Fluid JOURNAL
Official Journal of the Fluid Fertilizer Foundation
Late Spring 2008
Vol. 16 No. 3, Issue #61

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Managing To Reduce Greenhouse Gas Emissions

Managing at high yield levels creates large sinks for carbon and mineral N, providing prerequisite for reducing global warming potential.

Summary: *Intensification of cropping does not necessarily increase green house gas (GHG) emissions and global warming potential (GWP) of agricultural systems provided that crops are grown with best management practices and near yield potential levels, resulting in high resource-use efficiency. High-yielding continuous corn (CC) systems have significant potential for GHG mitigation, particularly if corn grain is converted to bio-ethanol. Managing at high yield levels creates large sinks for carbon (C) and mineral nitrogen (N), thereby providing the prerequisite for sequestering atmospheric carbon dioxide (CO_2) and reducing nitrous oxide (N_2O) emissions that could result from inefficient use of soil or fertilizer N. The differences in corn and soybean C sequestration potential suggest that CC systems may indeed hold greater promise for mitigation of global warming than the conventional corn/soybean rotation.*

Meeting the projected global demand for food and fuel from corn systems, while conserving natural resources and improving environmental quality, can only be achieved by the intensification of existing corn systems. Yield analysis of the central U.S. Corn Belt indicates that there is a large exploitable yield gap for corn. Since 1999 we have been experimenting with optimizing corn management systems to exploit corn yield potential. To date, our experience has shown that considerable yield increases are realized by choosing the right combination of adapted varieties, planting date, and plant populations to maximize crop productivity within a given climatic regime. In addition, more intensive N management strategies that focus both on improving crop N-use efficiency and residue C management also contribute to reducing N input over the longer term through increases in soil organic matter and N storage that can increase the indigenous soil N supply capacity. In addition, intensification has not resulted in significant increases in global warming potential for these cropping systems.

Defining potential

Corn yield potential represents the maximum achievable grain yield of an adapted cultivar or hybrid when grown with minimal biotic or abiotic stresses. Here the only limitations are temperature, solar radiation, and genetics. How do we measure yield potential for a given region? That is best done by cultivating the crop in field experiments under optimal management without nutrient or water limitations, plus careful control of diseases, pests, and weeds. An alternate and more convenient means of estimating yield potential is with well-calibrated mechanistic simulation models. Figure 1 shows a timeline of National Corn Growers Association yield contest winners in the irrigated and rain-fed categories for both first and second place winners each year. Except for 1999 to 2002, and the most recent year (2007), the first and second place yields are very similar and the gap between irrigated and rain-fed yields has narrowed owing to better-adapted, more stress- resistant

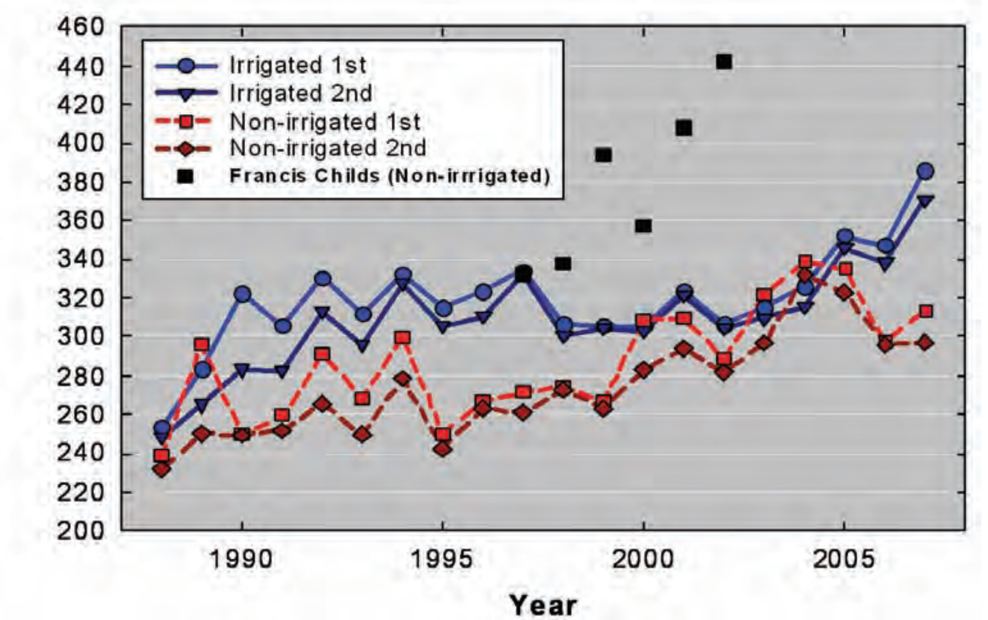

Figure 1. Yield trend for irrigated and non-irrigated corn yield winners of the NCGA through 2007.

cultivars. The outliers in 1999 to 2002 were the yields reported by Frances Childs from Manchester, Iowa, which could not be verified by simulation using the actual corn hybrid and climatic data at this site. They were subsequently disqualified because the standard yield verification procedures used at this site did not follow contest guidelines. The 2007 yields for the irrigated category also appear to be suspicious in that they are well above the trend line of the past 18 years. Until these yields can be verified with a robust crop simulation model, we do not believe they can be relied upon as evidence that the yield plateau has been broken for winning yields in the irrigated class.

Instead, we believe that corn yield potential for the irrigated category hovers around the 300 to 320 bu/A range, which identifies this as the probable yield ceiling, except in years with exceptional climate stress, such as the unusually high temperatures of the 1988 growing season. Figure 2 shows a similar exercise whereby yield potential is estimated with the Hybrid-maize model over a wide range of sites within the U.S. Corn Belt. Based upon these simulations, a ceiling yield for corn yield potential is estimated to be in the same range as those reported for the NCGA contest winners. The model simulation indicates that a minimum of 60 days of reproductive growth is needed to achieve this yield potential. Hence, abnormally hot years would limit corn yield potential due to rapid growing degree day (GDD) accumulation and a shortened grain-filling period. These data also suggest that limitations in nutrient management, plant population, and disease suppression have limited average Corn Belt farm yields to 60 percent of yield potential. At issue is whether closing this yield gap can be achieved in a sustainable fashion with minimal environmental impact and without increasing GHG emissions from agricultural land. To access such options requires full accounting of GWP of agricultural systems, including the net changes in soil organic carbon (SOC), the energy consumed in crop production, and trace gas emissions (notably N_2O) associated with N management.

Putting to test

In order to address these questions, a long-term experiment was established in 1999 in Lincoln, NE. The primary objective of this experiment was to evaluate resource-efficient management concepts for achieving crop yields that approach the climatic yield potential. The soil at this site is a deep Kennebec silty clay loam with high soil fertility status (pH 6 to 6.5, 2.5 to 3 percent organic matter, 300 to 400 ppm K, and 60 to 80 ppm Bray-1 P). The experiment was conducted with:

- Three crop rotations as main plots: CC, corn/soybean (CS) or (SC) with an entry point into each crop in each year
- Three plant population densities as subplots
- Two levels of nutrient management (recommended and intensive) as the final split.

Average crop yields in this experiment were close to the yield potential of soybean and corn at this location and significantly higher than the national or state average. Corn yields ranged between 215 to 287 bu/A

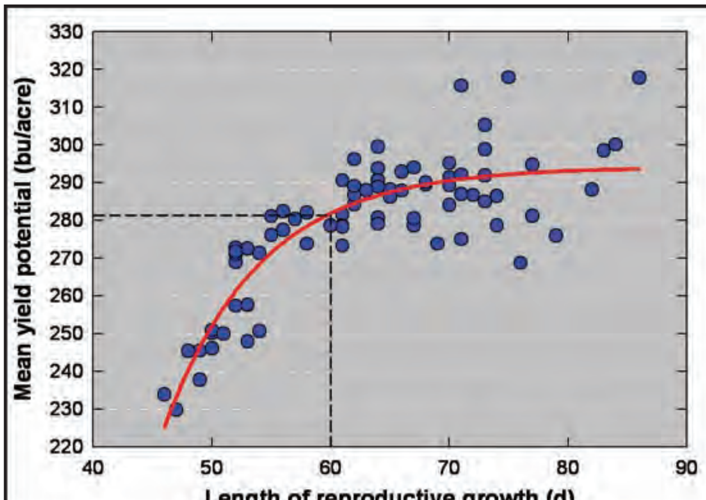

Figure 2. Hybrid-maize simulated corn yield for locations across the U.S. Corn Belt, 40,000 plants/A with no water or nutrient limitations.

or within 84 to 97 percent of the simulated yield potential. CS yielded about 5 to 11 percent higher than CC primarily due to fewer problems with stand establishment and fewer pest and disease problems.

Since the start of this experiment, large amounts of crop residue have been returned to the soil in all four management systems, but with significant differences among them in terms of dry matter amounts and composition. Corn returned 75 to 100 percent more residue than soybeans, but with a much wider C/N ratio. On a whole-crop rotation basis, average annual C return with above ground residue increased in the order of CS-rec < CS-int (+8%) < CC-rec (+22%) < CC-int (+39%), whereas residue N inputs followed the order CC-rec < CS-rec < CS-int < CC-int. Both residue C and N input were highest in the CC-int system, exceeding the more commonly practiced CS-rec system by 30 to 40 percent.

Soil C and N

In a complete two-year crop rotation with flux measurement conducted in corn and soybeans, soil CO_2 efflux (respiration) in the continuous corn system was 22 percent larger than in CS rotations at both levels of management intensity. With each crop rotation, intensified fertility management did not cause a significant increase in soil CO_2 emissions as compared to the recommended practice. As a result both SOC

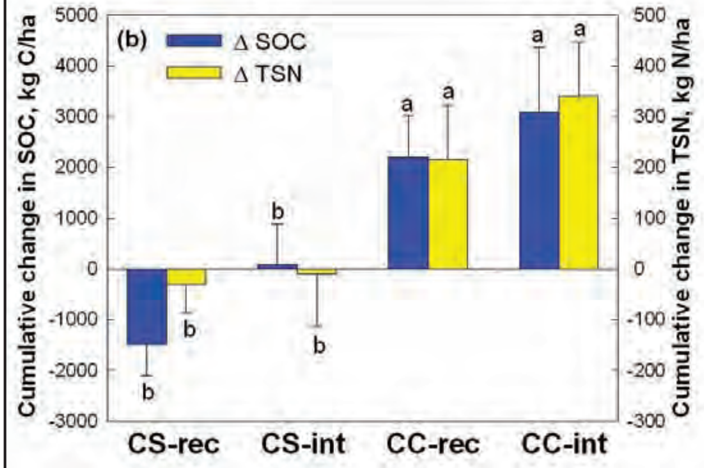

Figure 3. Cumulative change in soil organic carbon (SOC) and total soil nitrogen (TSN) after six years of treatment. CS = corn/soybean rotation; CC = continuous corn; rec = recommended nutrient management; int = intensive nutrient management.

and total soil N (TSN) increased in two CC systems, but decreased in the CS-rec or remained unchanged in the CS-int system. On the average, SOC declined at an average rate of 275 lbs/A/yr in the CS-rec, whereas it increased at the rate of 565 lbs/A/yr of N in the CC-intensive (0 to 12-inch depth). Similar trends were observed for TSN (Figure 3).

N-use efficiency

Table 1 presents the general N balance and N-use efficiency (NUE) of the four systems. Without consideration of the change in soil TSN status, most researchers would calculate NUE as the total amount of N in grain/N applications rate. This tends to give an artificially high NUE to the CS system because soil N is exploited in this rotation. It would seem more appropriate to calculate a system level NUE, given the measured loss in TSN and SOC with soybeans in rotation with corn. If this is done, NUE drops 13 percent in the CS-rec system but increases by 175 percent in the CC-int system!

Global warming

When fossil fuel consumption, CO_2-C losses, and trace gas emissions are factored into GWP of these systems, all four cropping systems were net sources of GHG, with GWP ranging from 0.54 to 1.02 tons of CO_2-C/A/yr. Positive or negative changes in SOC, intrinsic C costs associated with crop production, and soil N_2O emissions were major contributors to net GWP. Despite higher C cost associated with agricultural production and also higher N_2O emissions, net GWP in the continuous corn systems was lower than that of the CS systems because sequestration of atmospheric CO_2 in SOC was observed in only the CC systems. Although the amount of N fertilizer applied to corn grown in intensive cropping was 40 percent (CC) or 64 to 92 percent (CS) greater than the recommended treatments, N_2O losses were not directly related to the level of N input only as significant losses of N_2O were measured during the soybean year, especially after soybean harvest.

Table 1. System level NUE in CC and CS systems with recommended (-rec) or intensive (-int) management, 2000-2005)

	CS-rec	CS-int	CC-rec	CC-int
Annual N input, lbs/A	64	156	183	272
Annual N removal with grain, lbs/A	208	216	160	176
Change in total soil N, 0-12", lbs/A	-27	-9	195	309
NUE				
lbs N in C + S grain/lb N applied	3.27	1.38	0.88	0.65
lbs grain N + change in soil N/lb applied	2.84	1.33	1.95	1.79

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