Rotation and Nitrogen Fertilization Effects on Changes in Soil Carbon and Nitrogen

By G.E. Varvel

A long-term study comparing several different cropping systems showed soil carbon (C) levels were increased at rates up to 170 lb/A/yr in selected cropping systems at high nitrogen (N) fertilizer rates with conventional tillage.

LONG-TERM EFFECTS of management practices on soil properties provide information necessary to evaluate sustainability of cropping and tillage systems and their effects on the environment. Since soils can serve as both a source and a sink for atmospheric carbon dioxide (CO_2), soil and crop management can affect global balance of this greenhouse gas. Recent estimates indicate that for U.S. agriculture the current mix of tillage practices used in 1990 produced an emission rate of 8.8 million tons of CO_2 each year from soil organic C.

Reduced tillage, an obvious alternative, has been shown to reduce the rate of organic matter degradation. Research at several locations, especially in no-tillage systems, has shown increases in organic matter content as greater amounts of residue associated with increased yields are returned to the soil. Nitrogen fertilizer has also increased organic matter content, but mostly in monoculture systems.

Determination of long-term effects of cropping systems on soil properties, such as organic soil C and N levels, is necessary so accurate projections can be made regarding the sequestering and emission of CO_2 by agricultural soils. Our objective was to evaluate the effects of crop rotation and N fertilizer management on changes in total soil C and N concentrations that occurred during eight years in a long-term study in the western Corn Belt.

Long-Term Nebraska Study

A study, comprised of seven cropping systems (three monoculture, two 2-year, and two 4-year rotations) with three rates of N fertilizer, was conducted on a Sharpsburg silty clay loam near Mead, NE. Monocultures compared included continuous corn, continuous soybean, and continuous grain sorghum. The 2-year rotations in the study were corn-soybean and grain sorghum-soybean and the two 4-year rotations were corn-oat+clover-grain sorghum-soybean and corn-soybean-grain sorghum-oat+clover. Each phase of every rotation occurred every year. Nitrogen rates were 0, 80, or 160 lb/A for corn and grain sorghum and 0, 30, or 60 lb/A for soybean and oat+clover crops. Nitrogen was sidedressed as liquid urea-ammonium nitrate (UAN) solution (32-0-0) the first two years, and was broadcast as granular ammonium nitrate (34-0-0) in succeeding years. Oat+clover plots received broadcast N in May. Nitrogen was applied in early- to mid-June for corn, grain sorghum, and soybean.

Cultural practices were similar to those used by local producers. Previous crop residue from corn or grain sorghum was shredded in late fall with a rotary mower. Clover from the previous oat+clover plots was killed with a tandem disk in mid-April when weather permitted. Spring tillage usually consisted of disking once or twice 4 to 6 inches deep and then harrowing just prior to planting.

Soil samples were taken each spring prior to planting to evaluate the effects of rotations, crops, and N rates at depth

Dr. Varvel is with USDA-ARS, 199 Keim Hall, University of Nebraska, Lincoln, NE 68583.

increments of 0 to 3, 3 to 6, and 6 to 12 inches.

Results

Soil samples at the beginning of the study indicated no differences in total C or N concentrations between cropping system at any depth. Total C concentrations for the entire study in 1984 averaged 1.69 percent at the 0 to 3 inch, 1.47 percent at the 3 to 6 inch, and 1.20 percent at the 6 to 12 inch depths. Similarly, total N concentrations averaged 0.16 percent at the 0 to 3 inch, 0.14 percent at the 3 to 6 inch, and 0.12 percent at the 6 to 12 inch depths.

After eight years, rotations and N rates affected total soil C and N concentrations in the surface 0 to 3 inch depth. Total soil C and N concentrations (0 to 3 inch depth) for 1992 averaged 1.72 and 0.16 percent for continuous corn, 1.66 and 0.17 percent for continuous soybean, 1.76 and 0.17 percent for continuous grain sorghum, 1.63 and 0.16 percent in two-year rotations and 1.77 and 0.16 percent in four-year rotations, respectively.

Nitrogen fertilizer rate also affected total soil C and N concentrations during the first eight years. Total soil C concentrations (0 to 3 inch depth) for 1992 averaged 1.69, 1.73, and 1.77 percent and soil N concentrations averaged 0.16, 0.17, and 0.17 percent for 0, low, and high fertilizer N rates, respectively.

The cumulative amount of C and N sequestered or lost over the eight-year period in each of the cropping systems for the 0 to 6 inch depth is shown in **Table 1**. In actuality, most of the significant differences in total soil C and N concentrations occurred in the 0 to 3 inch depth, but because tillage is occurring on an annual basis to a greater depth than that, the total amount of C and N sequestered or lost to a depth of 6 inches is presented.

Summary

The results from this study indicate that selection of cropping system and the level of N fertilization can greatly affect CO_2 emissions and sequestration, even to a much greater extent than recently proposed. A study from the Council for Agricultural Science and Technology (CAST Report 119, 1992) calculated that soil C levels would be increased 890 to 2,670 lb/A in the next 40 years if high yielding varieties, N and phosphorus (P) fertilizers, no straw removal, and minimum tillage practices were adapted autonomously. In this study, soil C levels were increased at rates up to 170 lb/A/yr in selected cropping systems at high N fertilizer rates with conventional tillage systems. It appears that it is not only the amount of crop residue being returned to the soil that is important, but the amount and type of crop residue. Greater storage of C in soils with these practices suggests CO_2 emissions from agricultural soils could be decreased and may in the long term have a significant effect on CO_2 in the atmosphere under current climate conditions. ■

Table 1. Effects of crop rotations and N fertilization on total soil C and N sequestered in an 8-year period.

	N fertilizer rate		
Rotation[1]	0	Low	High
	---- C sequestered, lb/A (0-6 inches) -----		
CC	-477	166	1213
CSB	-764	-181	-324
CSG	231	1175	1374
C-SB	-252	-166	-62
SG-SB	298	203	796
C-OCL-SG-SB	777	575	1268
C-SB-SG-OCL	405	904	1126
	---- N sequestered, lb/A (0-6 inches) ----		
CC	13	99	169
CSB	-50	-4	-13
CSG	-17	76	104
C-SB	15	49	51
SG-SB	66	63	111
C-OCL-SG-SB	102	101	158
C-SB-SG-OCL	10	59	88

[1] CC = Continuous corn, CSB = Continuous soybean, CSG = Continuous grain sorghum, C-SB = Corn-soybean, SG-SB = Grain sorghum-soybean, C-OCL-SG-SB = Corn-oat+clover-grain sorghum-soybean, C-SB-SG-OCL = Corn-soybean-grain sorghum-oat+clover.