ILLINOIS

Annual Carbon Fluxes from No-Till Corn and Soybeans

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Continuous carbon dioxide (CO_2) and water flux monitoring from an 80-acre no-till field near Champaign, Illinois, was begun in August 1996. The field was in soybeans in 1996 and 1998 and corn in 1997. The objective of the continuous monitoring is to understand the annual water and C cycle for a typical Midwest no-till agriculture ecosystem.

High yield agriculture makes sense from the perspective of efficiently using natural resources to produce needed food and fiber. This research explores another benefit of high yield no-till agriculture – carbon (C) sequestration.

These measurements represent the only long term, continuous monitoring of CO_2 on a no-till corn and soybean ecosystem and provide valuable information regarding the role agriculture may play in sequestering CO_2. From an agricultural standpoint, a better understanding of the C cycle and of canopy CO_2 and water fluxes during the growing season will improve our knowledge of how weather impacts crop growth and yield under different management practices.

The role of agriculture in sequestering CO_2 is an important issue in the climate change debate and the subject of ongoing research. It is important to note that in the strictest sense, sequestering of CO_2 by agricultural ecosystems refers to organic C in the soil. The measurements reported here use a broader definition which includes soil organic C and C contained by the residue left on the surface. The C in the surface residue represents short-term C fixation but serves as a pool for the longer term CO_2 sequestering in the soil organic matter.

Measurements of atmospheric CO_2 and water vapor concentrations are obtained using an open-path infrared gas analyzer. The CO_2 and water vapor fluxes are computed from these measurements and wind data obtained from a 3-dimensional sonic anemometer. By convention, a negative CO_2 flux means the atmosphere is losing CO_2 while the ecosystem is gaining CO_2. Conversely, a positive CO_2 flux means the atmosphere is gaining CO_2 and the ecosystem is losing CO_2. Other continuous measurements taken at the site include air temperature, relative humidity, soil temperature, soil moisture, precipitation, barometric pressure, incoming global radiation, net radiation, incoming photosynthetically active radiation (PAR), and outgoing PAR. The flux station and weather instruments are located approximately 300 yards from the west, 300 yards from the south, and 100 yards from the north edges of the field. During the 1998 growing season, the leaf area index of the canopy

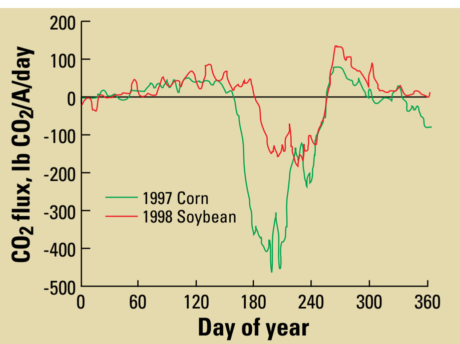

Figure 1. Carbon dioxide flux from a no-till corn (1997) and soybean (1998) field. A negative CO_2 flux indicates a gain of CO_2 by the ecosystem.

was measured weekly, and plants were destructively sampled to monitor above-ground plant biomass. Plant growth analysis will be continued in future years to study the effects of short-term weather events on crop growth and yields.

Data from two full growing seasons, one with corn (1997) and the other with soybean (1998), allow a preliminary comparison of the CO_2 cycles over a no-till ecosystem (**Figure 1**). Two major differences were observed between the two crops and the two years. The corn crop in 1997 reached a state of net fixation of CO_2 by the ecosystem (fluxes going negative) by June 8 (day 159). In 1998, when soybeans were in the field, net fixation of CO_2 did not occur until July 2 (day 183). The maximum ecosystem fixation rates were also different. Corn had a maximum fixation rate of 570 lb/A/day and soybeans 240 lb/A/day. The maximum soybean fixation rate was 42 percent of the maximum corn fixation rate. The maximum rate of ecosystem CO_2 loss, when crops were not growing, was greater for soybean (178 lb/A/day) than for corn (106 lb/A/day). The maximum CO_2 fixation rates observed are only slightly greater than the maximums computed in the mid-1960s for corn and soybeans. Average daily CO_2 fixation rates were also close to those reported in the literature.

In 1997 there was a net fixation of 9.2 tons/A of CO_2 from the time the crop was planted on April 18 until the crop was harvested on October 19. Of this C, approximately 3.1 tons/A were removed through the harvest of the grain. This represents a grain yield of 143 bu/A. A net of 6.1 tons/A was left on the land. The C left in the ecosystem represents the crop residue on the surface and old roots in the soil. The soybean ecosystem had a net CO_2 fixation of 2.3 tons/A from planting (June 1) to harvest (October 10) in 1998. The CO_2 removed in the grain was approximately 1.2 tons/A which represents a yield of 46.5 bu/A. Estimates of the CO_2 removed with the grain are arrived at by assuming that CO_2 comprises 92 percent of the corn and soybean grain. After the grain was removed from the field at harvest, an estimated 1.1 tons/A were left in the field in the form of surface residue and old roots.

The amount of C fixed by corn in 1997 might have been greater if a 20-day dry period had not occurred in late July (**Figure 2**). The decrease in the rate of CO_2 fixation from July 29 (day 210) to August 23 (day 235) was due to drought stress and cloudiness. Even though the canopy did not appear stressed, there was a reduction in the CO_2 fixation efficiency that began approximately 6 days after the last rain.

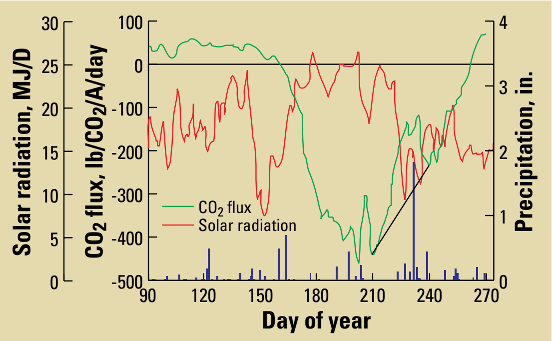

Figure 2. Carbon dioxide flux response of a no-till corn canopy in 1997 to solar radiation and rainfall. A negative CO_2 flux indicates a gain of CO_2 by the ecosystem.

TABLE 1. Seasonal net CO_2 exchange from a no-till field with corn in 1997 and soybeans in 1998.

Crop	Period	Net CO_2 exchange, tons	Evapotranspiration, in.	Precipitation, in.	Grain CO_2, tons
Soybean	Oct 20 1996 - Apr 18 1997	-1.56	5.05	6.42	–
Corn	Apr 18 1997 - Oct 19 1997	9.20	14.45	9.01	-3.13
Corn	Oct 20 1997 - Jun 1 1998	-1.58	8.33	10.67	–
Soybean	Jun 2 1998 - Oct 19 1998	2.22	14.46	7.59	-1.16
Soybean	Oct 20 1998 - Mar 31 1999	-1.15	3.95	5.06	–
Total	**Oct 20 1996 - Mar 31 1999**	**7.13**	**46.24**	**38.75**	**-4.29**

A negative CO_2 value indicates a C loss by the ecosystem.

Carbon dioxide fixation efficiency can be defined as the pounds of CO_2 fixed per acre per day divided by the solar radiation in megajoules (MJ) per day. In this case, CO_2 fixation efficiency was reduced by 40 percent. After the stress was reversed on day 220, CO_2 fixation rate never recovered to the pre-stress condition. Total CO_2 fixation was reduced by an estimated 0.25 tons/A. Because the crop was in the grain fill period, the yield loss during this period was approximately 8.8 bu/A, assuming that all the CO_2 fixed would have been stored in the grain and removed at harvest. The total yield loss due to the reduced CO_2 fixation efficiency was 5.7 bu/A, approximately 3 bu/A during the period from day 210 to day 220 and the rest from day 221 to day 235. An additional 3.1 bu/A was lost due to reduced solar radiation associated with the cloudiness during the rainy period from day 221 to day 235.

From October 20, 1996 to the end of March 1999, there was a net CO_2 gain of 2.84 tons/A. The average annual CO_2 gain for the ecosystem in a no-till corn and soybean rotation was 2.20 tons A/year. This compares to an estimated annual net fixation by a hardwood forest of 4.5 to 7.3 tons/A/year.

There was a net CO_2 gain of 4.49 tons/A to the ecosystem (**Table 1**) when the field was planted to corn in April 1997 and before the soybeans were planted in June 1998 and a net CO_2 loss of 0.09 tons/A from the field between the time soybeans were planted on June 1, 1998 and the end of March 1999. These totals also account for the CO_2 removed from the fields in grain. The difference between the two years was due mainly to the differences in the crop photosynthetic capacity and the residue left on the surface. Weather can also account for some of the differences. However, the weather effects in these data are masked by the large crop differences. To fully separate the effects of weather from the crop effects, simultaneous measurements need to be taken in corn and soybean fields. The soybean ecosystem experienced a greater loss of CO_2 due to the decomposition of the corn residue during the spring and summer and a large loss of CO_2 during the fall after the soybean crop was harvested. This large CO_2 loss (**Figure 1**) occurred after the soil and soybean residue were soaked by rain while soil temperatures were still above 50º F. The greater loss of CO_2 from the ecosystem in the spring of 1998 could also be attributed to the higher soil temperatures (**Figure 3**). The spring of 1997 was relatively cool and dry, while the spring of 1998 was warmer and wetter. The microbial activity necessary to decompose the surface residue is greater when conditions are wet and warm. Thus, the surface residue decomposes more rapidly.

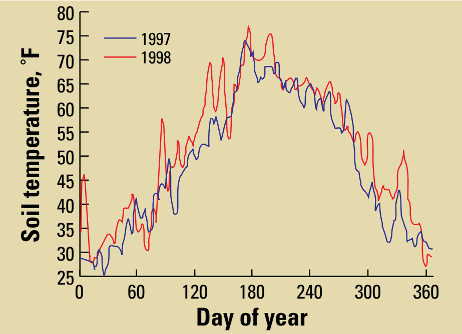

Figure 3. Annual soil temperature cycle at 3 inches during 1997 and 1998.

These CO_2 measurements show the potential for considerable short-term CO_2 sequestering by a no-till ecosystem in the Midwest. Additional monitoring of corn and soybeans over a no-till system during the same year is needed to determine the true contribution of no-till agriculture to CO_2 sequestering and the differences between the two crops. Earlier research showed that soil organic matter is decreased with conventional tillage practices. The degree to which this is true can also be investigated using the same instruments employed in this study. BC

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