UNIVERSITY OF MINNESOTA

Considerations for Corn Residue Harvest in Minnesota

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Introduction

In most fields, corn residue is incorporated into the soil with tillage or is left on the soil surface, but some livestock producers are harvesting corn residue for use as feed and bedding. There is also interest in using corn residue for biofuel production in order to reduce U.S. reliance on fossil fuels. However, soil organic carbon and ultimately soil productivity will be reduced if all of the corn residue in a field is regularly harvested and other sources of carbon are not returned to the soil.

Soil Organic Matter

Soil organic matter is composed of about 50% carbon. As a result, the terms soil organic carbon and soil organic matter are often used interchangeably, but scientists prefer soil organic carbon because it can be measured with more accuracy. Soil organic matter represents decaying plant and animal residues, microscopic soil organisms that decompose plant and animal residues, and substances that are released by these organisms into the soil.

For producers, soil organic matter is synonymous with soil productivity, since:

- It is a source of nutrients that will be slowly released over time
- It promotes aggregation of soil particles, which:
    - Improves the water holding capacity of the soil
    - Improves the rate of water infiltration
    - Decreases the potential for erosion
    - Increases the rooting ability of plants
    - Lowers the bulk density of the soil
    - Allows the soil to be tilled with less horsepower

Sustainable Harvest of Corn Residue

The amount of corn residue that can be sustainably harvested in the absence of supplemental carbon (manure, sewage sludge, perennials, or cover crops) depends on the crop rotation and tillage system. On average, the amount of corn residue that needs to be retained to maintain soil organic carbon and protect against water and wind erosion in the Corn Belt is shown in Table 1. It should be noted, however, that the amount of corn residue needed to protect against soil erosion is less than the amount needed to maintain soil organic carbon levels.

Table 1. *Maximum amount of corn residue that can be harvested while maintaining soil organic carbon levels and protecting against water and wind erosion for various crop rotations, tillage systems, and yield levels. Derived from Johnson et al. (2006).*

		Continuous corn		Corn-soybean rotation	
Corn grain yield	Corn residue yield	Moldboard plow	Conservation tillage†	Moldboard plow	Conservation tillage
bu/ac‡	bales/ac§	bales/ac that could be harvested§¶			
125	4.4	0.0	0.5	0.0	0.0
150	5.3	0.0	1.3	0.0	0.0
175	6.2	0.4	2.2	0.0	0.2
200	7.0	1.3	3.1	0.0	1.1
225	7.9	2.2	4.0	0.0	2.0
250	8.8	3.0	4.8	0.0	2.8

† A tillage system with at least 30% surface residue coverage after planting.
‡ Grain yield reported at 15.5% moisture.
§ Assuming dry residue and 1,200 lb round bales.
¶ Assuming no organic inputs such as manure to the soil.

Tillage

Tillage affects the quantity of residue that can be harvested. With more aggressive tillage, there is greater residue incorporation and increased aeration, which promotes decomposition of crop residues and soil organic matter by soil microorganisms. With decomposition, carbon in crop residues and soil organic matter is released into the atmosphere as carbon dioxide.

The potential for sustainable harvest of crop residues is much greater when a conservation tillage system is used. For example, with conservation tillage in continuous corn, up to 44% of the corn residue could be harvested annually if grain yields are consistently 200 bu/ac (Table 1). In comparison, only 19% of the corn residue could be sustainably harvested with a moldboard plow tillage system in continuous corn.

In continuous corn with moldboard plowing, no residue harvest is recommended when grain yield is 150 bu/ac or less, but three large round bales per acre could be harvested when yields are 250 bu/ac. This is because more residue is produced with higher grain yields. Since yield levels can fluctuate greatly from one year to the next, producers should take this into account, and possibly adjust the quantity of residue harvested from year-to-year.

Crop Rotation

The amount of corn residue that can be harvested is also influenced by crop rotation. This is because a greater quantity of root and shoot residue is produced with continuous corn than with the corn-soybean rotation. In addition, corn residue has a high carbon/nitrogen ratio when compared to soybean residue, making it more resistant to decomposition than soybean residue.

In a corn-soybean rotation, only 16% of corn residue can be harvested with 200 bu/ac yields and conservation tillage, but it would be difficult to uniformly remove such a small amount of residue. The same is true with continuous corn grown under moldboard plow tillage. Instead, residue removal is best suited to continuous corn grown with conservation tillage.

Method of Residue Removal

In continuous corn systems with conservation tillage, 35 to 44% of the residue could be harvested annually if grain yields are 175 to 200 bu/ac. However, harvesting only 36 to 44% of the corn residue can be difficult. Table 2 illustrates the amount of residue removed with different baling methods. If a rake is used to create windrows prior to baling, make sure that the rake is set as high as possible to avoid collecting too much residue, as approximately 65% of the residue is removed when the rake is set at normal operating height (Vagts, 2005). For reference, Figures 1 and 2 show surface residue coverage with removal of none and approximately all of the corn residue in a chisel plow tillage system.

Table 2. *Corn residue removal with various removal techniques and yield levels. Derived from Vagts (2005).*

		Corn residue removed with various removal techniques		
Corn grain yield	Corn residue yield	Bale windrow from combine† (50% removal)	Rake/bale‡ (65% removal)	Chop stalks/ rake/bale (80% removal)
bu/ac§	bales/ac¶		bales/ac¶	
150	5.3	2.7	3.5	4.2
175	6.2	3.1	4.0	4.9
200	7.0	3.5	4.6	5.6

† Turn off spreader on combine to create windrow.
‡ Rake set at normal operating height.
§ Grain yield reported at 15.5% moisture.
¶ Assuming dry residue and 1,200 lb round bales.

Figure 1. *Surface residue coverage after stalk chopping and chisel plowing in a field where no corn residue was harvested.*

Figure 2. *Surface residue coverage after chisel plowing in a field where corn residue was chopped, raked, and baled.*

Cost of Removing Residue

While hybrid, soil fertility, growing conditions, and yield can affect the nutrient value of corn residue, any form of residue removal will result in nutrient removal from the field. Eventually, these nutrients will need to be replaced in order to maintain soil productivity. Corn residue is a source of many nutrients, including nitrogen, phosphorus, potassium, calcium, sulfur, magnesium, copper, manganese, and zinc. When calculating the cost of removing residue, growers should consider the fertilizer costs for replacing the nutrients removed with the residue. The fertilizer replacement costs for phosphorus and potassium are listed in Table 3. While increased fertilization in fields where residue is harvested will help replace some of the nutrients removed in the residue, it will not compensate for the lost carbon. In agricultural fields, soil carbon levels are maintained by returning residue to the soil, rotating crops with pasture or perennials, or by adding organic residues such as animal manure, green manure, or sewage sludge.

Table 3. *Nutrient value of corn stover. Derived from Fixen (2007).*

Nutrient	Quantity of nutrient in corn residue	Cost of fertilizer†	Nutrient value of residue
	lb/bale‡	cost/lb	value/bale‡
P_2O_5	3.5	$0.84	$2.94
K_2O	19.2	$0.74	$14.21

† Fertilizer costs represent an average of quotes from western Minnesota fertilizer dealers on 30 Dec. 2008. Quotes for P_2O_5 and K_2O are based on 11-52-0 and 0-0-60, respectively.
‡ Assuming dry residue and 1,200 lb round bales.

A large round bale of corn residue contains approximately 11 pounds of nitrogen (Fixen, 2007), but this nitrogen would not be readily available to the subsequent crop if the residue had been returned to the soil. Instead, this nitrogen would slowly become available over time as the residue decomposes. Another consideration is that when residue is removed in continuous corn, the nitrogen fertilizer rate for the subsequent corn crop can be reduced, since corn residue promotes tie-up (immobilization) of nitrogen by soil microorganisms. Research at three locations in northern and central Illinois on dark prairie-derived soils in 2006 and 2007 showed that the economically optimum nitrogen fertilizer rate in continuous corn was reduced by 13% when half or all of the corn residue was harvested, and this was consistent for both chisel plow and no-tillage systems (Coulter and Nafziger, 2008).

A major cost of removing corn residue is harvesting and handling. These costs are listed in Table 4, and were estimated by Iowa State University. When calculating the total cost of removing residue, keep all of the expenses in mind. Conservative estimates of the costs associated with nutrient removal and residue harvest add up to $86.31 alone (Table 5). However, don’t forget about long-term costs that are less definable, such as the impact of carbon removal on soil. Soil carbon plays a vital role in maintaining soil productivity.

Table 4. *Average custom rates for harvesting and handling corn residue. Source: Edwards and Smith (2008).*

Service	Average rate of charge
Chopping corn stalks	$9.50/ac
Raking corn residue	$5.65/ac
Baling corn residue (large round bales)	$11.20/bale
Hauling (large round bales)	$0.14/loaded mile/bale
Moving large round bales to storage	$3.10/bale

Table 5. *Estimated cost for harvesting three bales of corn residue per acre using nutrient replacement values and custom rates in Tables 3 and 4.*

Expense	Cost
Baling windrow (large round bales)†	$33.60
3 miles of transport	$1.26
Nutrient replacement	$51.45
Total	**$86.31**

†Assuming windrow left by combine after spreader turned off.

Corn Cob Removal

Corn cobs are quickly becoming recognized as an important feedstock for ethanol and gasification plants. They have more consistent density and moisture than corn residue, and collection of cobs allows the remaining residue to be returned to the soil. In addition, corn cobs are easier to handle with a one-pass grain plus cob harvest. One-pass cob collection requires less equipment, labor, and trips over the field when compared to baling residue. This reduction in field traffic reduces soil compaction. In addition, there is minimal spoilage with outdoor storage of corn cobs.

In a typical field, there is approximately 1,500 pounds of dry corn cobs per acre, representing about 20% of all corn residue. Thus, when compared to harvest of all of the residue, the smaller quantity of material removed from the field when only the cobs are harvested results in less of an impact on long-term soil productivity. This allows cob harvest to be a sustainable practice in more cropping systems than residue harvest. The amount of phosphorus and potassium removed in corn cobs is listed in Table 6.

Table 6. *Nutrient value of corn cobs. Derived from Sawyer and Mallarino (2007).*

Nutrient	Quantity of nutrient in corn cobs	Cost of fertilizer†	Nutrient value of corn cobs
	lb/dry ton	cost/lb	value/dry ton
P_2O_5	1.8	$0.84	$1.51
K_2O	20.4	$0.74	$15.10

† Fertilizer costs represent an average of quotes from western Minnesota fertilizer dealers on 30 Dec. 2008. Quotes for P_2O_5 and K_2O are based on 11-52-0 and 0-0-60, respectively.

‡ Assuming dry residue and 1,200 lb round bales.

Summary

While it is critical to maximize profitability from the land, we need to balance short-term economics with long-term sustainability. When harvesting corn residue, use common sense and consider these guidelines to maintain soil organic matter levels and protect against erosion:

- Target corn residue harvest in fields that will be planted to corn next year
- Rotate residue harvest among fields so that residue is not removed from the same field every year
- Reduce tillage following residue harvest
- To add carbon back to the soil, use manure instead or in addition to commercial fertilizer
- Consider winter cover crops. Roots from winter cover crops are extremely effective at scavenging residual soil nitrate and adding carbon to the soil

References

Coulter, J.A., and Nafziger, E.D. 2008. Continuous corn response to residue management and nitrogen fertilization. Agron. J. 100:1774-1780.

Edwards, W., and D. Smith. 2008. 2008 Iowa farm custom rate survey. File A3-10. Available at http://www.extension.iastate.edu/publications/FM1698.pdf (posted Mar. 2008; verified 30 Dec. 2008). Iowa State Univ., Ames.

Fixen, P.E. 2007. Potential biofuels influence on nutrient use and removal in the U.S. Better Crops 91:12-14. Available at http://www.ipni.net/ppiweb/bcrops.nsf/$webindex/BD81AB2128ECC7D2852572DE005B4364/$file/07-2p12.pdf (verified 30 Dec. 2008).

Johnson, J.M.F., D.C. Reicosky, R.R. Allmeras, D. Archer, and W.W. Wilhelm. 2006. A matter of balance: Conservation and renewable energy. J. Soil and Water Conserv. 61:120A-125A.

Sawyer and Mallarino, 2007. Nutrient removal when harvesting corn stover. p. 251-253. *In*: Integrated crop management. Available at http://www.ipm.iastate.edu/ipm/icm/2007/8-6/nutrients.html (posted 6 Aug. 2007; verified 30 Dec. 2008). Iowa State Univ., Ames.

Vagts, T. 2005. Nutrient content and value of corn stover. Available at http://www.extension.iastate.edu/nwcrops/corn_stover.htm (posted 26 Jan. 2005; verified 30 Dec. 2008). Iowa State Univ., Ames.