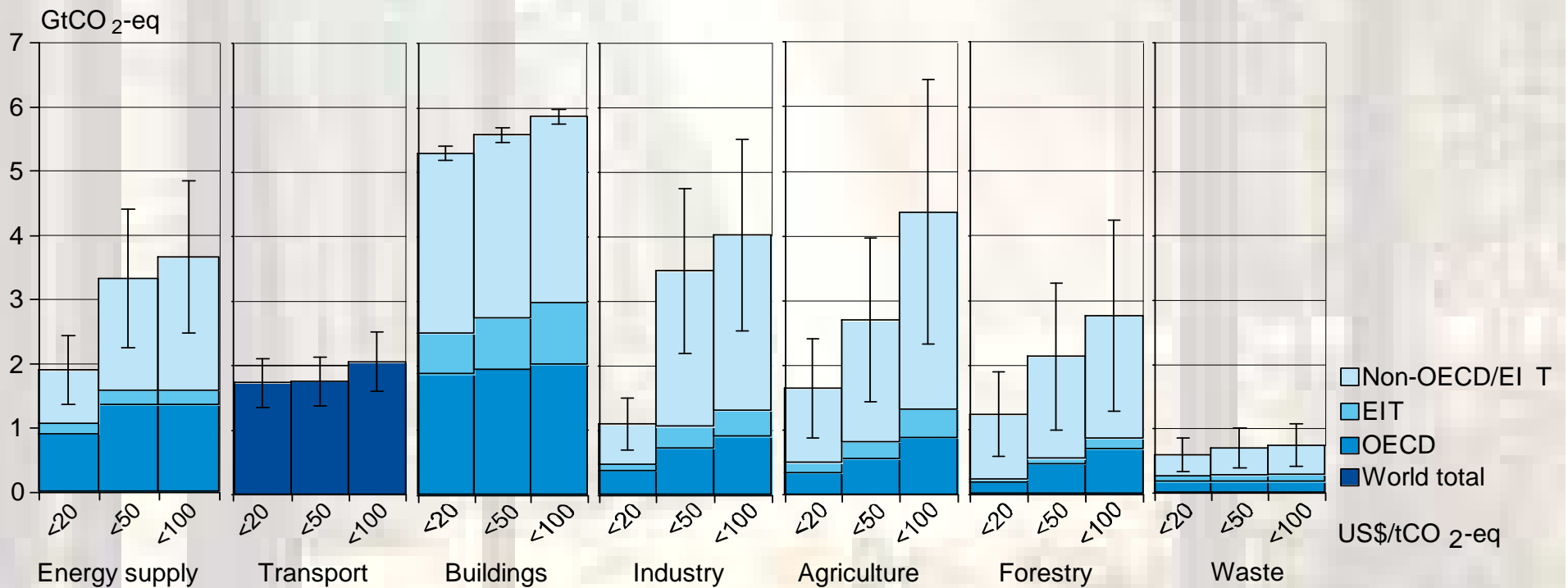
Atmospheric concentration



Atmospheric Concentrations of CO₂, Methane (CH₄), and Nitrous Oxide (N₂O) from 1000 A.D.

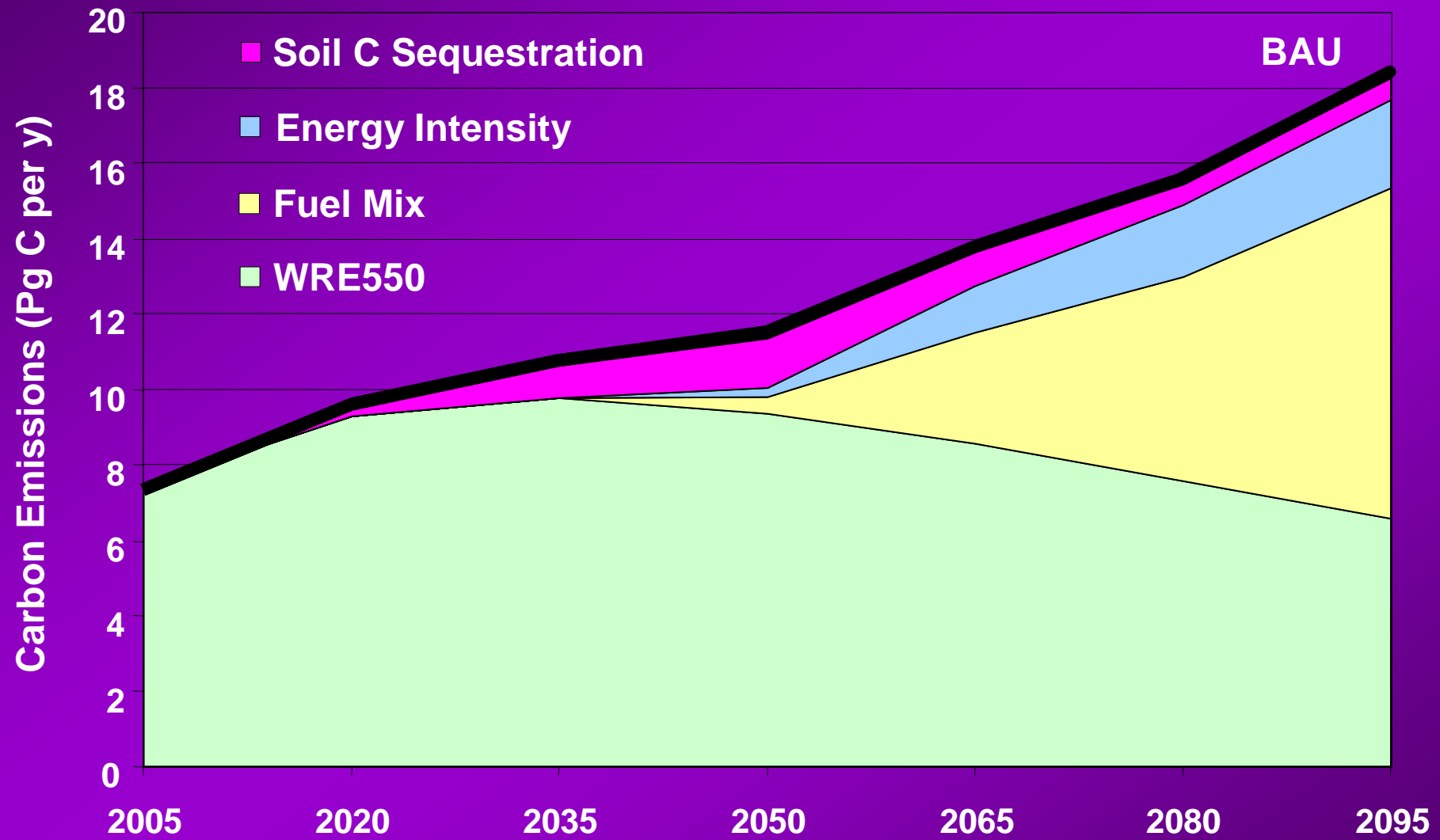
From IPCC (2001)

Global economic mitigation potential for different sectors at different carbon prices



IPCC, 2007

Carbon Emissions Reductions: WRE 550 with Soil Carbon Sequestration Credits



From: Rosenberg, N.J., R.C. Izaurralde, and E.L. Malone (eds.). 1999. Carbon Sequestration in Soils: Science, Monitoring and Beyond. Battelle Press, Columbus, OH. 201 pp.

Agriculture

- A large proportion of the mitigation potential of agriculture (excluding bioenergy) arises from soil C sequestration, which has strong synergies with sustainable agriculture and generally reduces vulnerability to climate change.
- Agricultural practices collectively can make a significant contribution at low cost
 - By increasing soil carbon sinks,
 - By reducing GHG emissions,
 - By contributing biomass feedstocks for energy use
- There is no universally applicable list of mitigation practices; practices need to be evaluated for individual agricultural systems and settings

Agricultural management plays a major role in greenhouse gas emissions and offers many opportunities for mitigation

- **Cropland**

- Reduced tillage
- Rotations
- Cover crops
- Fertility management
- Erosion control
- Irrigation management



No-till seeding in USA

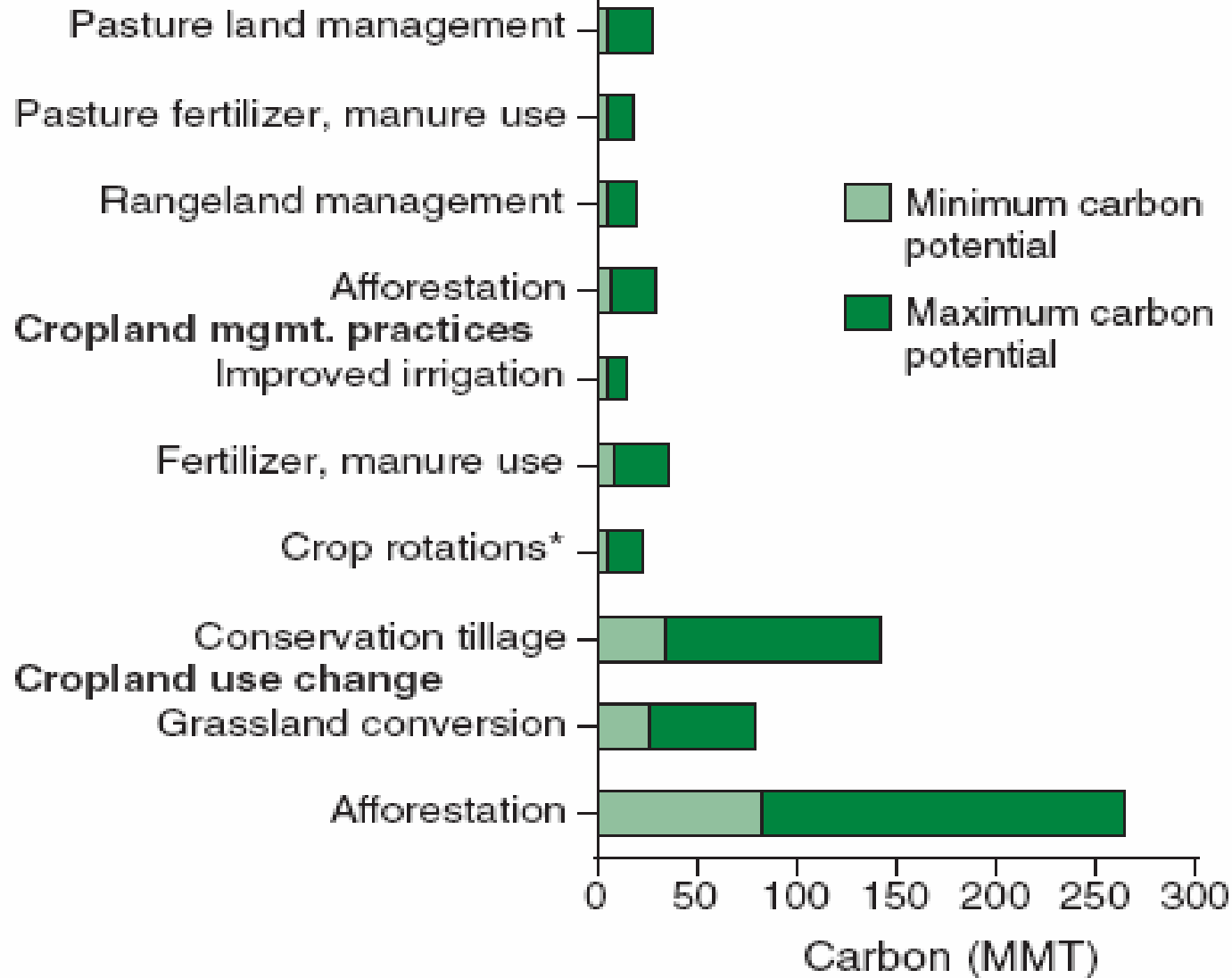
- **Grasslands**

- Grazing management
- Fire management
- Fertilization



Estimated potential carbon sequestration

Grazing land



* Includes winter cover crops and elimination of summer fallow.

Climate

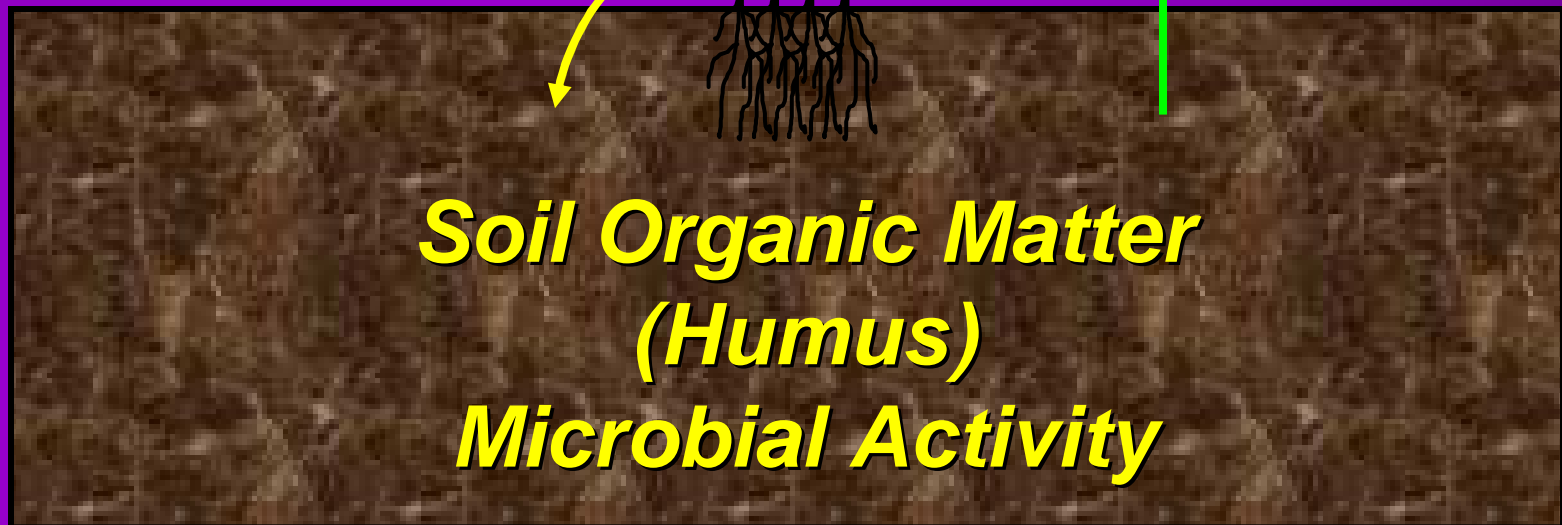
Soils

Management

Sunlight

CO₂

**Harvestable
Yield**



Soil C Sequestration with conversion to No-tillage

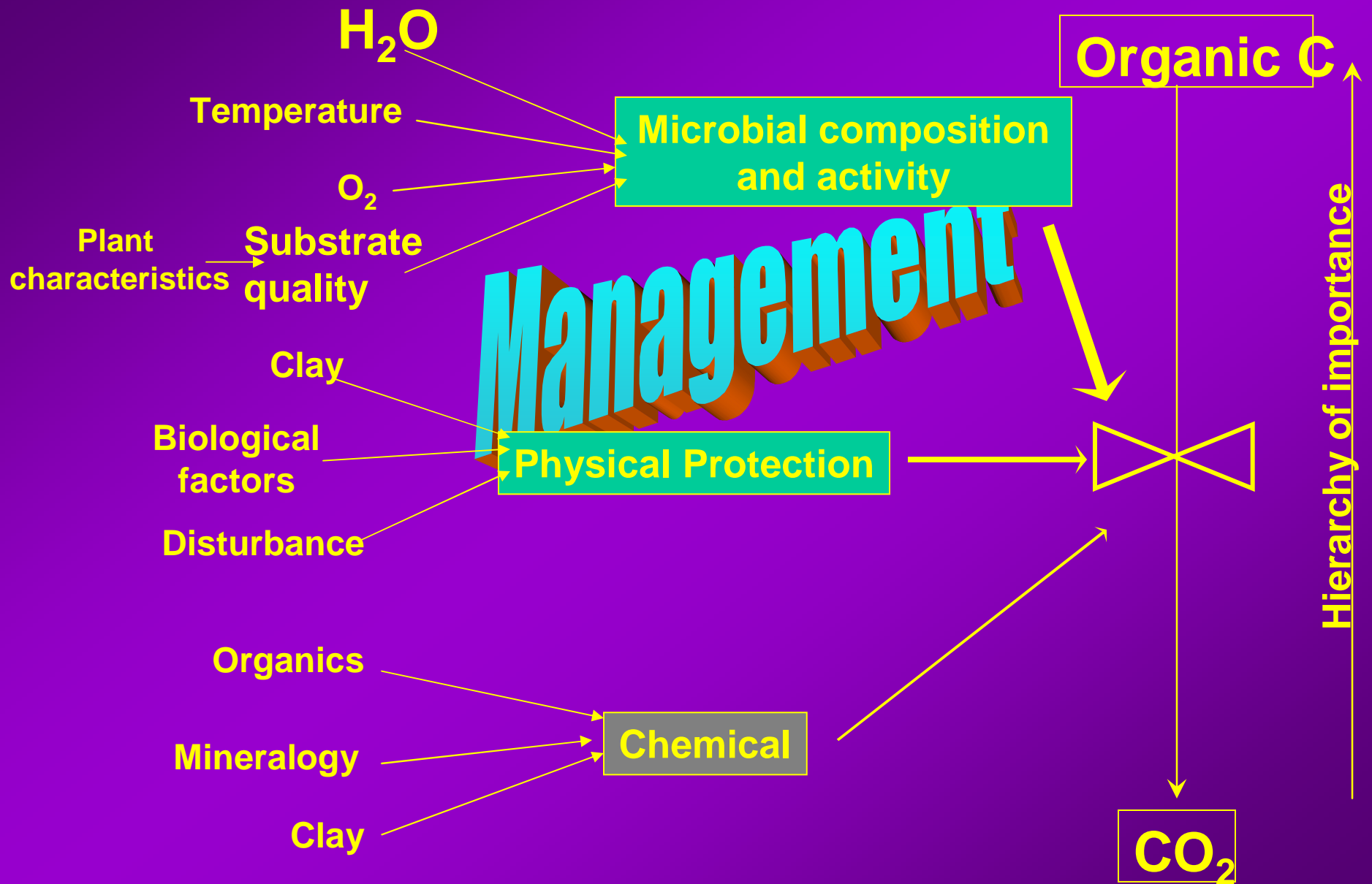
Site	Crop	MT C ha ⁻¹ y ⁻¹	(Mt CO ₂ /a/y)
CO & KS	Wheat	0-0.30	0-0.45
Kansas	Sorghum	0.088 – 0.605	0.13-0.90
KS, MI, OH	Maize	0.300 – 0.80	0.45-1.18
Kansas	Soybean	<0-0.128	0-0.19
Brazil		0.51-1.84	0.75-2.72
Global		0.57	0.84
Kansas	CRP	0.800	1.18

Carbon sequestration rate over 29y

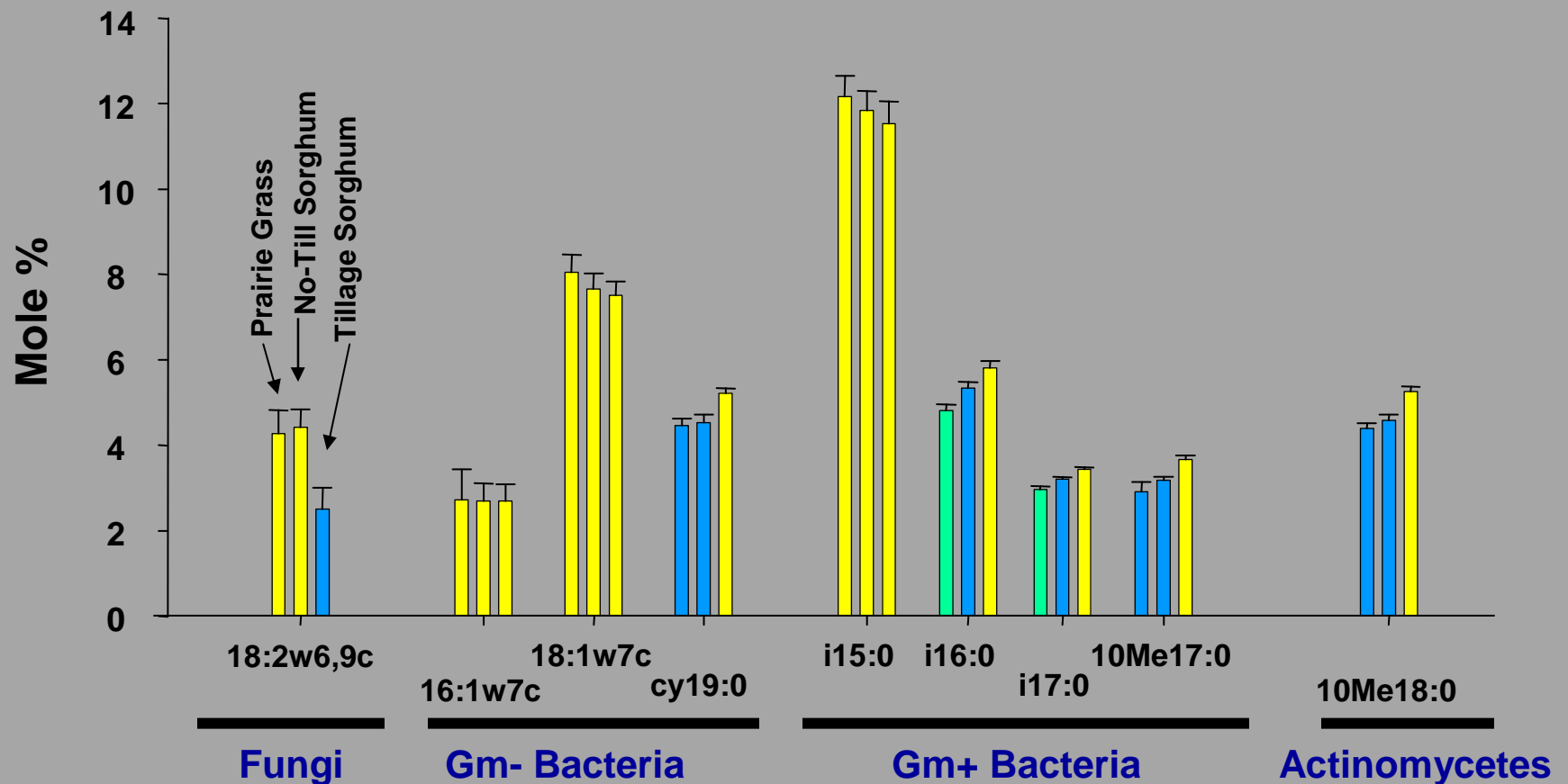
(Fabrizzi and Rice 2008)

Treatment	C sequestration Rate (Mg C/ha/y)
No-till	0.384
Reduced-till	0.346
Tilled	0.269
Soybean	0.066
Sorghum	0.292
Wheat	0.487

Conservation of Soil Carbon

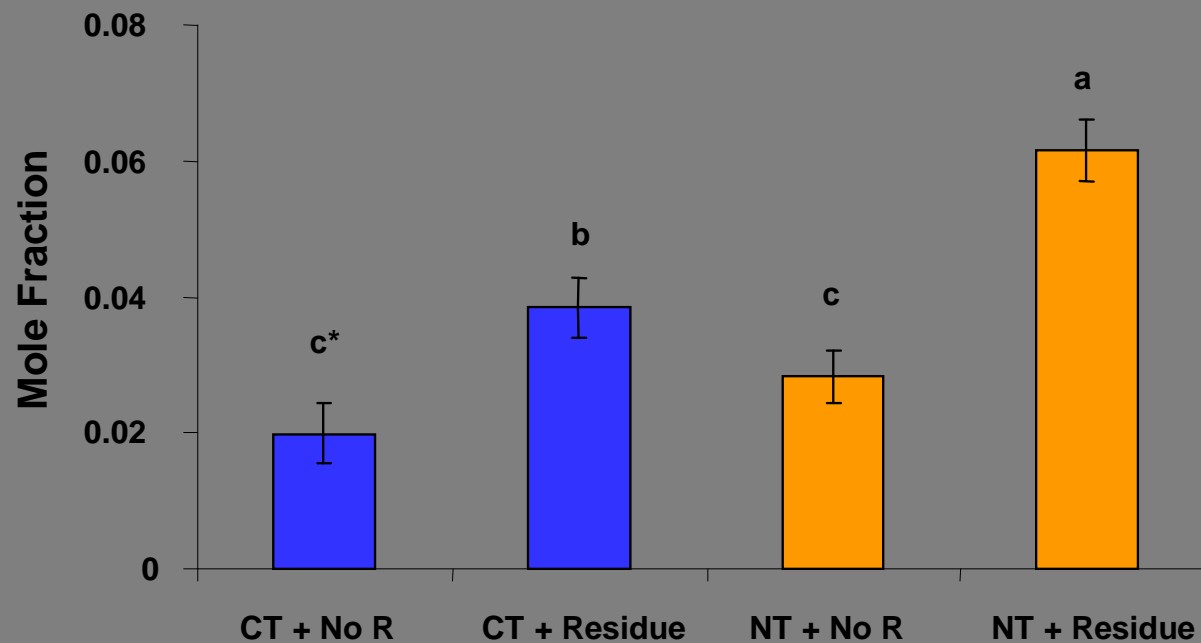


Microbial community - Phospholipid fatty acid levels (0-5 cm depth)



Bars of the same color for a given PLFA biomarker are not different ($p \leq 0.10$).
Lines are ± 1 standard error.

- Fungal Role (18:2w6 biomarker)
- Significant tillage X residue interaction ($p < 0.05$)



Frey et al. (1999) found greater fungal networks optically in NT as compared to CT for the same soil.

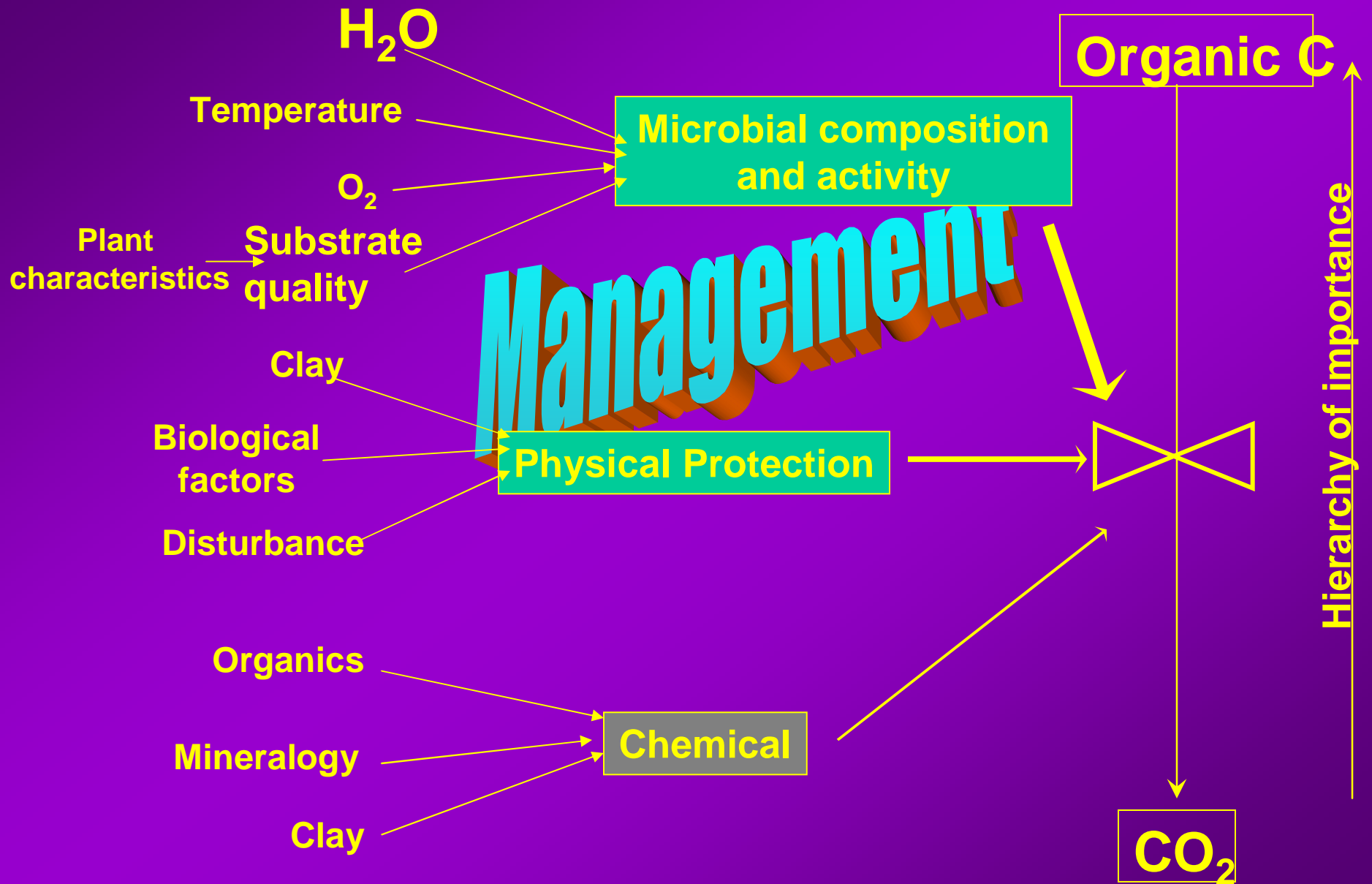
White and Rice, 2007



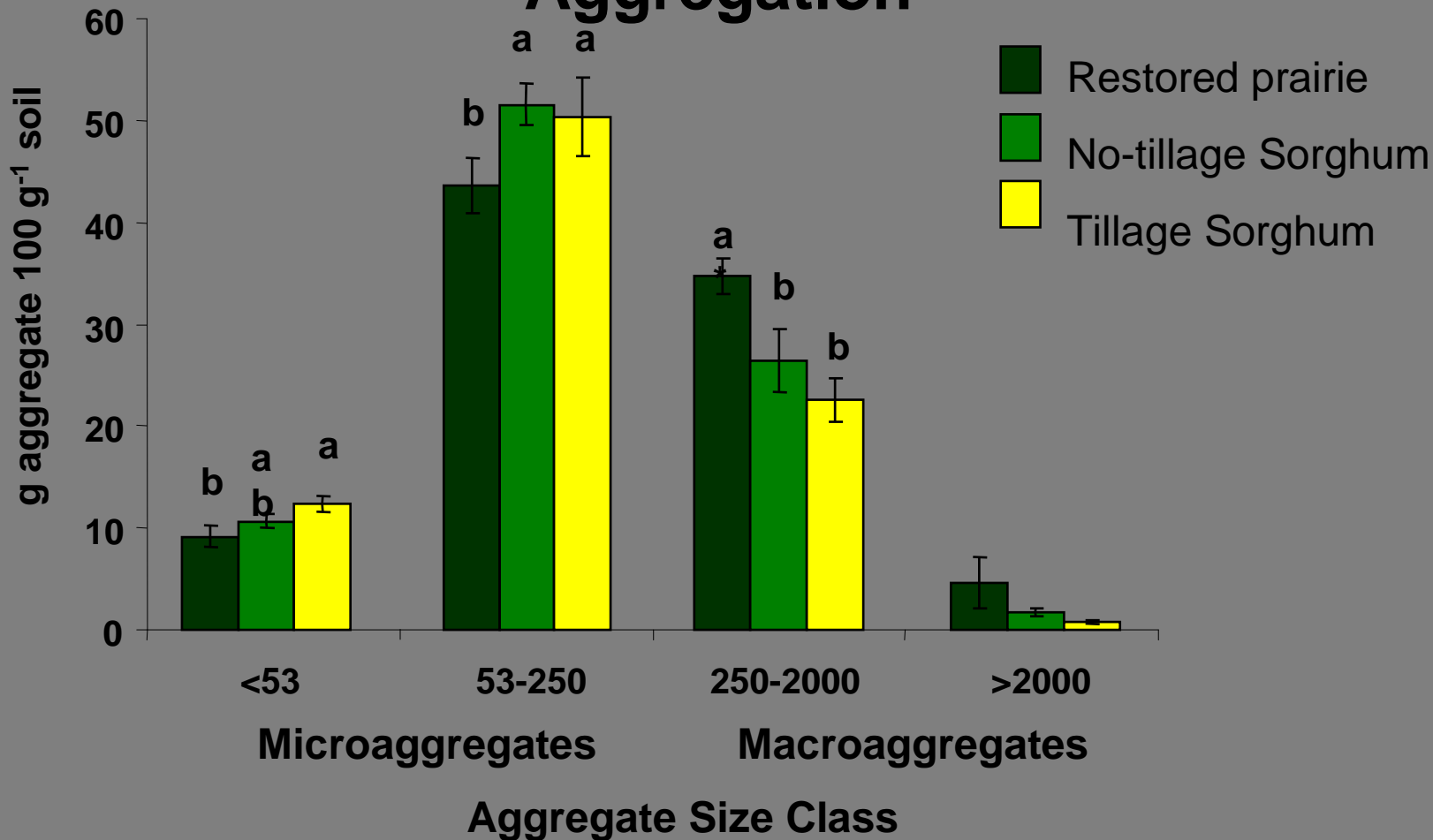
5 cm

From: Juca Sá

Conservation of Soil Carbon

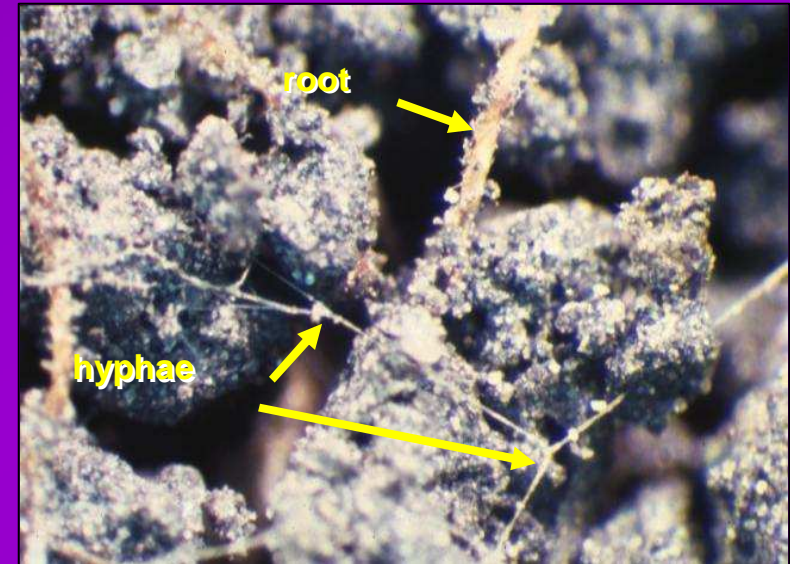
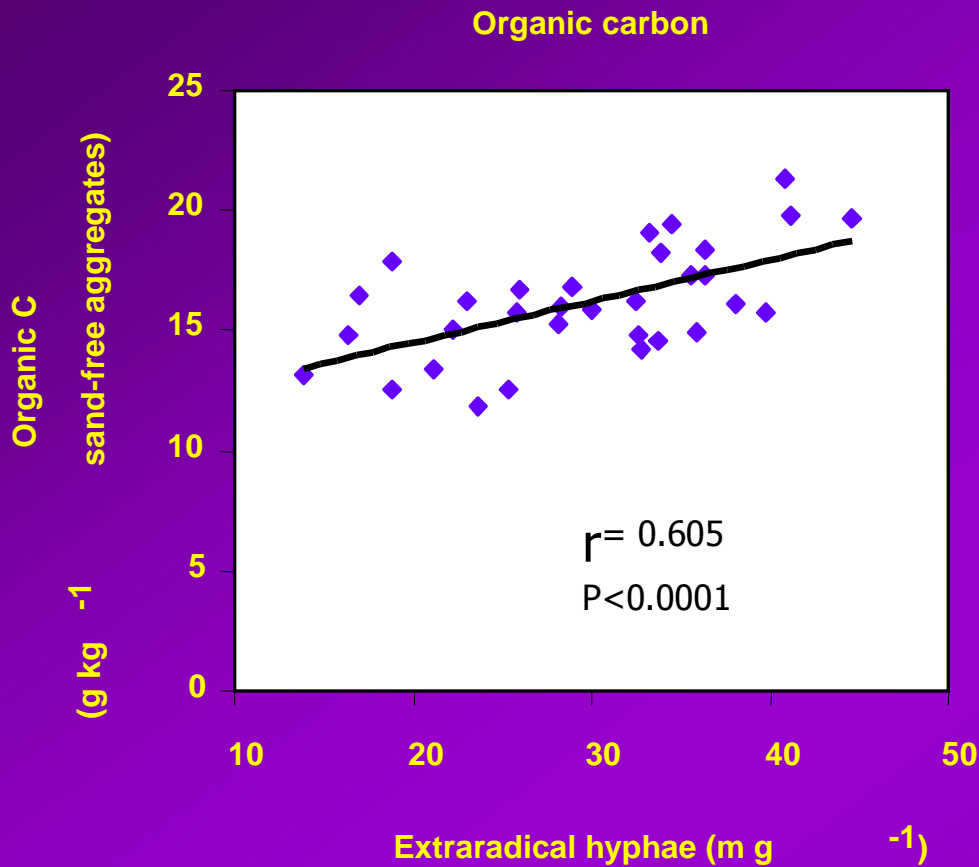


Soil Aggregation



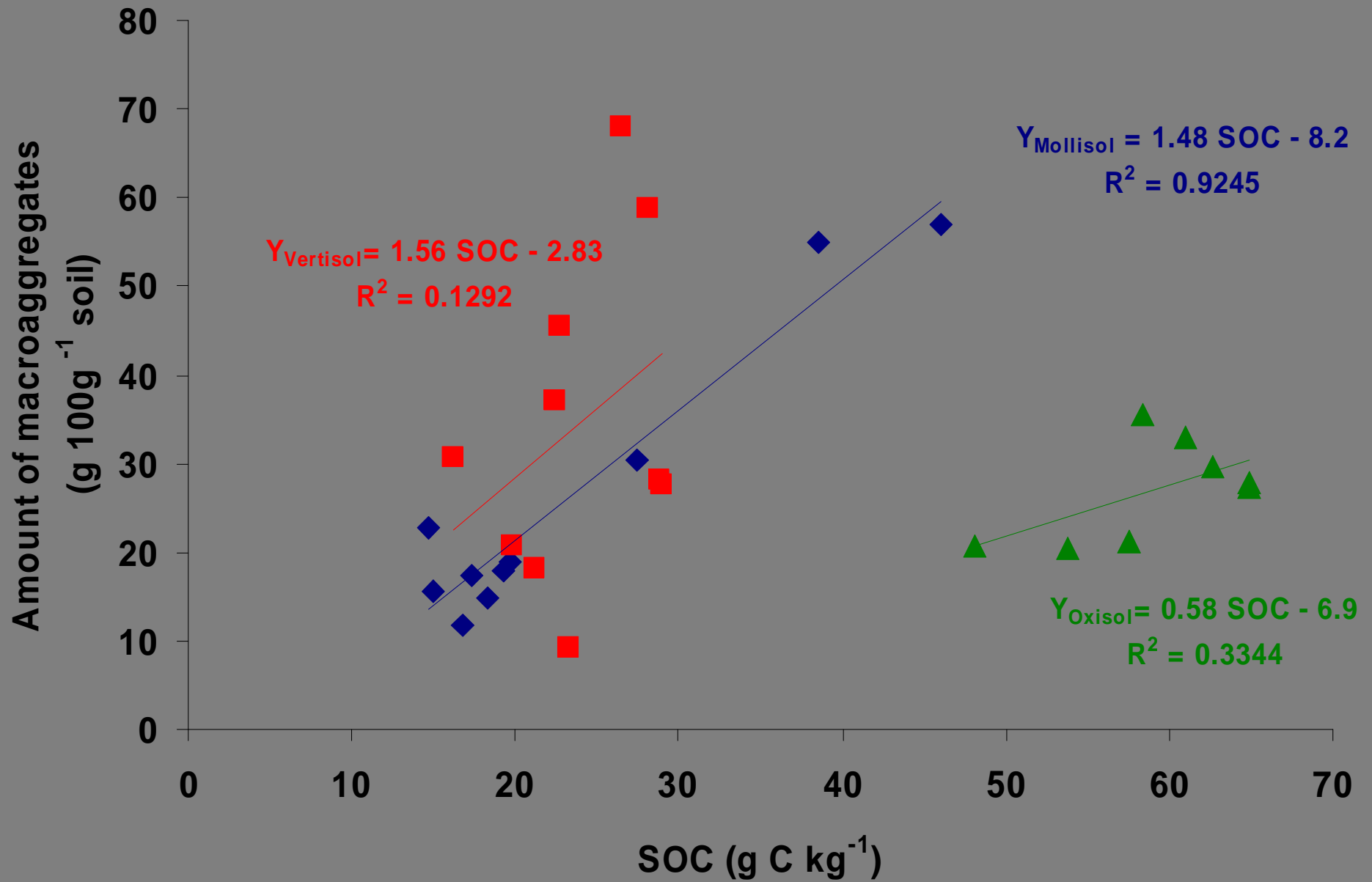
More macroaggregates were present in RP after 3 y, as compared to the agro-ecosystems. *Bars with the same letter within size class are not different ($p < 0.05$). Lines are ± 1 std error.

White and Rice, 2007



Increases in fungal hyphae increases the amount of carbon sequestered in the soil. Formation of soil aggregates physically protects soil carbon from decomposition.

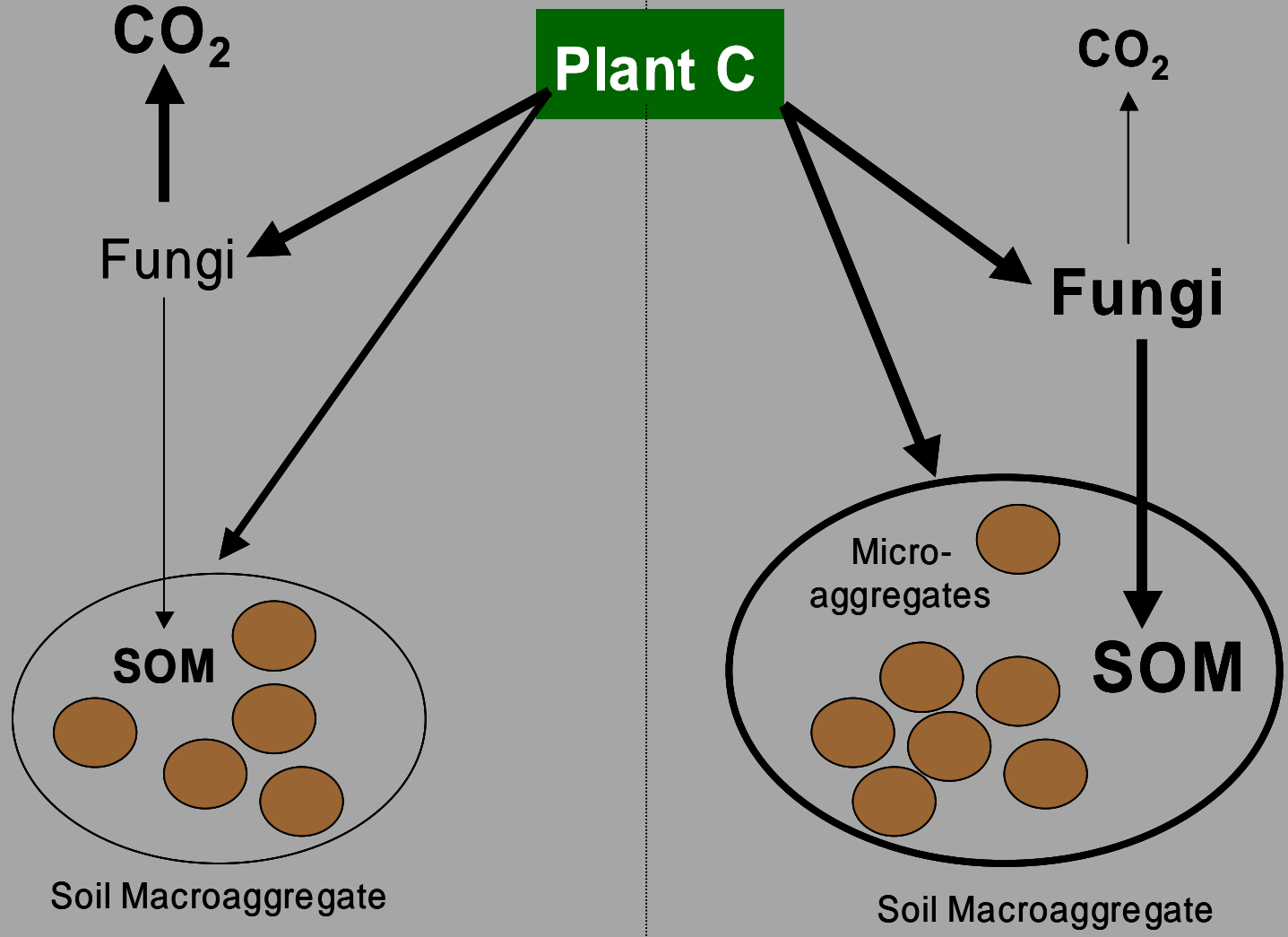
Data from Wilson and Rice; Photo from Mike Miller and Julie Jastrow



Fabrizzi, 2006

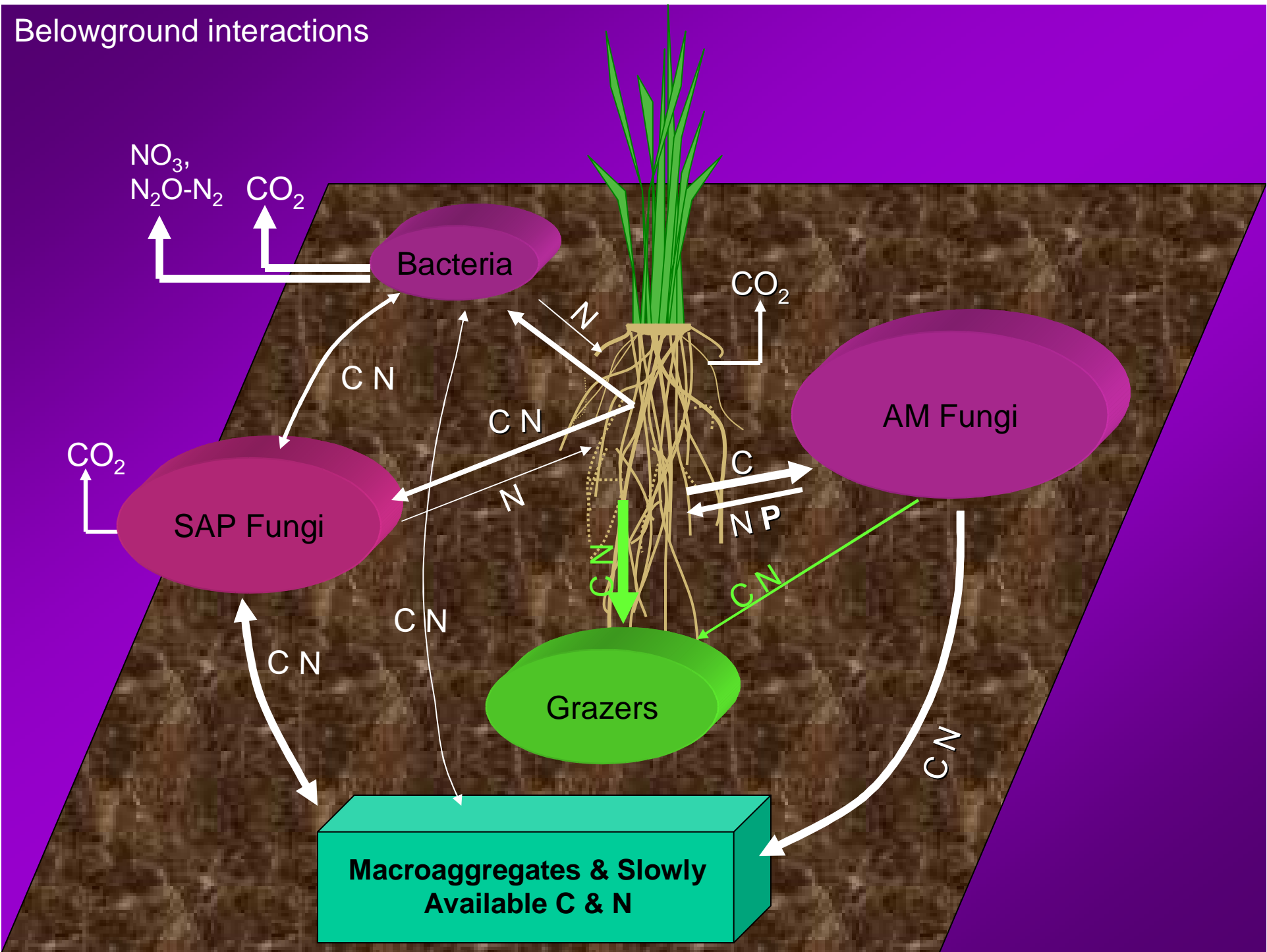
Tillage = Higher disturbance

No-Till = Lower disturbance



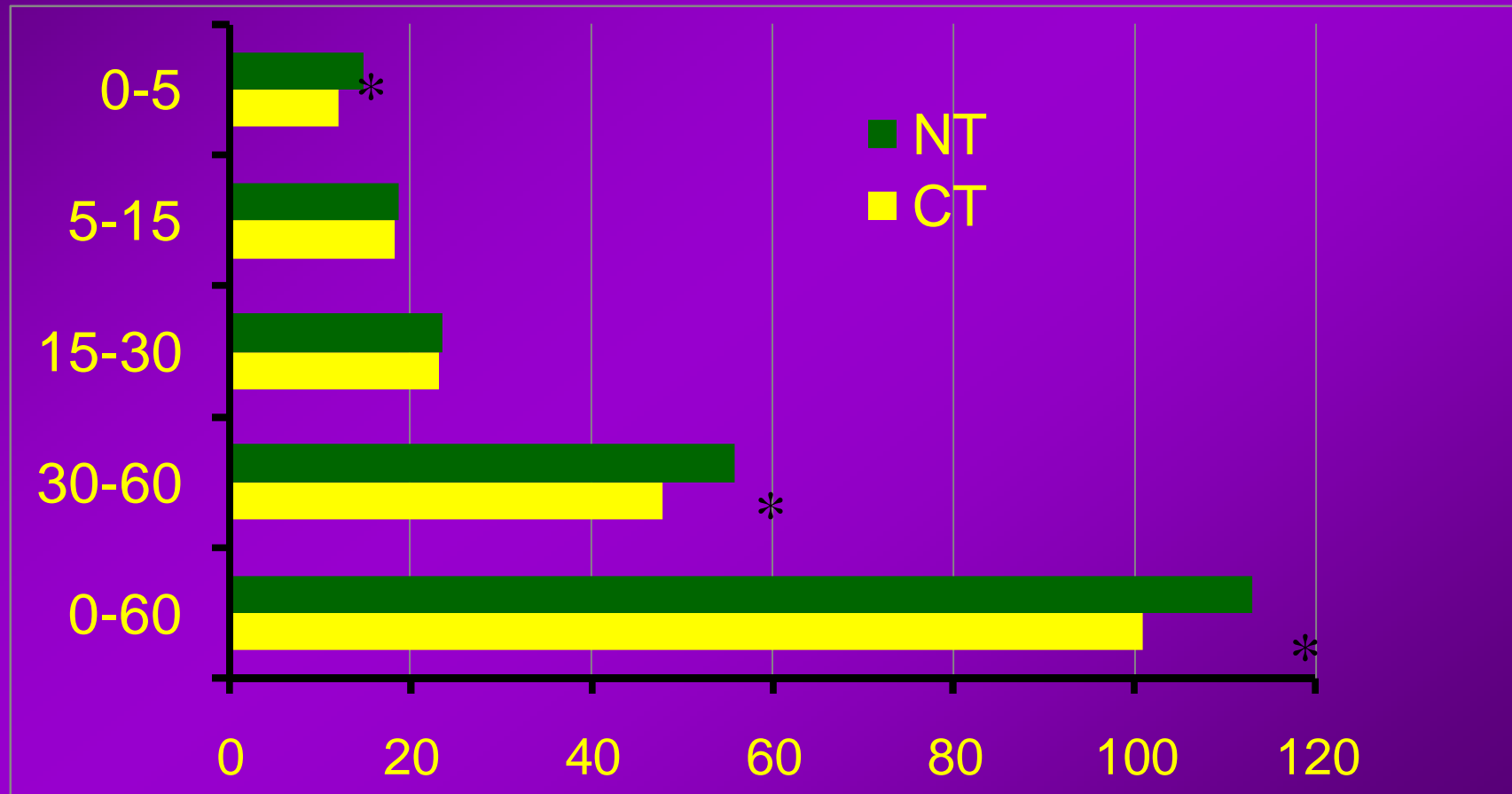
White and Rice, 2007

Belowground interactions

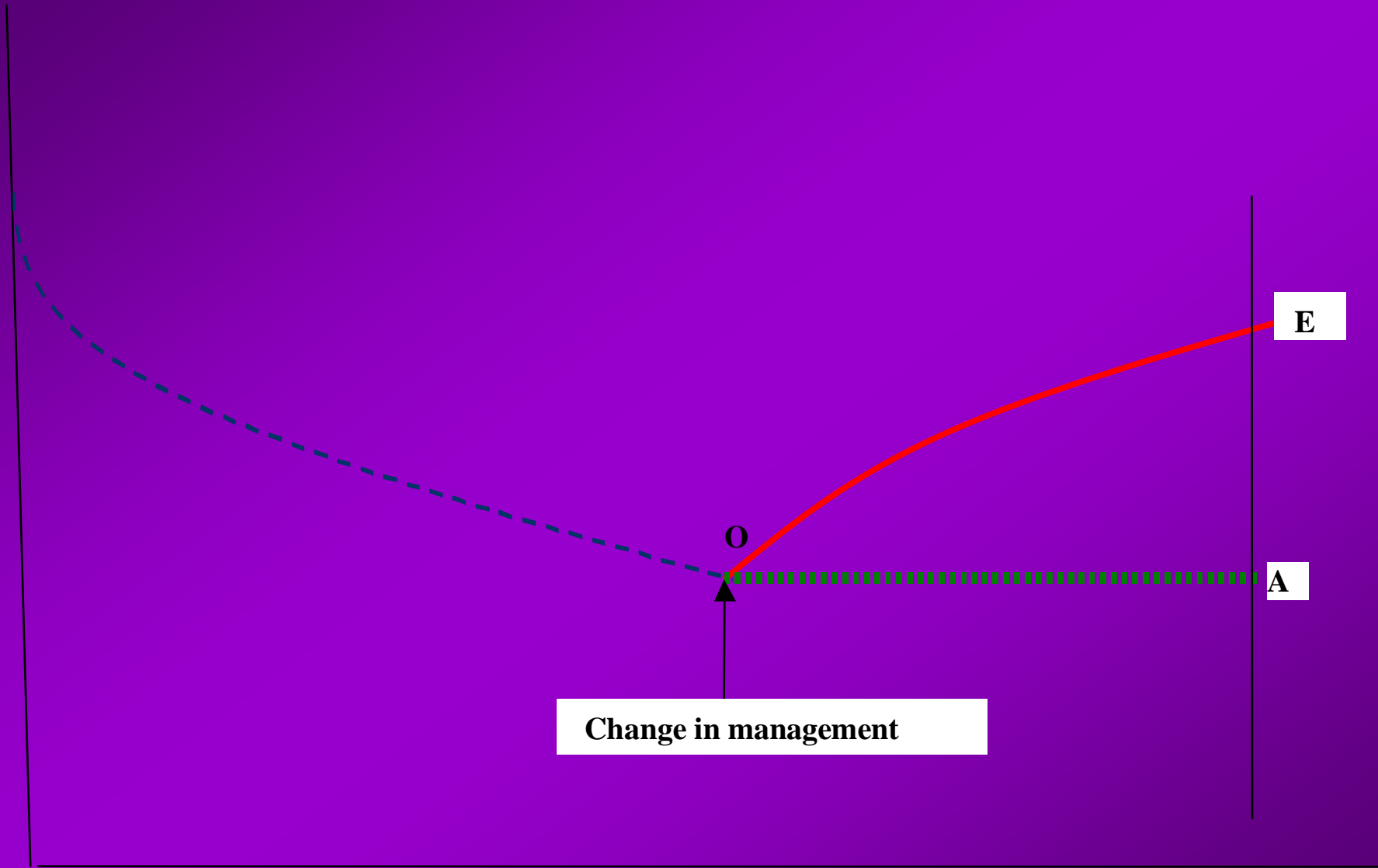


Carbon Stocks and Depth

Soil C stocks after 18 years



SOC levels (Mg C ha



Change in management

Years of cultivation

E

A

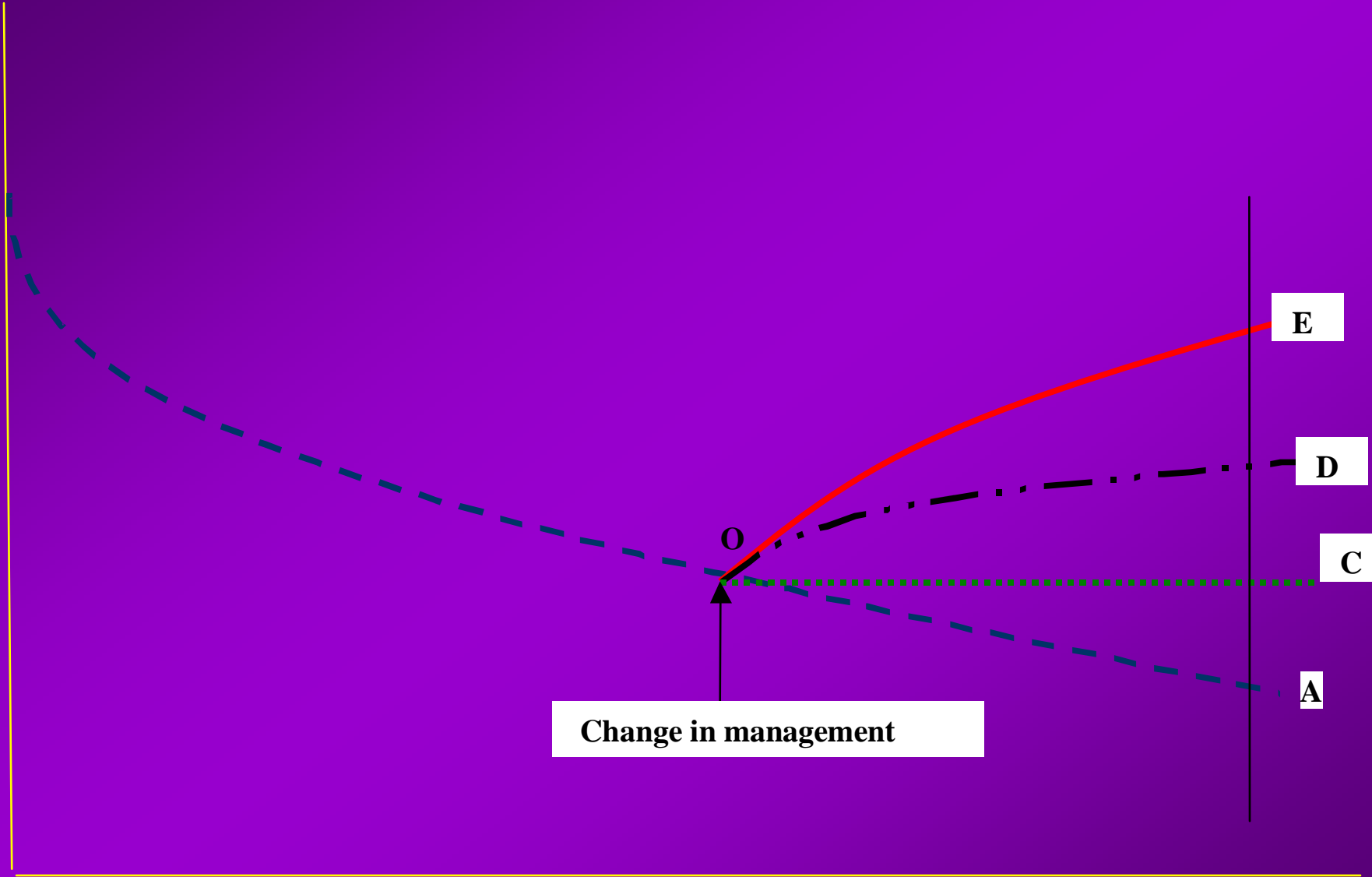
O

Soil C sequestration rates for 15 years (Mg C/ha/y)

Depth	Fertilizer N Tilled	Fertilizer N No-till		Manure N Tilled	Manure N No-till
cm					
0-5	0.161	0.351		0.393	1.182
0-15	0.254	0.497		0.792	1.402
0-30	0.336	0.717		0.839	1.387
0-60	0.146	1.325		0.733	1.141

NT > Tilled
What is baseline?

SOC levels (Mg C·ha)



Change in management

Years of cultivation

E

D

C

A

O

Net effect of NT for 15 years NT (0-15y) –Till (0-15y)

Depth	No N	0.5 Fertilizer N	Fertilizer N	0.5 Manure N	Manure N
cm			Mg/ha/y		
0-5	0.187	0.450	0.190	0.468	0.789
0-15	0.182	0.371	0.243	0.402	0.610
0-30	0.174	0.311	0.381	0.417	0.548
0-60	-0.443	-0.191	1.179	0.961	0.408

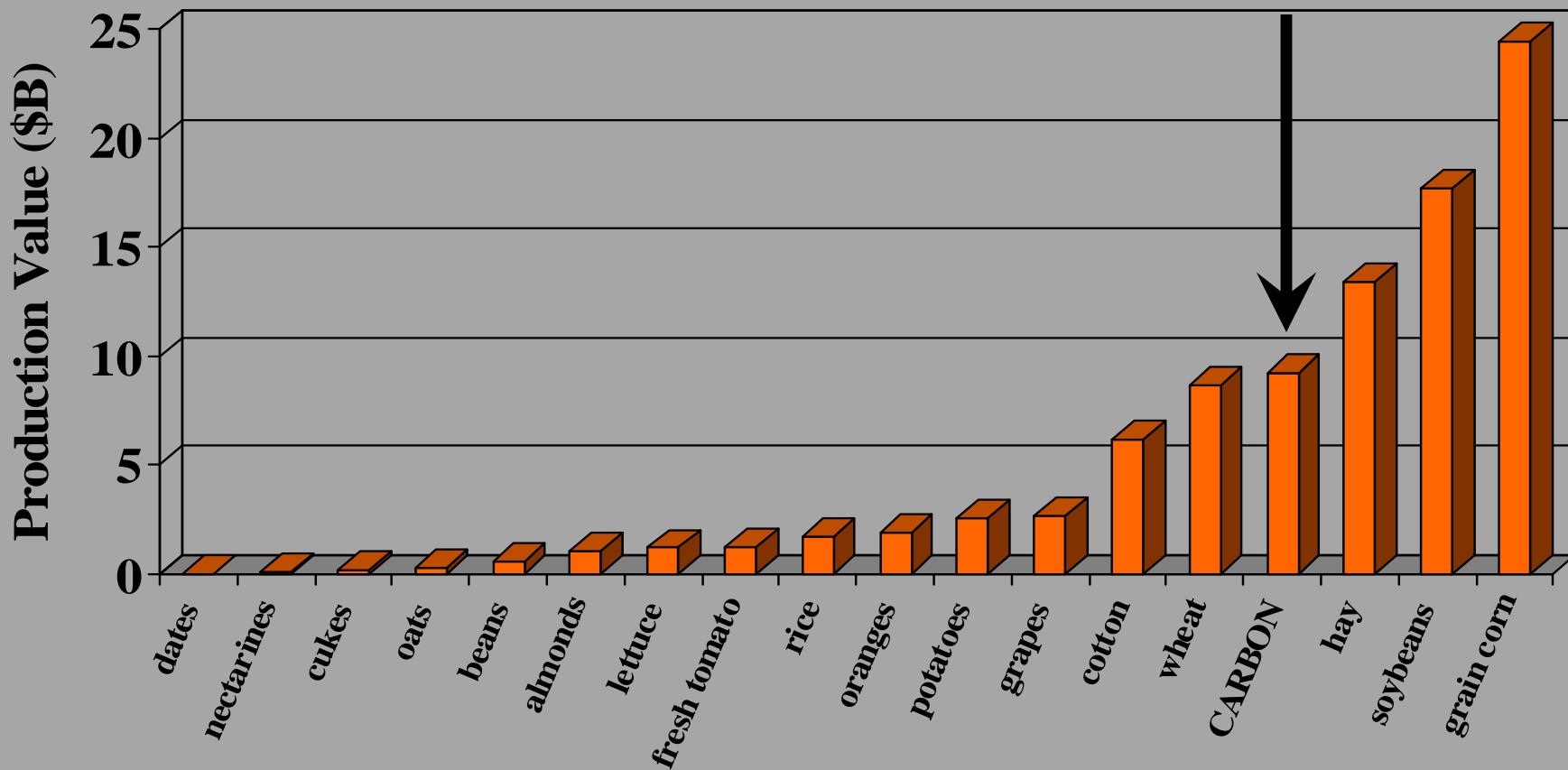
Relative Yield, Economic, and Sequestration Characteristics for adopting NT continuous Corn, NE Kansas

	NT
Mean Yield (bu/a) 86 CT	87.7
Δ Net Return (\$/a)	26.50
Δ Soil Carbon (tons/a/y)	0.465
Δ Total C Emissions (tons/a/y)	-0.0087
Δ Net Carbon (tons/a/y)	0.481
Soil C Value (\$/a/y) \$4.00 value	\$2.76

10% additional income

*Illustrative Ranking of Carbon as a Crop in U.S.
Per Proposed GHG Limits in
Senate Bill 280 (Lieberman-McCain) 1/12/07*

Carbon at \$10/MT CO₂e,



[Crop Source: USDA - National Agricultural Statistics Service – US Crop Rankings - 1997 Production Year Ranking Based on Value of Production]

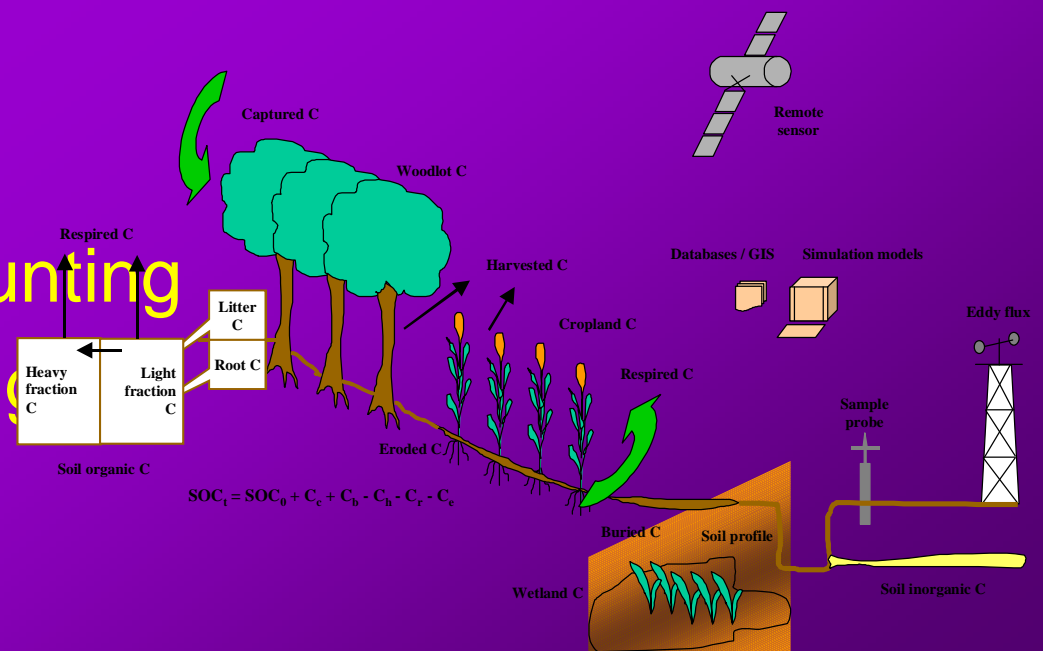
So What is the Potential?

- *Globally*
 - It is estimated that soil has the potential to offset 30% of the annual CO₂ emissions
- *United States*
 - It is estimated that soil has the potential to offset 15% of the annual CO₂ emissions
 - Additional options for N₂O and CH₄
- The economic potential is ~30-50% of that value

Measurement, Monitoring and Verification

- Detecting soil C changes
 - Difficult on short time scales
 - Amount changing small compared to total C
- Methods for detecting and projecting soil C changes (Post et al. 2001)
 - Direct methods
 - Field measurements
 - Indirect methods
 - Accounting

- Stratified accounting
- Remote sensing
- Models



Summary

- Soil C sequestration
 - Available technology at low cost
 - Significant impact on emissions: “Bridge to the Future”
 - Need advancement in MMV to account for variability
- Agricultural soil C sequestration
 - Keeps land in production thus providing food security and rural economic development (no leakage)
 - Improves soil quality
 - In many cases increases profitability for the farmer
 - Provides other environmental benefits to society
 - Water quality (less runoff, less erosion)
 - Flood control
 - Wildlife habitat
 - May help adapt to climate change as well as mitigate
- *Therefore a Win-Win Situation*

Chuck Rice

Phone: 785-532-7217

Cell: 785-587-7215

cwrice@ksu.edu



- Websites

www.soilcarboncenter.k-state.edu/

www.casmgs.colostate.edu/



K-State Research and Extension

KCCM

Kansas Coalition for Carbon Management