Managing Nitrogen Fertilizer for Economic Returns and Greenhouse Gas Reductions in Irrigated Cropping Systems

By David W. Archer and Ardell D. Halvorson

Research shows that increasing N fertilizer rates generally increase net greenhouse gas (GHG) emissions from irrigated cropping systems in Colorado. Applying N fertilizer at rates above the economic optimum increases net GHG emissions and reduces profitability. Results of this study show avoiding over-application of N fertilizer and combining careful N fertilizer management with appropriate changes in tillage and crop rotation practices can reduce net GHG emissions while maintaining profitability.

Greenhouse gas emissions from farming activities can be influenced by tillage and N fertilizer management decisions. While N fertilizer is important for increasing crop productivity, which can help maintain soil organic carbon (SOC) levels, N application generally increases nitrous oxide (N_2O) emissions from irrigated cropping systems in the Central Great Plains (Mosier et al., 2006; Halvorson et al., 2008, 2009). Additionally, N fertilizer use leads to indirect GHG emissions due to manufacturing and transportation of fertilizer to the farm. Tillage practices also influence GHG emissions, with greater tillage intensity generally associated with higher GHG emissions due to lower SOC storage and higher fuel use (Lal, 2004). There can be important interactions between N fertilizer and tillage management decisions, with higher N needed to minimize reductions in irrigated corn yield associated with no-till (NT) corn production (Maddux and Halvorson, 2008).

Tillage and N fertilizer decisions at the farm level are driven largely by economics. While management can lead to reductions in GHG emissions, producers are understandably unlikely to adopt management practices that are not profitable. This paper looks at the economic feasibility of reducing net GHG emissions using results from an irrigated cropping systems field study conducted near Fort Collins, Colorado. Cropping systems included conventional plow tillage continuous corn (CT-CC), no-till continuous corn (NT-CC), and no-till corn-soybean or dry bean (NT-CB). Nitrogen fertilizer rates applied to corn ranged from 0 to 220 lb N/A (0 to 246 kg N/ha) and rates applied to soybean or dry bean ranged from 0 to 50 lb N/A (0 to 56 kg N/ha). The highest N rate applied to corn varied with year (180, 200, and 220 lb N/A in 2002, 2003-2004, and 2005-2006, respectively). For the NT-CB system, corn was grown in 2002, 2004, and 2006, soybean was grown in 2003, and dry bean was grown in 2005. (See Halvorson et al., 2006; Halvorson and Reule, 2006; and Archer et al., 2008 for further details). Emissions of CH_4 and N_2O were measured from 2002-2006 for the 0, 60, 120, and 180+ lb N/A fertilizer rates in the CT-CC and NT-CC systems and for the 0 and high N rates in the NT-CB system using vented static chambers (see Mosier et al., 2006; Halvorson et al., 2008; and Alluvione et al., 2009 for details on GHG flux methodology).

Enterprise budgets were calculated for each system with costs calculated based on the operations and inputs used in the field study each year. Annual crop yield response to applied N was estimated using nonlinear regression and a logistic response function. Annual net returns were calculated using the estimated annual crop yield response, assuming crop prices of \$4.00/bu, \$10.60/bu, and \$23.80/cwt for corn, soybean, and dry bean, respectively, and N fertilizer price of \$0.51/lb. Enterprise budgets did not include management or land costs, so net returns represent net returns to labor and management. The economic consequences of achieving GHG emission reductions were analyzed by combining the enterprise budget data with net global warming potential (GWP) calculated as CO_2 equivalents with 1 unit CH_4 = 23 units CO_2 and 1 unit N_2O = 296 units CO_2. Net GWP was calculated as the sum of CO_2 equivalents from irrigation, farm operations, N fertilizer production, soil N_2O emissions, and soil CH_4 emissions minus the annual increase in SOC. (See Archer et al., 2008, and Archer and Halvorson, 2010, for details on economic analysis and net GWP methodology).

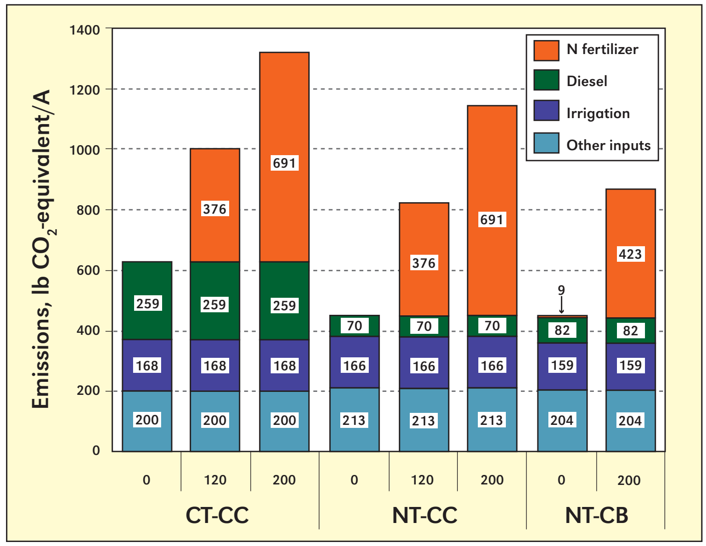

Figure 1. Average (2002-2006) greenhouse gas emissions from crop production activities (N fertilizer, diesel, irrigation, other inputs) for conventional-till continuous corn (CT-CC), no-till continuous corn (NT-CC), and no-till corn-bean (NT-CB) systems at 0, 120, and 200 lb N/A fertilizer application rates (corn year only).

Average emissions of GHG from production activities (irrigation, farm operations, N fertilizer production) are shown in **Figure 1**. At the highest N fertilizer rates, emissions associated with N fertilizer manufacture and transportation account for about half of the emissions from production activities. Excluding N fertilizer emissions, average production activity GHG emissions for the NT systems were 178 to 182 lb CO_2-equivalent/A lower under NT than under CT, primarily due to lower diesel fuel use. Average annual soil GHG

Abbreviations and notes: N = nitrogen; CH_4 = methane; CO_2 = carbon dioxide.

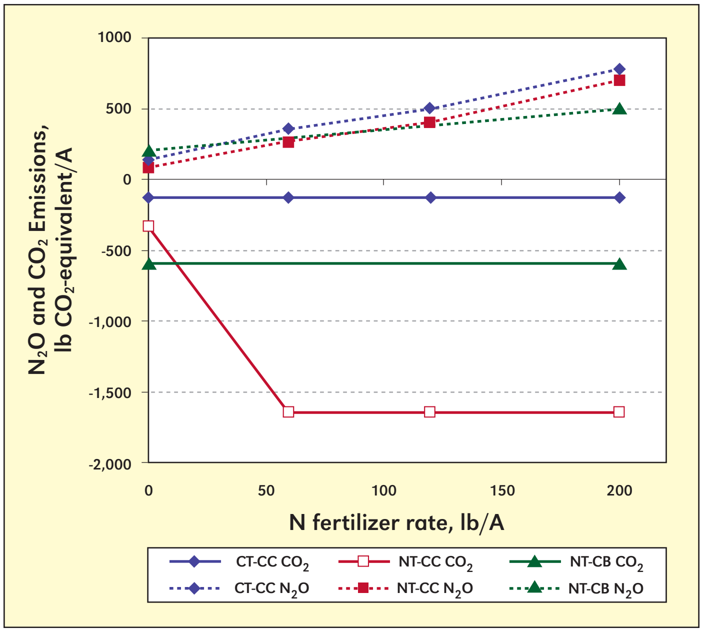

Figure 2. Average (2002-2006) CO_2 and N_2O soil emissions for conventional-till continuous corn (CT-CC), no-till continuous corn (NT-CC), and no-till corn-bean (NT-CB) systems as a function of N fertilizer application rate.

emissions used in calculating net GWP are shown in **Figure 2**. Annual emissions of CH_4 were negligible, ranging from 3 to 5 lb CO_2-equivalent/A (data not shown). Annual N_2O emissions increased with increasing N fertilizer rate (Mosier et al., 2006; Halvorson et al., 2008, 2009). All treatments increased SOC over time (1999-2007), so average annual soil CO_2 emissions for all treatments were negative (as measured by change in SOC). There were no significant differences in CO_2 emissions among N rates for CT-CC. Similarly, there were no differences in CO_2 emissions among N rates under NT-CB, so the average across all N rate treatments was used in calculating net GWP for CT-CC and NT-CB. Emissions of CO_2 were not significantly different among the 60, 120, and 200 lb N/A rates under NT-CC, but the CO_2 emissions at these rates were lower (greater SOC storage) than at the 0 lb N/A rate. Average annual CO_2 emissions were lower for NT-CC and NT-CB than under CT regardless of N fertilizer rate.

Net GWP emissions were calculated by adding emissions associated with production activities to soil GHG emissions. Combining net returns with net GWP shows some opportunities for managing GHG emissions while increasing profitability (**Figure 3**). Excessive application of N fertilizer reduces profitability while increasing net GWP. For a producer growing CT-CC, the economic optimum N fertilizer rate in this study was 130 lb N/A. A producer applying 200 lb N/A would increase GHG emissions by 460 lb CO_2-equivalent/A while reducing profitability by $16/A compared to the economic optimum for the CT system. Reducing N fertilizer rates within a tillage-rotation system below the economic optimum could further reduce net GWP, but these reductions would come at a cost to the producer. However, switching from CT to either of the two NT systems offers opportunities to increase profitability while further decreasing net GWP. Comparing systems at the economic optimum N rates of this study, switching from CT-CC

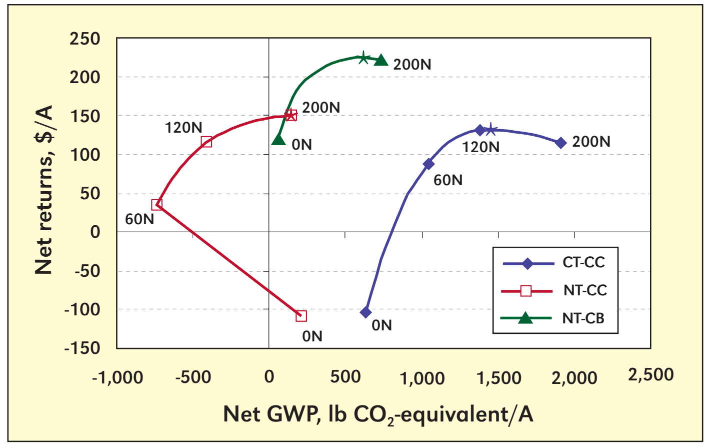

Figure 3. Relationship between average (2002-2006) net returns and average net global warming potential for conventional-till continuous corn (CT-CC), no-till continuous corn (NT-CC), and no-till corn-bean (NT-CB) systems. Point labels indicate N fertilizer application rates (lb N/A).

* Denotes economic optimum within each tillage-crop rotation system.

to NT-CC increases net returns by $19/A and reduces GWP by 1,310 lb CO_2-equivalent/A, while switching from CT-CC to NT-CB increases net returns by $92/A and reduces GWP by 830 lb CO_2-equivalent/A.

While GHG emissions tend to increase with increasing N fertilizer application rates, N fertilizer is necessary to maintain crop productivity and economic viability. For irrigated corn production in northeastern Colorado, our results indicate that GHG emissions can be reduced and profitability improved by avoiding over-application of N fertilizer. Further reductions in GHG emissions and increases in profitability could be realized by switching from CT to NT production systems. BC

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