Drs. A Dobermann, D. Walters, F. Legoretta, T. Arkebauer, K. Cassman, R. Drijber, J. Lindquist, J. Specht, and H. Yang

Unlocking The Secrets of Carbon/Nitrogen Cycling

Corn yields and N-use efficiency highest in intensive corn/soybean systems.

Summary: *In intensive continuous corn (CC) systems, incorporation of large amounts of residue carbon (C) and nitrogen (N) has led to a significant buildup of soil organic matter over a few years, which most likely has contributed to the increased N-use efficiency (NUE) observed. Although corn yields and NUE were highest in the intensive corn/soybean (CS) system, this excellent performance was achieved at the cost of exploiting soil C and N reserves. Large grain N removal, less residue input, and rapid cycling of soybean residue through young organic matter fractions were observed in the CS rotation. The N-credit attributed to CS rotations appears to be due to "mining" of soil N reserves. In contrast, in systems that accumulate soil organic matter (SOM), credit should be given to the efficiency of added fertilizer N in augmenting soil N sequestration.*

The University of Nebraska research program on Ecological intensification of irrigated maize-based cropping systems was established in 1999 to 1) improve understanding of the yield potential of corn and soybeans and how it is affected by climate and management, 2) develop approaches for managing CC and CS rotations at 80 to 95 percent of yield potential, 3) conduct integrated assessment of productivity, profitability, input-use efficiency, energy balance, and environmental consequences of intensified cropping systems, and 4) develop a scientific basis and decision tools for extrapolation at other locations. The project has resulted in 1) a new physiologybased corn growth model and its user-friendly software, 2) new information on radiation-use efficiency in high-yield corn, 3) understanding of regional variation in corn yield potential, 4) new information on NUE, C and N cycling, greenhouse gas emissions in CC and CS systems, and 5) detailed data on soybean phenology and yield response to management and climate.

New developments

We have previously reported how differences in residue input and changes in SOM over time may affect yield performance and NUE. Since then, we have expanded our data collection and analysis, leading to somewhat different conclusions from those previously reported. Table 1 summarizes key results for four contrasting treatments that represent recommended and intensive crop management systems.

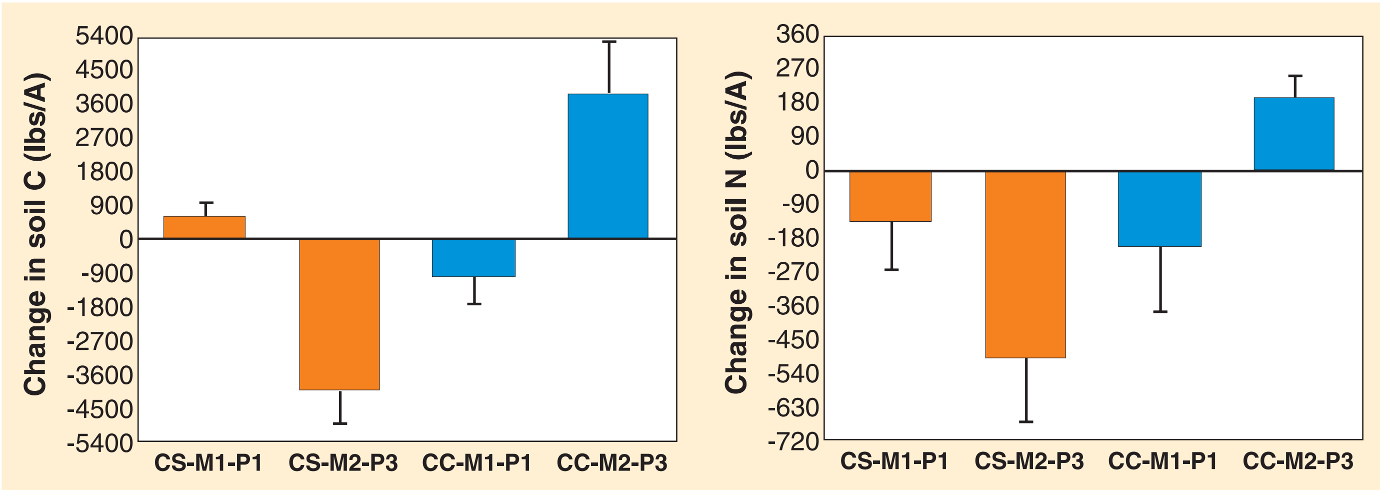
In a period that included four years (2 complete CS cycles), the cumulative crop residue C input amounted to 17,410 lbs C/A (or 8.7 tons/A) in the CS-P1-M1 treatment, which serves as our reference because it represents a recommended best management practice. Compared to this, residue C input increased by 5 percent in CS-P3-M2, but by 11 percent and 35 percent in CC with recommended (CC-P1-M1) or intensive management (CC-P3-M2), respectively. In contrast, N recycled in crop residues was highest in the CS rotation (Table 1).

Increased C inputs to soil can only build SOM if losses of CO_2-C from soil respiration are not elevated and N is available for humification processes. Monitoring of soil CO_2-C respiration has shown no significant differences between recommended and intensified management systems within each rotation, but generally has shown larger

4-Year C and N budget 2000 to 2003/4	Recommended P1-M1		Intensive P3-M2	
	CS	CC	CS	CC
Corn yield — bu/A	241	223	261	251
C recycled with residues[1]—lbs C/A	17,411	19,286	18,304	23,571
Annual soil CO_2 flux, corn—lbs C/A	4,634	5,973	4,598	5,813
Change in soil C, 0 to 1 foot—lbs C/A	620	-980	-3,990	3,890
N recycled with residues[1]—lbs N/A	469	272	500	420
Fertilizer N input—lbs N/A	246	696	638	1,088
N removal with grain—lbs N/A	861	601	900	709
Fertlilzer N—grain N removal—lbs N/A	-615	95	-263	381
Change in soil N, 0 to 1 foot—lbs N/A	-134	-205	-500	196

1 Aboveground corn and soybean residue

Table 1. Components of the C and N budget under recommended and intensive management practices in CC and CS rotation



soil respiration losses in corn following corn than in corn following soybeans (Table l). The latter difference is primarily due to significantly greater residue amounts remaining after corn than after soybeans. However, within each rotation, increases in soil C and N should result from greater biomass production. Because of the large residue C input, the CCP3-M2 system is likely to have the greatest potential for building up SOM. Other important C budget components include C recycling from roots and CO_2 respiration losses under soybeans and we will quantify those in the future.

Unlike the carbon budget, a partial N budget analysis suggests that N removal in CS systems exceeded that of the CC systems by far (Table 1). Depending on yet to be quantified N contributions from N_2 fixation and roots, as well as gaseous and leaching losses of N, changes in soil N may range from depletion to accumulation in these systems.

Increase in NUE

Figure 1 and Table 1 show the change in both soil C and N from June 2002 to June 2004. In the recommended CS system (P1-M1), corn yields were high (241 bu/A, Table 1) and soil C remained virtually unchanged, but a small loss of 134 lbs/A of N occurred over the four yearperiod. However, significant losses of both soil C (-3,990 lbs/ A) and soil N (-500 lbs/A) were measured in the intensive CS system (P3-M2), which also had the highest average yields (261 bu/A). In the recommended CC system (P1-M1), corn yields were lowest (223 bu/A, Table 1) and losses of both soil C and N were observed.

In contrast, the intensive CC system (P3-M2) was the only one with a significant accumulation of both soil C (+3,890 lbs/A) and N (+196 lbs/A) over time. Stabilization of soil N in this system has probably resulted in increased indigenous soil N supply and better congruence of N supply with crop N demand during the growing season. This has probably been a major factor in the increase in NUE we have observed over the last five years in this treatment.

Quantifying changes

The results shown in Figure 1 differ from our previous reports. One more year of data was included in Figure 1, but the major reason for the revised conclusions was that we have used an improved method for quantifying changes in soil C and N over time. Soil C and N stocks were measured based on a fixed amount of dry soil sampled in each year, which better accounts for annual fluctuations in bulk density and moisture. This method provides more accurate estimates than methods that express C and N on a constant soil volume basis. In our example, volume-based estimates suggested an increase in soil C in CC-P3-M2 that was nearly twice as much as the actual increase calculated on constant soil mass basis. Similarly, the soil-mass calculation showed a large decline in soil C in CS-P3-M2 (-4,000 lbs/ A), but the volume-based estimate suggested a loss of only –800lbs/A.

Qualitative differences

More detailed studies were conducted to better understand qualitative differences in SOM in the different CS and CC systems. In particular, we were interested in finding more evidence and reasons for the decline in SOM under intensive CS management as opposed to the large buildup of SOM under intensive CC. C signatures were measured in archived soil samples (1999 to 2003) for both bulk soil and different organic matter fractions, including a mobile humic acid fraction (MHA). The MHA fraction is of particular interest for C and N cycling because it is a young pool (<10 years) of SOM with a faster turnover time. MHA is much involved in N mineralization, but probably also the precursor to more stable humus. It is less recalcitrant than other humic acids due to a lower degree of complexation with cations, has higher N (+ or – 5%) and lower C (+ or – 50%) contents than more humified material.

Drs. Dobermann, Walters, Leogretta, Arkebauer, Cassman, Drijber, Lindquist, Specht, and Yang are research scientists in the Department of Agronomy and Horticulture, University of Nebraska. ❑