ACHIEVING ECONOMIC AND GREENHOUSE GAS GOALS THROUGH TILLAGE AND N MANAGEMENT

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ABSTRACT

A field study was conducted near Ft. Collins, CO evaluating irrigated continuous corn production under conventional tillage (CT) and no-till (NT) with six N fertilizer application rate treatments. Economic return response functions were developed for each tillage system and combined with net global warming potential estimates for a subset of treatments to determine whether economic and greenhouse gas emission improvements could be achieved. Results show economic returns can be increased by \$19 ac^{-1} while reducing net global warming potential through adoption of no-till production and at economic N fertilizer application rates.

INTRODUCTION

Farmers in the South Platte River Valley of northeastern Colorado predominantly use intensive tillage, including moldboard plow tillage, to prepare a seedbed and to manage the large quantities of crop residues returned to the soil surface in irrigated crop production. These practices contribute to wind and water erosion, and may exacerbate global climate change through emission of greenhouse gases. Conversion of irrigated cropland from moldboard plow tillage to less intensive tillage systems would not only reduce the potential for soil erosion, but may increase C storage in soils, enhancing soil organic carbon (SOC) sequestration and reducing CO_2 emissions (Entry et al., 2002; Halvorson et al., 2008). Greenhouse gas emissions can also be affected by nitrogen fertilizer management (Mosier et al., 2006). Less intensive tillage systems, like NT, must provide adequate economic returns if they are to be adopted by producers. The objective of this study was to identify the potential tradeoffs between economic returns and greenhouse gas emissions in these systems, including interactions with fertilizer N management decisions.

MATERIALS AND METHODS

A field study was conducted on a Fort Collins clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalf) with a 1 to 2% slope at the Agricultural Research Development and Education Center (ARDEC) (40°39'6" N, 104°59'57" W; 5035 ft a.s.l.) near Fort Collins, CO. The study was initiated in 1999 on a field previously cropped to corn for 6 years using a CT system. The CT system included fall moldboard plow and tandem disk tillage with roller harrowing, landplaning, and field cultivation in the spring for seedbed preparation. In the NT system, corn was direct-planted into the previous year's corn stalks each spring without any other field operations for seedbed preparation. The corn was fully irrigated during the growing season with water applied as needed (determined weekly by appearance and feel).

Six N rates (0, 30, 60, 90, 120, and 180 lb N ac^{-1} referred to as N1, N2, N3, N4, N5, and N6, respectively) were established in 2000 in the NT system. In the CT system, only the N1, N3, N5, and N6 treatments were present in 2000 and 2001. In 2002, the N2 treatment was added, and in 2003 the N4 treatment was added to the CT system. The same rate of N was applied to the same plots each year with the exception of the N6 treatment. The N6 application rates were 150, 180, 200, 200, 220 lb N ac^{-1} in years 2001-2005, respectively. The N source was UAN (32–0-0), which was applied with a liquid fertilizer applicator that banded the N about 2 inches below the soil surface in bands spaced 13 inches apart (parallel to the corn row, but at varying distance from the corn row) the day before corn planting. However, for the economic analysis, it was assumed the N fertilizer was applied with the planting operation, representing a more likely producer practice. In 2005, one-half of the N fertilizer was applied prior to planting as UAN, and one-half was applied on June 9 as a dry granular polymer-coated urea with a broadcast applicator. This second N fertilizer application was included as a separate operation for the economic analysis. Additional details on the field study may be found in Halvorson et al. (2006).

Fluxes of CO_2, N_2O, and CH_4 were measured using static, vented chambers, one to three times per week, year round from April 2002 through October 2004 on the N1, N5, and N6 treatments. SOC was measured based on the difference between total soil C and soil inorganic C from soil samples (0-3 in. depth) collected in 1999 and 2004. Annual changes in SOC were estimated using regression trends between the 1999 and 2004 SOC levels. Further details on the greenhouse gas and SOC analysis may be found in Mosier et al. (2006). Cumulative annual fluxes of CO_2, N_2O, and CH_4, and changes in SOC were related to N rates by linear interpolation of the fluxes observed on the three measured N rate treatments. Cumulative fluxes were converted to a C-equivalent basis using the 2001 IPCC 100-year global warming potential factors (IPCC, 2001). Two different measurements of CO_2 emissions were obtained: 1) net balance of CO_2 flux measurements and annual crop residue inputs, and 2) annualized measure of changes in SOC. These resulted in two different estimates of net global warming potential (GWP) denoted GWP respiration, and GWP soil C, respectively.

Enterprise budgets were constructed for each treatment based on the operations and inputs used in the field study each year, but using fixed input costs. Machinery costs were from University of Minnesota Extension Service (Lazarus and Selley, 2005). Irrigation costs and herbicide costs were from University of Nebraska Extension Service (Selley et al., 2006; Bernards et al., 2005). Fuel, fertilizer, and seed costs were the April 2006 costs from the USDA-National Agricultural Statistics Service (USDA-NASS, 2006). Nitrogen fertilizer price was \$0.40 lb^{-1}, and net returns were calculated using a corn price of \$2.38 bu^{-1} which was calculated to include government loan deficiency payments using the 10-yr average of the higher of the 2005 commodity loan rate or the annual marketing year average corn prices for Colorado from 1997-2006 (USDA-NASS, 2007; USDA-FSA, 2005). Government payments of \$62 ac^{-1} were also included for calculating returns, based on typical direct payment and historical countercyclical payment rates that would occur with the farm program provisions in 2005. No land or management costs were included in the production costs, so net returns represent returns to land and management. Further details on the economic analysis may be found in Archer et al. (2008).

A logistic function was used to estimate yield response to applied N for each tillage system each year. These were combined with corn price and production cost information to estimate annual net return response functions for each tillage system. Expected yield and expected net return responses to applied N were estimated using the 2000-2005 averages of the annual yield and net return response functions, respectively. Economic optimum N rates were calculated from the yield response functions by maximizing expected net returns. Greenhouse gas emissions from production activities were calculated from estimated diesel fuel and irrigation energy use and observed pesticide and fertilizer inputs using the factors published by West and Marland (2002).

RESULTS AND DISCUSSION

A summary of the economic optimum N rate, along with the expected yields, economic performance, and greenhouse gas emissions at the economic optimum N rate is shown in Table 1. Note: negative greenhouse gas emissions indicate a net reduction in emissions to the atmosphere. The economic optimum fertilizer N rate was 50 lb ac^{-1} higher under NT than under CT, but expected yields were 16 bu ac^{-1} lower for NT than for CT. However, both operating and machinery ownership costs were lower for NT than for CT resulting in a \$19 ac^{-1} net return advantage for NT over CT. We anticipated greenhouse gas emissions from production activities to be lower under NT than CT due to reductions in diesel fuel use for tillage operations. However, the higher fertilizer N rate under NT offset much of this advantage, resulting in only a 14 lb C-equivalent ac^{-1} reduction in greenhouse gas emissions from production activities for NT compared to CT. Net GWP based on the respiration measurements showed expected net GWP

Table 1. Economic optimum N rate, and expected yield, economic performance, and greenhouse gas emissions at the optimum N rate for conventional-till (CT) and no-till (NT) irrigated continuous corn.

	CT	NT
Fertilizer N	----------lb ac^{-1}----------	
Economic Optimum N rate	138	188
Production	----------bu ac^{-1}---------	
Expected Yield	189	173
Economics	----------\$ ac^{-1}----------	
Total Operating Costs	375	352
Machinery Ownership Costs	100	65
Total Costs	475	417
Net Returns	37	56
Greenhouse Gas Emissions	--lb C-equivalent ac^{-1}--	
Production Activities	290	276
N_2O	184	184
CH_4	2	2
Soil respiration	2807	2470
Crop residue	3608	3892
SOC storage	19	595
Net GWP respiration	-325	-960

declined at the optimum N rate under both tillage systems with NT resulting in a 635 lb C-equivalent ac^{-1} greater decline than CT. Net GWP based on the SOC measurements showed an increase in net GWP under CT and a decrease in GWP under NT, with NT resulting in a 589 lb C-equivalent ac^{-1} reduction relative to CT.

Based on respiration measurements, net GWP declined with increasing fertilizer N under both tillage systems (Figure 1). Expected net returns were higher and net GWP lower under NT than CT over a wide range in N rates, showing potential for both economic and environmental improvements through adoption of NT. Under NT, the lowest observed net GWP occurred near the economic optimum N fertilizer rate, so it is unclear whether further increases in N rates above the economic optimum would continue to decrease GWP. Under CT, it appears further reductions in GWP might be achieved by N rates above the economic optimum; however, this would reduce economic returns due to increased N fertilizer costs. Also, this does not include other possible environmental effects, such as reductions in water quality, which might occur with N fertilizer application rates above the economic optimum.

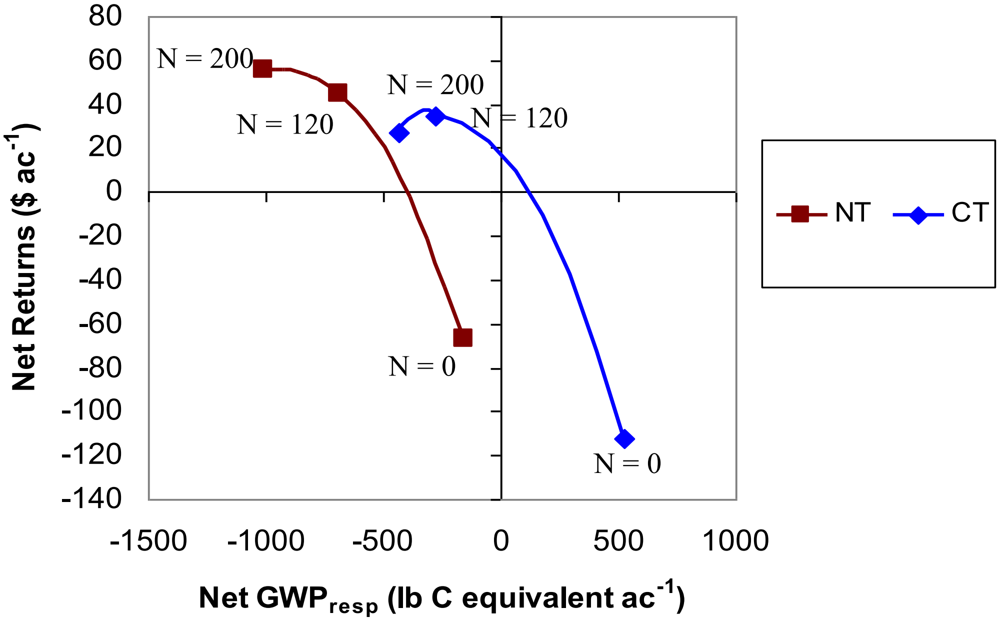

Figure 1. Expected net returns and net global warming potential based on soil respiration (GWP$_{resp}$) response to fertilizer N under conventional-till (CT) and no-till (NT). Labeled points indicate N fertilizer application rates (lb ac^{-1}).

In contrast with GWP respiration, net GWP based on SOC measurements showed increasing net GWP with increasing N fertilizer rates under CT (Figure 2). So, over-application of fertilizer N under CT would have both negative economic and environmental consequences. If N fertilizer were applied at economic optimum rates under CT, further reductions in GWP would require reducing N rates, resulting in reductions in net returns due to yield decreases. As with GWP respiration, GWP based on soil C measurements was near the observed minimum under NT for N fertilizer application rates at the economic optimum. Net GWP was lower for NT than for CT at all N fertilizer rates, showing a likely economic and environmental win-win situation for adoption of NT.

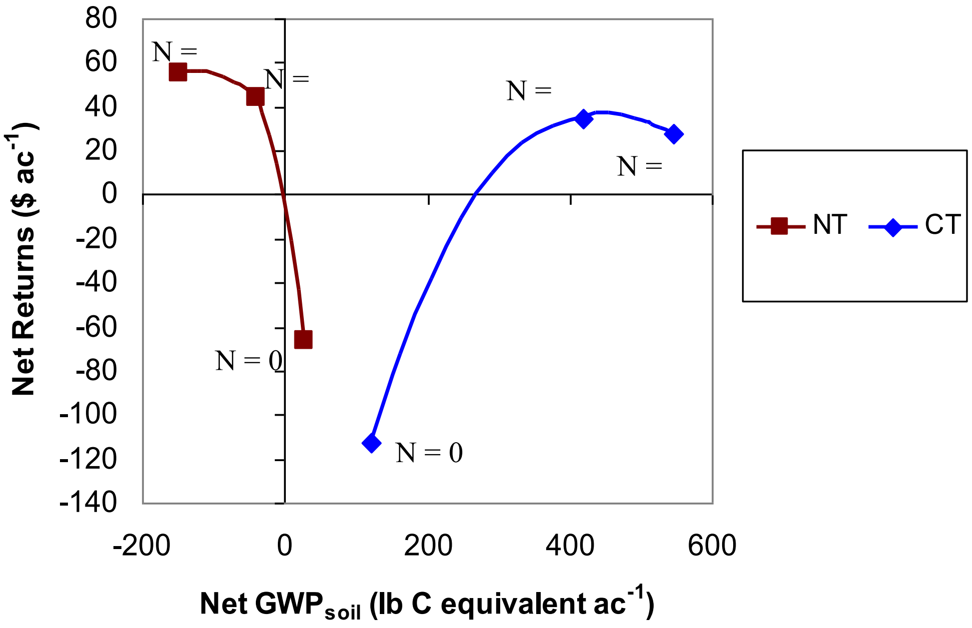

Figure 2. Expected net returns and net global warming potential based on soil C (GWP_{soil}) response to fertilizer N under conventional-till (CT) and no-till (NT). Labeled points indicate N fertilizer application rates (lb ac^{-1}).

CONCLUSION

Combining net GWP measurements with economic analysis of irrigated continuous corn under CT and NT showed that net greenhouse gas emissions may be reduced while increasing economic returns through adoption of NT. Furthermore, greatest greenhouse gas reductions for NT occurred near economic optimum fertilizer N application rates, indicating that managing N for profitable corn production under NT may also provide environmental benefits. While net greenhouse gas emissions might also be reduced under CT by adjusting N fertilizer rates, lowest emissions did not coincide with economic optimum N rates, and thus would require tradeoff between environmental and economic performance. Additionally, the direction of the effect of N fertilizer applications on net GWP under CT differs depending on the method used in measuring GWP, indicating a need for further research on these impacts.

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