Soil Carbon Cycling, Trace Gas Emission, Tillage and Crop Residue Management

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Introduction

Agriculture can be both a source and sink of greenhouse gas (GHG), which includes CO_2, CH_4 and N_2O. Crop type, fallow frequency, residue management, soil amendments, cover crops, rotations, tillage, irrigation, drainage, mulching and fertilization influence C storage and GHG emission (Paustian et al., 1997). Sequestering C is expected to provide positive environmental feedback, so long as these benefits are not offset by unintended increases in GHG emission. In addition, management decisions have a strong economic component, environmentally favorable practices will not be adopted unless they are also economically sound. This work contributes to the USDA-Agricultural Research service – GRACEnet project.

Hypothesis

Minimizing tillage and increasing crop diversity can improve soil quality and enhance economic and environmental sustainability.

Objectives

- Identify and develop economically viable and environmentally sustainable farming systems
- Characterize risks and benefits associated with various management strategies
- Measure GHG emission from three management scenarios
- Quantify changes in soil organic C associated with various management strategies

Management Scenarios Defined

- Business as usual (BAU)- chisel plow (soybean) or moldboard plow (corn), high fertilizer inputs, corn-soybean rotation.
- Maximum C sequestration (MaxC) strip tilled with mole-knife, high fertilizer inputs, corn-soybean-wheat/alfalfa-alfalfa rotation. Tillage occurs after corn and alfalfa .
- Optimum greenhouse gas benefits (OPT) strip tilled with a mole-knife but receives no fertilizer inputs in a corn-soybean-wheat/alfalfa-alfalfa rotation. Tillage occurs after corn and alfalfa.

References:

Archer et al., 2007. Crop Productivity and Economics during the Transition to Alternative Cropping Systems. Agron. J. 99:1538-1547.

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IPCC. 2001. Climate Change 2001: The Scientific Basis. Contributions of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, p. 881, *In* J. T. Houghton, et al., eds. Cambridge University Press, Cambridge, United Kingdom and New York, NY.

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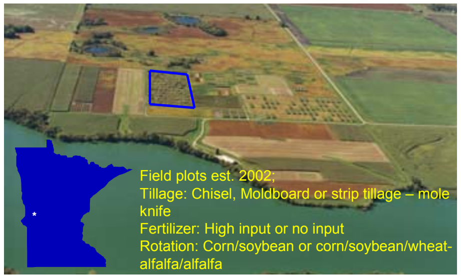
Materials and Methods



GHG Emission

- Static, vented chambers (Hutchinson and Mosier, 1981)
- Collars (26 cm dia X 7 cm tall), inserted 5 cm (two per plot) inter-row and row – in corn; soybean, random in wheat; alfalfa
- Chambers PVC (26 cm dia., 12 cm tall; vent 3.8 by 175 mm)
- CO_2 and N_2O – 2004, 2005, 2006 , early 2007
- CH_4 – 2006, early 2007
- Cumulative emission calculated by triangulation

Collateral Information

- Precipitation, soil and air temp (5 cm), vol. soil moisture (5 cm)

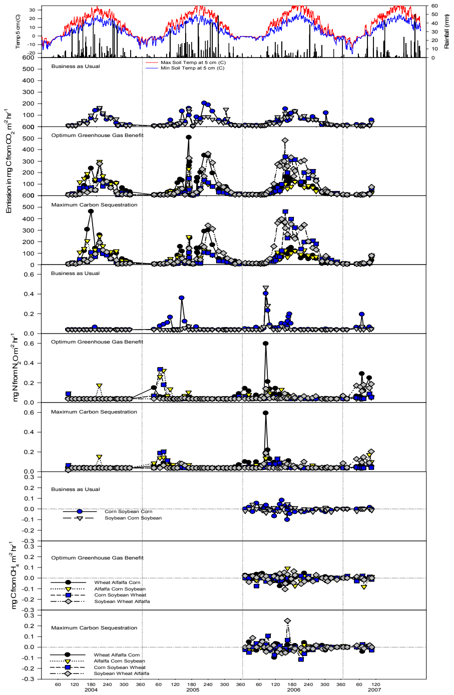
Aboveground Biomass Collection:

- Corn and soybean 1.5 m^2 collected at harvest – grain and biomass, wheat 1 m^2 at harvest, alfalfa sum of three 1 m^2 harvests.

Root Collection:

- Roots collect in grid pattern, at four horizontal positions from row to inter-row or crossing two rows in wheat and alfalfa; pooled per plot.
- Sampled to 60 cm
- Corn – 75% silk, Soybean – R4, Wheat – late boot, alfalfa – after 3rd cutting

Results and Discussion



- CO_2 flux includes both soil and root respiration and in the case of wheat and alfalfa the shoot respiration as the plants were included in the chamber.
- The largest N_2O flux peaks occurred during early thaw events and in response to N-fertilizer.
- CH_4 flux was near zero.

Annual average greenhouse gas emission from each scenario

Scenario	CO_2 [†]	N_2O	CH_4	GWP[††]			Scenario GWP
				CO_2	N_2O	CH_4	
		kg ha^{-1}			CO_2 equivalents * 10^3		
BAU	3610[b§]	3.4[a]	-0.4[a §§]	300[b]	36[a]	-0.70[a]	334[b]
MaxC	5600[a]	3.5[a]	-0.3[a]	470[a]	37[a]	-0.51[a]	506[a]
OPT	5480[a]	3.8[a]	-0.4[a]	460[a]	41[a]	-0.73[a]	500[a]

[†] CO_2 and N_2O; 2004 – 2007; CH4 2006-2007. [††]1 mole N_2O equivalent 296 mole CO_2 and 1 mole CH_4 equivalent 23 mole CO_2 on a 100-yr time frame (IPCC, 2001). [§]Values followed by the same letter within a column are not different at P≤0.05. [§§]Negative value indicated consumption.

At first glance it appears that BAU has the lowest GWP, however this is an artifact of sampling that excluded shoot material for row crops. Therefore additional information is needed to determine GWP from CO_2. There were no significant differences in cumulative N_2O and CH_4 GWP among the scenarios.

Average (2004, 2005 and 2006) plant biomass

Scenario	Corn	Soybean	Wheat	Alfalfa	Rotation Average
			Mg Shoot ha^{-1}		
BAU	15.8[a]	4.17[a]	--	--	10.0[a]
MAX C	14.8[b]	4.30[a]	7.34[a]	9.38[a]	8.96[b]
OPT	12.2[c]	3.82[b]	4.78[b]	6.66[b]	4.91[c]
			Mg Root in surface 60 cm ha^{-1}		
BAU	0.88[a]	0.13[b]	--	--	0.69[a]
MAX C	1.04[a]	0.23[a]	0.39[a]	1.24[a]	0.79[a]
OPT	0.86[a]	0.20[a]	0.35[a]	1.17[a]	0.69[a]

[†]Values followed by the same letter within a column are not significantly different at P≤0.05.

BAU treatment, produced on average the largest aboveground biomass (shoot plus grain), but not necessarily the most root biomass. Alfalfa and corn had the largest root mass. Wheat includes both wheat and first year alfalfa roots. There were no significant differences among treatments.

Economic analysis of three scenarios based on 2002-2005 yields and costs, adapted from Archer et al., 2007.

Scenario	Yield				Production cost[†]	Net return[‡]
	Corn	Soybean	Wheat	Alfalfa (hay)		
		Mg ha^{-1}			$ ha^{-1}	
BAU	10.0[a§]	2.7[a]	--	--	495	216[a]
MaxC	8.4[bc]	2.6[a]	3.0[a]	9.9[a]	428	145[ab]
OPT	7.5[c]	2.4[a]	2.3[b]	7.2[b]	379	95[b]

[†]Production costs include grain drying, diesel, labor, seed, fertilizer, chemicals and machinery ownership (e.g. repair, maintenance, insurance, interest on capital).
[‡]Crop prices ($ Mg^{-1}) of 86.23 - corn, 210.58 - soybean, 130.46 - wheat, 84.53 - alfalfa including government loan deficiency payments (USDA-NASS, 2006)
[§]Values followed by the same letter within a column are not significantly different at P≤0.05.

Net returns represent average annual returns to land and management occurring during the transition from BAU to the alternative systems. Note that, during the transition, alfalfa was not harvested in 2002 for the MaxC and OPT treatments, so average annual net returns for these scenarios were lower than what would be expected in the long term.