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Carbon and nitrogen cycling with corn biomass harvest

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Abstract
Increasing demand to use corn plant biomass for producing energy and other products has spurred interest in harvesting corn stover. What is the effect on soil carbon (C) and nitrogen (N) with stover removal? While C is an essential plant nutrient, C fertilization is not practiced as C is supplied to crops via photosynthesis from carbon dioxide (CO_2) in air. However, with current issues about greenhouse gases, increased awareness of the importance of soil C sequestration, and efforts to reduce soil erosion, concerns have focused on the impact of corn stover removal.

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Carbon and nitrogen cycling with corn biomass harvest

by John Sawyer and Antonio Mallarino, Department of Agronomy

Increasing demand to use corn plant biomass for producing energy and other products has spurred interest in harvesting corn stover. What is the effect on soil carbon (C) and nitrogen (N) with stover removal?

While C is an essential plant nutrient, C fertilization is not practiced as C is supplied to crops via photosynthesis from carbon dioxide (CO_2) in air. However, with current issues about greenhouse gases, increased awareness of the importance of soil C sequestration, and efforts to reduce soil erosion, concerns have focused on the impact of corn stover removal. Corn stover harvest removes C that potentially could be recycled and incorporated into soil organic matter pools. However, the large processing of crop residue by soil microbes with associated large C loss as CO_2 is not widely recognized. Table 1 gives an estimation of corn stover C remaining and lost from soil over time with two corn production levels and with and without 70 percent stover harvest. In the first year, the estimate is 67 percent of stover C lost as CO_2 from microbial processing, 80 percent lost after four years, and 85 percent lost after eight years. The rate of C processing and loss declines over time as the organic material becomes harder for microbes to degrade and the material becomes more like soil organic matter or humus. Considering the amount of C in corn stover in relation to total plant C, the large amount of C recycled to the soil in corn roots is often overlooked.

While the effect of stover harvest on the amount of C remaining in soil is not large on the short term, it will affect soil organic matter over a long time period. The impact on other soil properties can be important and immediate. These include soil cover (protection from raindrop impact and erosion control), soil microbial processing that produces materials that help "glue" soil particles together (improving soil aggregation and stability, bulk density, and root growth), total soil N, and nutrient cycling.

The majority of N contained in soils is in soil organic materials, and with high soil organic matter levels, the total N is quite large. Removing corn stover not only reduces C return to soil but also N. While the amount of N in the non-grain portion of the corn plant is not the largest component of total plant N (including roots), the reduction in N return to soil due to stover removal will have a long-term effect on soil organic matter and total N (soil organic matter has a relatively constant 10:1 C:N ratio). Fertilizing corn with N offsets this impact

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due to less than 100 percent fertilizer N use efficiency (plant uptake is typically less than 50 percent of applied N), which leaves N in the soil for residue degradation and soil processing. Therefore, the short-term effect of stover removal on soil N and N fertilization requirements will be minimal and could even lead to more crop-available N due to lower microbial N requirements to degrade high C containing residue not returned to the soil. Measurement of soil N in long-term N rate studies has shown that total soil N is reduced when no N is applied but only a small change at low rates of N. Furthermore, long-term research at the Northeast Research and Demonstration Farm (Nashua, IA) is showing no clear difference in N fertilization requirement of continuous corn harvested for grain or for silage. Data in Table 2 summarize results for the last four years of the study and indicate a lack of difference even after more than 24 years of N application and harvest. Soil nitrate concentrations in the same recent time period (one-foot samples collected in late spring) for the fertilized treatments were slightly higher (5 ppm higher on average) in the corn silage harvest than grain harvest system. However, soil organic matter was slightly lower with silage harvest (3.55 percent compared to 3.80 percent in the top 6 inches of soil). This indicates that increased N removal from fields with stover harvest will not have large immediate effects on total soil N but can on the very long term.

Table 1. Corn stover carbon remaining in soil over time and with stover harvesting at 70 percent.

	240 bu/acre Grain Crop (5.3 ton/acre Stover)		**178 bu/acre Grain Crop (3.3 ton/acre Stover)**	
Time Period	No Stover Harvest	70% Stover Harvested	No Stover Harvest	70% Stover Harvested
	- - - - - - - - - - - - - - lb carbon (C)/acre - - - - - - - - - - - - - -			
Starting corn stover	4,240	1,270	2,600	780
Remaining after 1 year	1,400	420	860	260
Remaining after 4 years	850	250	520	160
Remaining after 8 years	640	190	390	120
Total lost from soil	3,600	4,050	2,210	2,480

Assume stover contains 40 percent C.

Assume 33 percent of stover C remains after one year, 20 percent of original stover C remains after four years, 15 percent of original stover C remains after eight years.

Corn grain at 15.5 percent moisture. Corn stover (including cob) dry matter basis.

Corn stover data from 2006 Lewis and Ames sites at 120 lb N/acre N rate.

Carbon loss/remaining estimates from *Cycles of Soil, 1986, and Humus Chemistry*, 2nd edition, 1994, by F. J. Stevenson.

Table 2. Effect of yearly grain or silage harvest on response to applied N with continuous corn.

	Component Harvested	
N rate	**Grain**	**Silage**
lb N/acre	**bu/acre**	**ton/acre**
0	56	4.3

80	119	7.9
160	161	8.8
240	166	9.6

Northeast Research Farm rotation study, 2003-2006 average after 24 years of N application and harvest. Grain yield at 15% moisture basis and silage on dry matter basis.

John Sawyer is an associate professor of agronomy and Antonio Mallarino is a professor of agronomy, both with research and extension responsibilities in soil fertility and nutrient management.

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