Tillage and Corn-Soybean Sequence Effects on SOC Dynamics Estimated from Natural ^{13}C Abundance

D. R. Huggins, USDA-ARS, Pullman, WA
R. R. Allmaras, USDA-ARS, St. Paul, MN
C. E. Clapp, USDA-ARS, St. Paul, MN
J. A. Lamb, Univ. of Minnesota, St. Paul
G. W. Randall, Univ. of Minnesota, Waseca

Tillage X Rotation Interactions

- Yang and Kay (2001) Hypothesized that reduced tillage would accentuate rotation effects on SOC
- Also our working hypothesis

Tillage X Rotation Interactions

- Semi-arid climates
  - Reduced soil disturbance increased SOC, but only in conjunction with intensification of the crop rotation and elimination of fallow

(Campbell et al., 1995; Potter et al., 1997; Schomberg and Jones, 1999; and Halvorson et al., 2002)

Tillage X Rotation Interactions

- Cold, humid climates
  - Rotation combinations (corn, soybean, wheat, barley) were comparable under different tillage treatments (Yang and Kay, 2001; Angers et al.,1992)

Tillage X Rotation Interactions

- Warm, sub-humid climates
  - Rotation effects (cont. soy., sorghum) on SOC were primarily due to differences in C inputs (Havlin et al., 1990)
  - BUT, tillage by rotation interactions occurred at site with fine-textured soil, where no differences in SOC occurred among tillage treatments for cont. soy. rotation, while increases in SOC occurred with no-tillage in the cont. sorghum rotation

Objectives

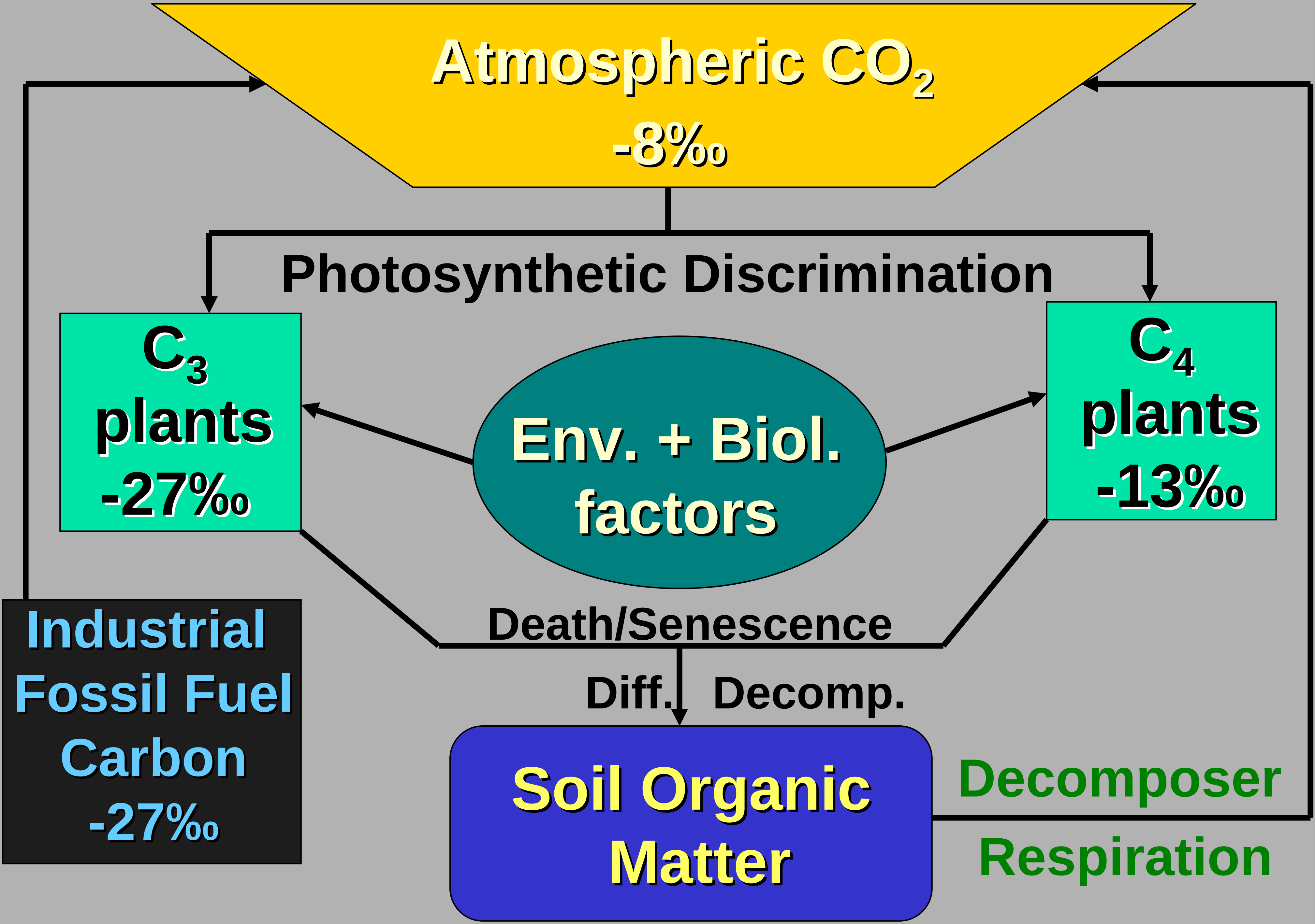
- **Evaluate tillage practice (moldboard plow, chisel plow and no-tillage) and crop sequence (continuous corn, continuous soybean and corn-soybean) effects on SOC storage and dynamics**
- **Assess use of natural ^{13}C abundance to quantify interactive effects of tillage and crop sequence on SOC**
- **Incorporate into simple C model to estimate C dynamics**

Methods

- Webster clay loam (33% clay), Waseca
- 1980-1994
- Crop Rotation: CC, CS, SS
- Tillage: MP, CP, NT
- Split-plot design, 4 reps.
- Grain yield, AGB, $\delta^{13}C$
- Fallow Alleys

Methods

- Composite of 12 soil cores (0-7.5, 7.5-15, 15-30, 30-45 cm)
- Bd, pH, SOC, δ13C



Atmospheric CO_2

-8‰

Photosynthetic Discrimination

C_3
plants
-27‰

Env. + Biol.
factors

C_4
plants
-13‰

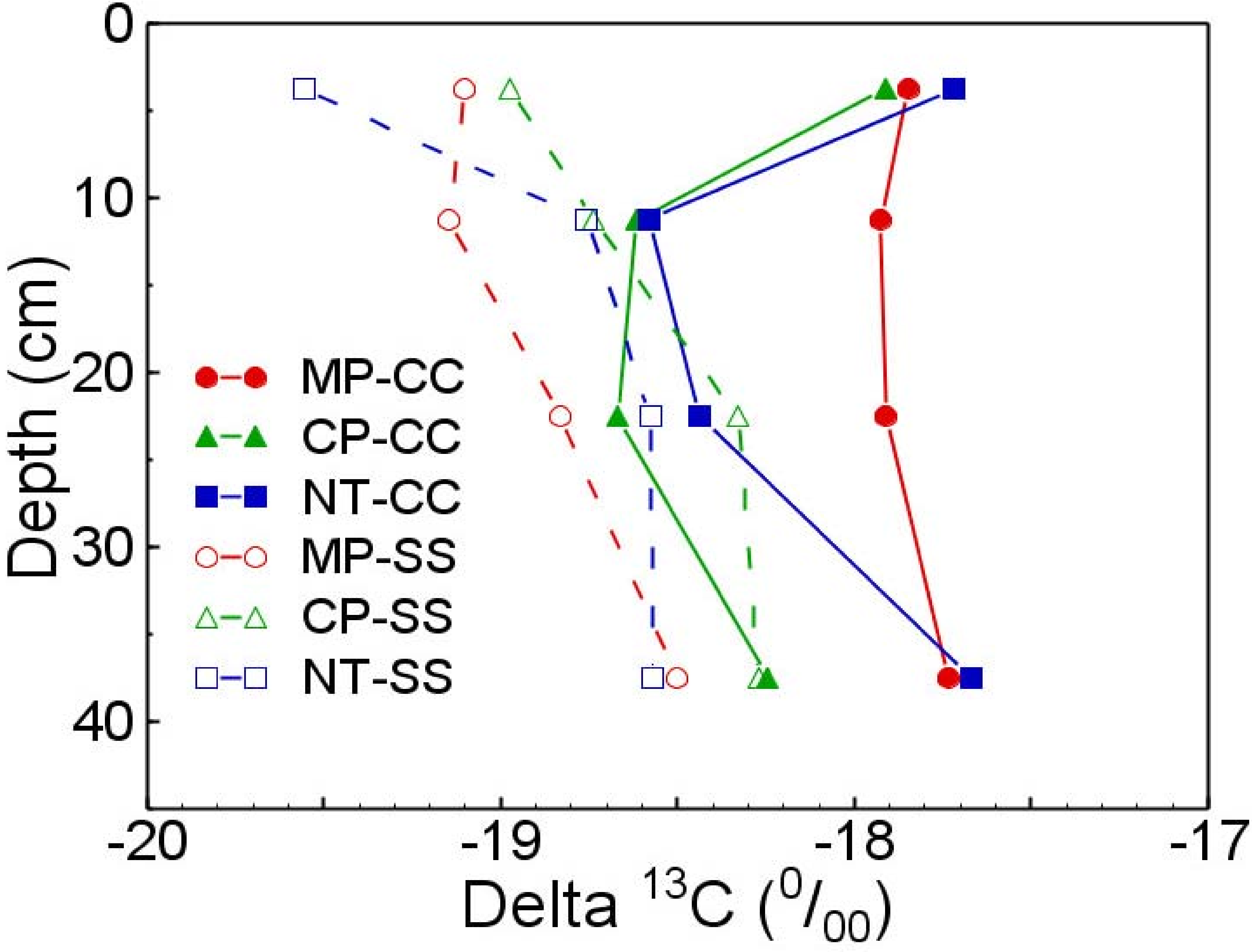
Death/Senescence

Diff. Decomp.

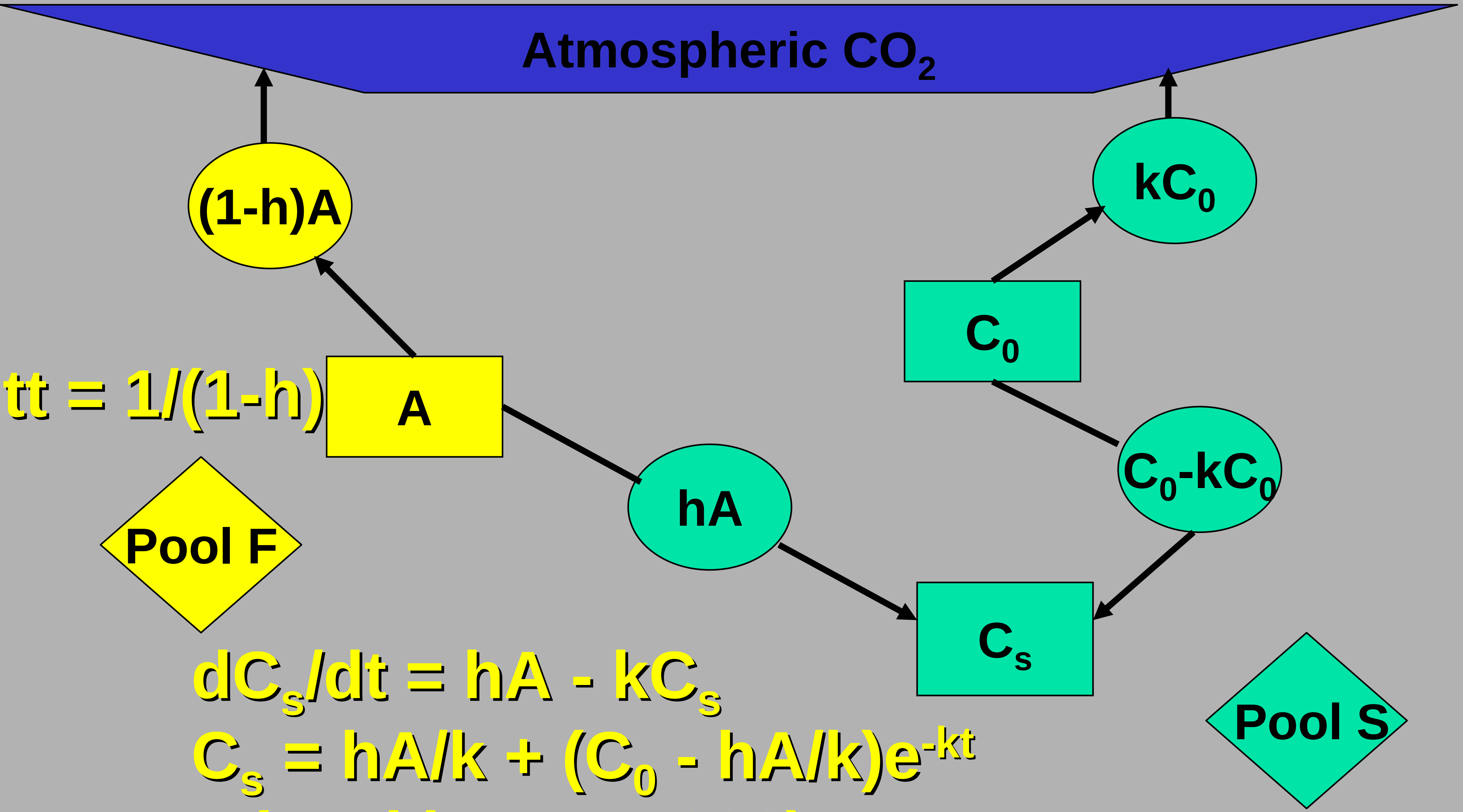
Industrial
Fossil Fuel
Carbon
-27‰

Soil Organic
Matter

Decomposer
Respiration


0
10
20
30
40
Depth (cm)
-20
-19
-18
-17
Delta ^{13}C ($^{0}/_{00}$)
MP-CC
CP-CC
NT-CC
MP-SS
CP-SS
NT-SS

Simple Carbon Modeling



tt = 1/(1-h)

$dC_s/dt = hA - kC_s$

$C_s = hA/k + (C_0 - hA/k)e^{-kt}$

(Jenkinson, 1988)

Where $A=0$, $C_s = C_0e^{-kt}$

tt = 1/k

$C_e = hA/k$

Treatments where A=0, $C_s = C_o e^{-kt}$

- Fallow: C_4-SOC and C_3-SOC
- Cont. Corn: C_3-SOC
- Cont. Soybean: C_4-SOC

C_3-derived SOC and Decay Rate Constants *(k)*

Management	C_3-derived SOC Mg/Ha (0-45 cm)	Decay Rate (*k*): C_3-derived SOC
Fallow	59.4b	0.025
Moldboard Plow Continuous Corn	54.6b	0.033
Chisel Plow Continuous Corn	78.4a	0.001
No-tillage Continuous Corn	68.4a	0.012

SOC and Decay Rate Constants *(k)*

Management	C_4-derived SOC Mg/Ha (0-45 cm)	Decay Rate (*k*): C_4-derived SOC
Fallow	67.8a	0.023
Moldboard Plow Continuous Soy.	66.1a	0.038
Chisel Plow Continuous Soy.	79.0a	0.010
No-tillage Continuous Soy.	73.3a	0.016

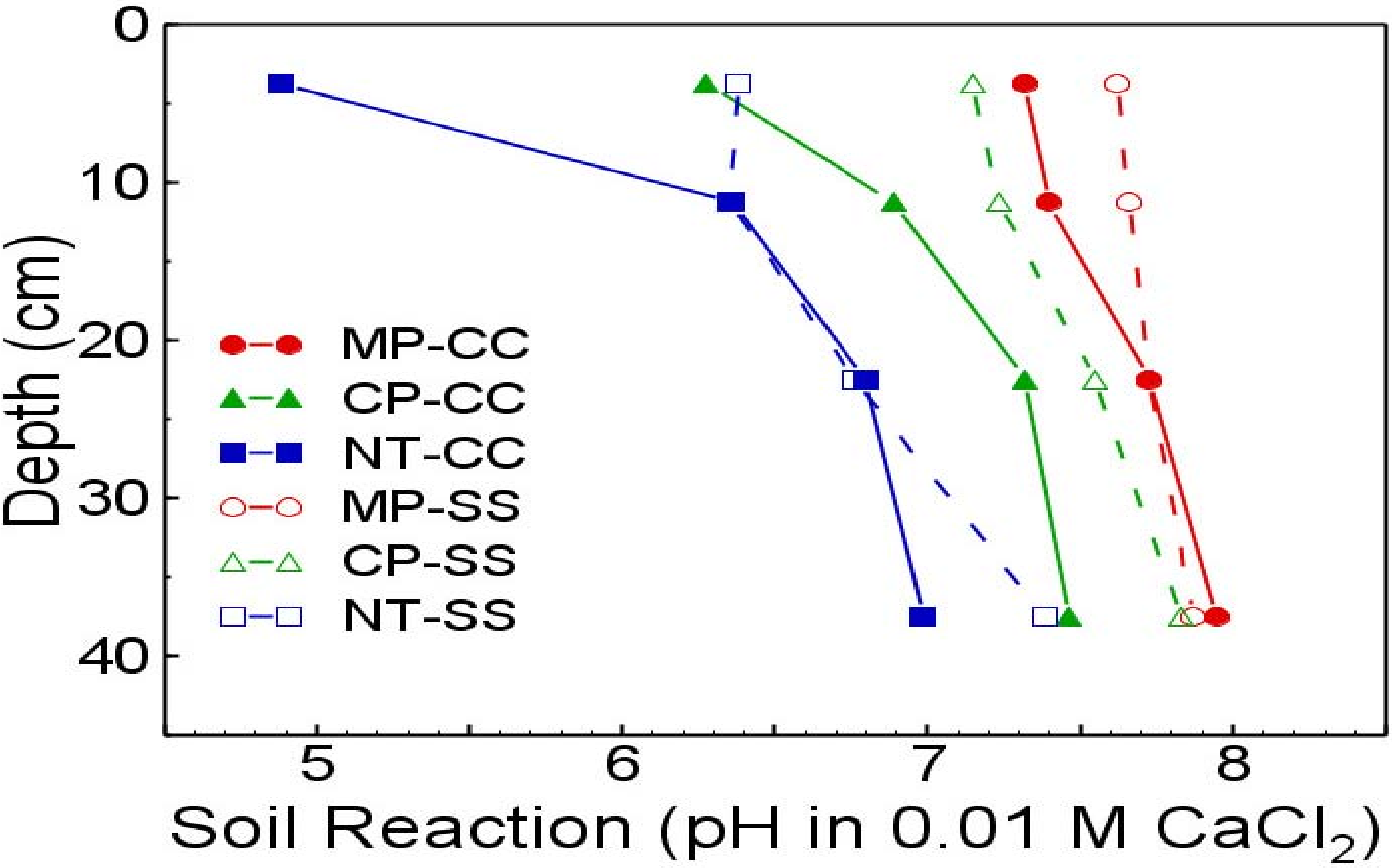
Tillage and Crop Sequence effects on SOM (Mg C/ha, 0-45 cm)

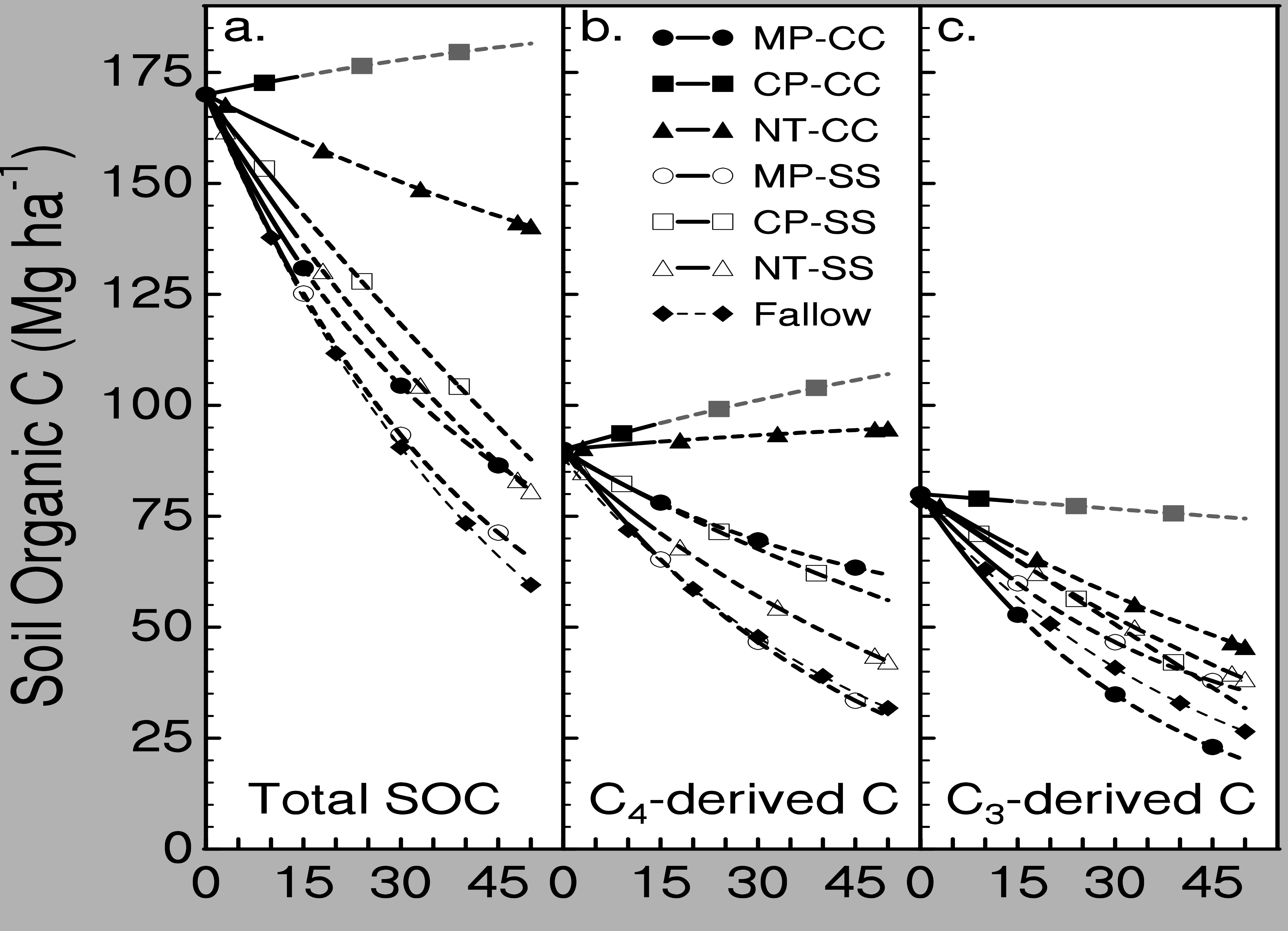
Crop Sequence	MP	CP	NT	$LSD_{0.05}$
Cont. Corn	**133**	**174**	**160**	25*
Cont. Soy.	**127**	**145**	**139**	27
Corn-Soy.	**132**	**163**	**143**	25*
$LSD_{0.05}$	14	14*	15*	

Fallow: 127 (Mg C/ha)

Contributing Factors

- C inputs of corn about 1.8 x soybean
- Soybeans reduce soil aggregate size, stability and C content (Fahad et al., 1982; Bathke and Blake, 1984; McCracken et al., 1985; Ellsworth et al., 1991)
- Contrasting seasonal soil water use (Allmaras et al., 1975)
- Soybean residues have low C/N ratio
- Soybeans priming C mineralization? (Cheng et al., 2003)
- Soil pH effects on decomposition


0
10
20
30
40
Depth (cm)
MP-CC
CP-CC
NT-CC
MP-SS
CP-SS
NT-SS
5
6
7
8
Soil Reaction (pH in 0.01 M $CaCl_2$)



(Preliminary analyses)

Summary

- SOC least in MP and greatest in CP, but significant rotation x tillage interactions occurred
- No rotation effect on SOC in MP tillage (similar to fallow)
- In cont. corn, NT and CP 15 to 20% more SOC (resp.) than cont. soybean
- No tillage effect on SOC in continuous soybean
- NT and CP had 20 and 30% more SOC (resp.) than MP tillage in cont. corn
- Study represents tillage and rotation effects where SOC had high initial levels of labile C—evidence that reduced tillage can maintain SOC levels similar to native prairie?