Responsible Stover Harvest

The Benefits and Detriments of Corn Stover Harvest.

Since the beginning of cellulosic ethanol research, it was understood that there would be questions about the sustainability of biomass removal from corn fields. To address these questions, several companies and universities has been conducting harvest and storage research to better understand the impact of corn biomass removal.

This guide will address both the advantages and disadvantages of residue removal. It will also demonstrate how biomass removal can be done in a way that doesn't deplete soil organic carbon and manages nutrient removal.

Why Corn Residue?

Corn is the most widely cultivated crop in the U.S. and produces the highest volume of residue per acre of all of the major crops that are raised in the United States. Ethanol production facilities are most common in the middle of corn producing areas in the Midwest where residue is readily available. If cellulosic biorefineries are co-located next to these existing facilities this would allow for lower transportation costs as the biomass is delivered. Furthermore, it has been shown that corn has a harvest index of 0.53 (Johnson et al., 2006) which means that for every dry pound of grain produced there is just under a pound of biomass produced. This relationship indicates that as grain yields increase, so will biomass yields. This increase in tonnage will serve as an opportunity for biomass to be marketed for additional revenue per acre. All of these factors combine to make corn residue a very appealing choice for cellulosic ethanol production, but only if it can be done in a sustainable manner.

Sustainable Biomass Harvesting

While working on cellulosic ethanol technology, POET has researched several different collection methods trying to find approaches that would be sustainable over the long term. When looking for sustainable harvest methods, the main criteria were: minimal nutrient removal, leaving enough residue for erosion control, and maintaining current soil organic material and carbon levels.

The most ideal method, due to the lower dirt contamination levels, fewer passes over the field, and a smaller nutrient impact, was 2^{nd} Pass baling. This method produces bales with less contamination because the material isn't being raked or chopped. And since the raking is avoided, at least one additional pass across the field is eliminated when it is compared to traditional stover baling. By using this method, only 20-25% of the above ground corn residue is collected. At that rate and with a yield of 180 bu/ac, roughly 1 dry ton of residue would be removed. This differs with traditional rake and bale stover removal, which usually removes around 65% of the total residue (DeJong-Hughes and Coulter, 2009). Through research conducted by the USDA and ISU (Karlen and Birrell, 2011), it has been shown that removing 1 to 1.5 dry tons of biomass per acre is a viable as long as corn yields are above 150 bu/ac (DeJong-Hughes and Coulter, 2009) and the area to be harvested has a slope of less than 4%. If an area with a slope of greater than 4% is to be harvested, an agronomist should be consulted to ensure that enough residue will be left to manage erosion and maintain organic matter in the soil. Besides erosion, the main concern with removing too much residue is the depletion of soil organic carbon and overall organic material in the soil. These studies have confirmed that, under conventional tillage practices, there is enough residue produced to remove 1 to 1.5 tons of biomass and still maintain soil organic carbon levels on most fields as long as the yield is at or above 150 bu/ac (Karlen and Birrell, 2011; DeJong-Hughes and Coulter, 2009). However, if it is a concern, this is another topic that could be discussed with an agronomist.

Yield Increases

Harvesting biomass can have beneficial effects to your farming operation. One such example is increased soil temperatures in the spring. By removing some of the residue, more black soil is exposed to sunlight. This soil then warms up faster and creates a better environment for seed germination (Coulter and Nafziger, 2008). This directly relates to the reasons no-till planters are outfitted with row cleaners, to create a better seed bed and allow more sunlight to warm the soil. This is also a benefit of residue removal. It was this same study by Coulter and Nafziger that showed that if partial residue removal is practiced on no-till ground under a corn on corn rotation, yield increases of up to 12.5 bu/acre could be realized. This helps bring no-till yields closer to that of conventional tillage. In research conducted by ISU and the USDA this germination boost has led to yield increases up to 5% when 20-25% of the residue is removed (Karlen and Birrell, 2011), versus ground that had no residue removed (Table 1). The bottom line is that residue removal rates at this level have shown no harm to grain yields; and may help increase them. These warmer soil temperatures may also help to increase soil microbial activity which speeds up the breakdown of the remaining residue from the previous year, as long as enough residue is left to maintain soil moisture levels (Meentemeyer, 1978; Monsanto, 2010). This increase in breakdown speed also helps keep the amount of remaining residue in check. If the residue doesn't breakdown fast enough in corn on corn fields, the cycle of un-broken down materials will lead to a buildup of residue which cools soil temperatures further. This will lead to longer germination times and other agronomic issues that will impact yields as the residue amounts increase.

Table 1: Yield Increases compared to no removal.

Stover Harvest Treatment	3-year average yield	3- Year Avg. Yield Increase
	bu/acre	%
No Removal[1]	163	0.00
First Pass Baling[2]	164	1.00
Second Pass Baling[3]	169	4.00
Rake and Bale Stover[4]	167	2.00

All values may vary by ±2%
1) No residue removal.
2) Square baler attached to combine.
3) Baled windrow behind combine.
4) Field raked into windrow and baled.
(Karlen and Birrell, 2011)

Nitrogen Reduction

While corn residue is important to soil organic matter and erosion control, too much residue can actually lead to nitrogen immobilization (Coulter and Nafziger, 2008; Burgess et al., 2002; DeJong-Hughes and Coulter, 2009). Anytime plant matter lacks sufficient nitrogen to decompose itself, microbes trying to break the residue down will pull nitrogen out of the surrounding soil. This nitrogen will only be available to the crop after the residue is broken down. This is known as nitrogen immobilization and it's what happens when decaying plant matter has a higher carbon to nitrogen ratio then 24:1 (USDA, 2011). In corn on corn rotations where large amounts of residue are continuously deposited back on the soil, this breakdown cycle never ends. This almost non-stop cycle of decomposition ties up nitrogen so it is not available to the plants. It has been reported, that by removing some of the residue, nitrogen applications can be reduced by as much as 13% (Coulter and Nafziger, 2008).

It's also important to remember that collection methods can affect the type and amount of biomass collected. Unlike a rake and bale stover bale, which only contains around 9% cob by weight, a 2nd Pass bale contains about 35% cob by weight. By getting more cobs off the field, which take the longest to break down due to their high carbon to nitrogen ratio (Table 2), the nitrogen cycle can be shortened and the amount of time the nitrogen remains immobilized is reduced which makes it available to the plants faster.

Table 2: Carbon to nitrogen ratios rise as the plant matures.

Carbon to Nitrogen Ratios of Corn Components			
Component	Cobs	Stalks	Leaves/Husks
Carbon: Nitrogen	60-125:1	60-70:1	40-50:1

Reduced Disease Pressure

The amount of residue left on the field has been proven to directly correlate to disease severity in the following crop (Robertson and Munkvold, 2007), especially in corn on corn acres. This is because excessive crop residue creates the perfect cool and moist environment that breeds mold spores. These spores then spread to the crop themselves, either while they're in the ground as a seedling or once they mature by rain splash and wind. This can lead to foliar diseases which spread from the lower canopy to the upper canopy as the growing season progresses. Often times, foliar diseases are followed by stalk rot due to the fact that several stalk rot diseases are caused by stressful conditions due to reduced photosynthesis (Robertson and Munkvold, 2007). These diseases can include anthracnose leaf blight and stalk rot, gray leaf spot (Figure 1) and northern corn leaf blight (Coulter and Nafziger, 2008). All of these diseases can negatively affect both grain yields and stalk strength. By removing some of the residue, there is less material for these diseases to thrive on over the winter and the potential of infecting the following crop can be reduced.

Figure 1: Gray Leaf Spot disease is directly associated with the amount of surface residue. (Robertson and Munkvold, 2007)

Soil Nutrients

Corn residue contains minerals that are important to soil and plant health. The average phosphorous and potassium composition of stover at crop maturity can be found in Table 3. But, using nutrient levels from crop maturity can lead to overestimation of nutrients since the level of nutrients in the plant begins to drop once the plant reaches maturity (Johnson et al., 2010), as can be seen in Table 4. This is especially true for potassium, which dissolves easily in water (Sawyer and Mallarino, 2007). This means that after the corn reaches maturity, each rainfall gives the potassium another opportunity to leach back into the soil. On a year with average rainfall this will lead to a good portion of the potassium leaching into the soil between maturity and harvest. Of course not all potassium will leach back, and other minerals will still remain in the baled residue. Since each field is different, it is still a good idea to perform normal soil testing to understand the nutrient profile and the effect of residue removal.

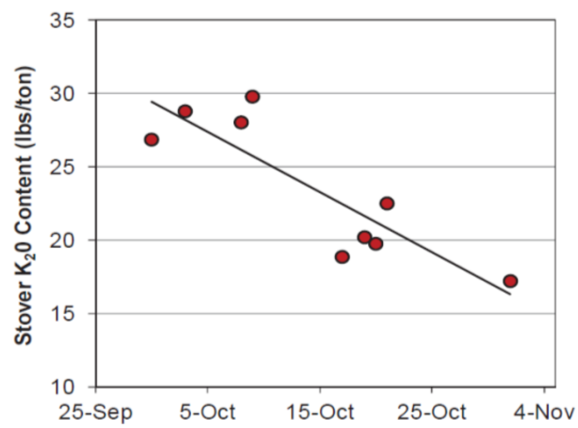
Another factor that affects nutrient removal is what parts of the corn plant are actually being removed. For a second pass bale, the amount of nutrients removed are usually between zero and three pounds of phosphorous and 10 to 16 pounds of potassium per dry ton of residue removed from the field. These amounts are significantly lower than traditional stover bales (Table 3) due to the components that are baled. With a traditional stover bale, about 30 - 35% of the bale is stalk. Whereas a second pass bale only 15 - 20% is stalk, most of it being the top portion of the stalk. This is important because after maturity, the corn plant begins to lose minerals in the top half of the plant. Because of this, by comparison the bottom of the stalk tends to contain more minerals than the top portion of the stalk (Johnson et al., 2010). By focusing on the upper parts of the plant, fewer nutrients are removed. This leads to lower overall replacement levels when comparing second pass baling to traditional stover baling.

Table 3: Average P and K removal rates

Phosphorous and Potassium Removal Rates		
lbs/ton of dry biomass		
Source	**P**	**K**
Iowa State[1]	5.9	25.0
Michigan State[2]	3.6	19.7
Univ. of Wisconsin[3]	3.3	35.7
Univ. of Illinois[4]	7.0	30.0
Dupont - Rake and Bale[5]	4.4	23.5
Avg. Rake and Bale	4.8	26.8
POET - 2nd Pass Bale[6]	2.8	15.8

1) Sawyer et al. 2011
2) Gould 2007
3) Bundy 1998
4) Fernandez 2007
5) DuPont Iowa Corn Stover Test Harvest 2011
6) POET Iowa 2nd Pass Bale Test Harvest 2009 and 2010

Table 4: Potassium loss in Stover Over Time[1]



1) Jeschke and Heggenstaller, 2012

Field Operational Savings

There are several different areas where sustainable residue removal can lead to field operations savings.

Using POET's 2nd Pass Baling method, combine operators are asked to turn off the chopper and/or spreader on the back of the combine. The chopper on the back of most combines uses 30 hp to power itself. By turning this off, those

30 hp can either be used for additional threshing hp or, by changing nothing; roughly ½ gallon of fuel per acre can be saved.

As yields and residue levels increase in the coming years, tillage alone won't be able to incorporate all of the residue left after corn is harvested. These increases are due to projected yield increases from seed companies such as Monsanto (Hugh, 2007). With all of this excess residue, more aggressive tillage will be required to incorporate it into the soil. But this can be potentially minimized with partial residue removal. In addition to the savings during harvest, partial residue removal can also equate to tillage savings. With less overall residue to incorporate into the soil, fewer passes or less aggressive tillage can be used to achieve the same amount of residue incorporation. This reduction in fuel and wear and tear on equipment can lead to substantial savings over the long term, or it could offer a pathway to make a move to no-till a viable option.

Responsible Residue Harvesting

Amid all the growing talk of utilizing corn residue for cellulosic ethanol, it's important to remember practice responsible residue harvest. By coupling soil testing with sustainable residue harvesting practices, nutrient and soil organic matter levels can be maintained or even increased while doing partial residue harvest. Typically, at the removal rates associated with second pass baling, enough residue is left to protect against wind and water erosion. By focusing on these concerns first, potential financial and agronomic opportunities such as: increased yields, improved residue management, and the minimization of plant diseases may be achieved.

Partial residue harvesting is a management tool or strategy that can be included in your operation to improve the soil health, productivity, and manage the residue levels created by higher yields. All of these factors may open the door towards the realization of additional profits without planting additional acres.

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