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How residue removal affects nutrient cycling

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Abstract
Leaving crop residue on the soil surface will improve nutrient cycling and, ultimately, soil quality that will increase and sustain soil productivity. Through conservation practices that include balanced residue management and soil fertility, environmental quality can be substantially enhanced. By retaining crop residue on the soil surface, soil organic carbon (SOC) and nutrient-holding capacity are increased while protecting the soil from wind and water erosion. The recent wet conditions in the state demonstrate the value of leaving crop residue on the soil surface to reduce surface runoff, sediment loss, and associated nutrient losses. On the contrary, alternative uses of corn residues for various purposes, such as baling residue for animal use or for ethanol production from lignocellulosic biomass, potentially have adverse effects on soil and water quality.

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How residue removal affects nutrient cycling

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Leaving crop residue on the soil surface will improve nutrient cycling and, ultimately, soil quality that will increase and sustain soil productivity. Through conservation practices that include balanced residue management and soil fertility, environmental quality can be substantially enhanced. By retaining crop residue on the soil surface, soil organic carbon (SOC) and nutrient-holding capacity are increased while protecting the soil from wind and water erosion. The recent wet conditions in the state demonstrate the value of leaving crop residue on the soil surface to reduce surface runoff, sediment loss, and associated nutrient losses. On the contrary, alternative uses of corn residues for various purposes, such as baling residue for animal use or for ethanol production from lignocellulosic biomass, potentially have adverse effects on soil and water quality.

The reduced nutrient supply associated with corn stover removal represents an economic loss in the short term, but it will have a long-term negative effect on soil quality, water quality, and agriculture sustainability. The loss of nutrients from stover removal depends on residue type, amount of residue, soil type, climate, soil organic matter, rate of residue decomposition, tillage, and other management practices. If unsustainable amounts of stover are removed from the field, wind and water soil erosion will intensify while accelerating the loss of SOC and other nutrient levels and potentially can reduce future yields. Residue removal in Iowa may have a small effect on soil productivity in the short term due to rich organic matter soils; however, this will not be a sustainable practice in the long term as demonstrated by many studies where the acceleration of soil and nutrient losses were significant. In a normal rainfall, raindrops 6 millimeters in diameter hit the ground at 20 miles per hour. The cumulative impact of raindrops can be incredible, dislodging soil particles and "splashing" them up to 3-5 feet away. The splashed particles clog soil pores, effectively sealing off the soil surface and leading to soil crust and poor water infiltration.

Instead of soaking into the soil, water collects and moves down-slope in sheet or rill erosion, forming gullies and carrying soil particles to rivers and streams.

Potential corn stover nutrient removal based on different harvest scenarios is summarized in Table 1. Possible short-term impacts can include additional nitrogen (N), phosphorus (P), and potassium (K) fertilization to replace harvested stover nutrients lost and nutrient deficiencies in the long term. Removing residue at a low cut (4-inch) stubble would leave a small amount of residue on the soil surface, leading to an increased nutrient loss, higher replacement costs, and an increased risk of soil erosion. These nutrient losses represent the potential amount of nutrients that would be released to the soil from crop residue. However, the additional nutrients lost are those from the soil due to soil erosion, which is well documented and represent a long-term impact of residue removal on the soil nutrient pool and nutrient cycling (Table 2). The additional nutrient inputs to compensate for the lost nutrients with the removed residue are only a small measure to sustain soil productivity in the short term.

Long-term effects of removing high levels of corn residue can lead to net losses of nutrients under standard fertilization practices (Table 2). One study measured water runoff and soil erosion from rainstorm events on continuous corn under two tillage practices of no-tillage and reduced tillage as affected by residue treatments. Results show water runoff and soil erosion increased at higher rates with increased corn residue removal for both no-tillage and reduced-tillage systems (Table 2). Nutrient losses, particularly N and P, due to erosion represent significant amounts as soil erosion levels approached the soil loss tolerance level of 5.0 ton/acre. Regardless of tillage system, residue removal increased surface runoff and nutrient loss due to soil erosion. Even with no-tillage or reduced tillage, lack of residue cover has led to significant nutrient losses with higher concentrations of nutrients at the soil surface. It also was reported that one long-term effect of corn residue removal, especially with a no-tillage system, is the increase in K deficiency over time because of exposure of high K soil surface concentration to soil erosion. In general, the impact that residue removal has on nutrient cycling is highly affected by the amount of residue removed, which ultimately leads to higher nutrient cost input in the short term and reduction in soil quality and productivity in the long term. In addition to the amount of residue left on the soil surface, the manner in which residue is harvested and the uniformity of residue distribution on the soil surface to prevent potential soil erosion must be considered.

Table 1. Nutrient removal associated with four corn stover harvest scenarios in Iowa (Hoskinson et al., 2006).

	N	P	K	Nutrient Replacement Cost**
Residue Harvest Scenario*	**lbs per acre**			**$ per acre**
High cut top (30" stubble)	30.69	3.39	30.51	13.11
High cut bottom (4" stubble)	12.31	0.89	29.88	7.57
Low cut (4" stubble)	42.02	3.65	38.89	17.41
Normal cut (15" stubble)	37.47	3.56	30.60	15.02

* high cut top was just below ear; high cut bottom, two passes were made, once just below ear and second at low cut level so that only the stalk between 4 inches above ground and just below the ear was harvested; the low cut treatment removed all stover, leaving approximately 4 inches of stubble above the ground; normal cut was midway between base of ear and 15 inches above ground.

** fertilizer prices used to calculate were anhydrous at $550/ton, $330/ton for diammonium phosphate (DAP), and $270/ton for muriate of potash (MOP) in Iowa.

Table 2. Nutrient removed by grain harvest, stover harvest, runoff, and soil erosion during 1981 in loam soil (Morris, MN) and 1984 in silty clay loam (Madison, SD) growing seasons (Lindstorm, 1986).

	Nutrient Removal (lbs per acre)		
	Nitrogen	**Phosphorus**	**Potassium**

Tillage and Residue Treatement	Grain Harvest	Stover Harvest	Runoff	Soil Erosion	Total	Grain Harvest	Stover Harvest		Soil Erosion	Total	Grain Harvest	Stover Harvest		Soil Erosion	Total
1981															
Conventional	95	0	1	23	119	17	0	<1	5	23	24	0	<1	1	25
Reduced 0.5 Y	95	49	2	41	187	17	8	<1	9	35	24	60	<1	2	87
Reduced Y	95	38	1	24	158	17	6	<1	5	29	24	46	<1	1	72
Reduced 2 Y	95	16	1	8	120	17	3	<1	2	23	24	20	<1	<1	46
1984															
Conventional	107	0	7	57	171	18	0	1	21	30	26	0	2	7	35
No-till 0.5 Y	107	61	10	114	292	18	9	5	42	74	26	79	22	23	150
No-till Y	107	54	6	30	197	18	8	3	12	41	26	71	13	6	116
No-till 2 Y	107	38	4	17	166	18	5	3	6	32	26	50	16	4	96

*Y = 2,000 lb/acre in 1981 and 1,500 lb/acre in 1984, to keep soil erosion at the standard T-value of 5.0 ton/acre/year or below. Conventional treatment was added as a control and corn stover was *not harvested.

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