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To Harvest Stover or Not: Is it Worth it?

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Corn stover is a readily available source of biomass for the production of biofuels. Three US refineries - Poet, Abengoa and Dupont - are converting it at commercial scale to biofuel. These biofuel facilities partner and contract with farmers to procure the stover feedstock used in processing. Farmers face a choice of whether or not to harvest the corn stover, and the proportion of the residue available in the field to harvest. These decisions impact the costs associated with harvesting stover, and the delivery price at which it is profitable to do so. The production of corn stover for a biorefinery may also create incentives to change management practices, such as crop rotations and tillage practices.

This article uses research from the University of Illinois (Dwivedi, et al. 2015) to summarize the process of harvesting stover, including the additional costs created by stover collection and the stover prices needed to justify those additional costs under different productivity, crop rotation, and tillage practice scenarios.

Stover Yields and Harvesting/Removal

Whether it is economically viable for a farmer to harvest the corn stover and the production methods to use will depend on the price offered for the stover biomass relative to the additional costs associated with harvest, collection, and storage. These additional costs depend to a large extent on the stover yield, or amount of stover available on each acre, which in turn depends on corn yields. The amount of stover produced is typically equal to the corn grain yield per acre on a weight basis, but it could be 10-20% higher or lower than the corn yield. For example, a 150 bushel per acre corn yield would imply a 4.2 ton per acre corn stover yield. This comes from 150 bushels at 56 lbs/bu, which equals 8,400 lbs. or 4.2 tons.

Removal of stover can affect soil fertility by reducing soil organic matter and nutrients while also contributing to runoff from water erosion and soil loss from wind erosion. Some of these effects are site-specific and it is important to determine what effects different levels of stover removal have on the soil. Recommended stover removal rates depend on soil characteristics, climate, management practices (tillage), and other factors that determine the loss of soil organic matter and run-off. Studies show that the proportion of stover that can be harvested varies between 30% and 50% depending on the type of tillage practice used and soil and other site-specific characteristics (Scarlat, Martinov, and Dallemand 2010). It is generally recommended that only about 30% of the stover be harvested with conventional tillage but that 50% of the stover can be harvested with no-till practices. This implies that the harvested yields of corn stover with a 150 bushel corn yield would range between 1.26 to 2.1 tons per acre.

Stover Production, Harvest, and Storage Costs

Corn stover harvesting must be accompanied by additional fertilizer applications to replace the nutrients that are removed with the stover. Removal of corn stover implies additional fertilizer applications for the main macronutrients nitrogen (N), phosphorus (P), and potassium (K). Research suggests 7 additional lbs of nitrogen be applied per ton of stover removed. For phosphorus and potassium, 1.6 and 15.20 additional lbs are recommended per ton of stover removed on each acre (Sheehan et al., 2003).

Harvesting of corn stover typically involves mowing, raking and baling operations. These harvesting operations are capital intensive and require equipment such as a tractor, mower, rake, baler, and bale transporter. Other harvesting costs include labor and fuel. The large fixed cost component implies economies of scale if the harvesting equipment can be used over a larger acreage. For any given biomass yield level, harvesting costs per acre fall as the acres harvested annually increase. As yields increase, the fixed cost per ton also falls but the speed at which the implements are operated changes and may reduce maximum capacity to harvest (in terms of annual harvested acres). Furthermore, labor and fuel requirements for baling may increase as tonnage or removal rates increase.

Biomass can be stored after harvest in several ways including on-farm open-air, on-farm covered, or storage in a centralized covered facility. Open air storage could be unprotected on the ground or on crushed rock or covered by reusable tarp. The covered storage could be a pole frame structure with open sides on crushed rock or it could be an enclosed structure on crushed rock. The loss in biomass is highest when biomass is left unprotected and lowest in the enclosed structure. These losses depend on the number of days the biomass is stored and need to be weighed against the costs of installation, land, labor, and materials as well as the biomass quality that is needed by the bio-refinery. A centralized covered storage facility could be shared by many farms but would require producers to incur biomass handling and transportation costs to move the biomass from their farms. The optimal choice of storage facility is likely to depend on the volume of biomass and the length of time that it has to be stored, the price of biomass, the quality of biomass required, and the weather conditions within the region.

Break-even Stover Price Examples

Tables 1 and 2 summarize a range of different scenarios for stover production and their associated break-even stover prices, or the minimum price the farmer would need to receive to justify harvesting the stover residue on the farm. Table 1 illustrates four different management practice scenarios for a farm with relatively high productivity – 180 bushel/acre expected corn yields in a corn-soy rotation and 158 bushel/acre expected corn yields in a continuous corn rotation.

In a continuous corn rotation, the expected yield of 158 bushels/acre translates to a harvested stover yield of 1.33 tons/acre when using conventional tillage, or 2.21 tons/acre when using no till practices due to the higher removal rate. Accounting for 15% moisture and assuming 7% storage losses results in 1.05 dry tons/acre, with conventional tillage and 1.75 dry tons/acre under no till, which would be available for the farmer to sell to a bioprocessing facility.

The additional costs associated with nutrient replacement are shown as $8.81/acre under conventional tillage, and increase to $14.68 under the no till practice due to the higher stover removal rate. These nutrient replacement costs are based on the nutrient replacement need assumptions outlined previously and nutrient prices of $565/ton for anhydrous ammonia, $468/ton for diammonium phosphate (DAP), and $362 per ton for potash.

Harvesting and storage costs include fixed costs of mowing and raking, baling (which includes both fixed and variable components), and variable costs that increase with stover yields/removal rates for staging, loading, and storage. Total harvesting and storage costs ranges from $55.33/acre for conventional tillage to $69.11 per acre with no till due to the larger amount of stover being harvested.

Table 1. Break-even Stover Prices with High Productivity

	Continuous Corn		Corn-Soy Rotation	
	Conventional Tillage	No Till	Conventional Tillage	No Till
Corn Yield (bu/acre)	158	158	180	180
Stover Yield (tons/acre)	4.42	4.42	5.04	5.04
Removal Rate	30%	50%	30%	50%
Harvested Stover[1] (tons/acre)	1.33	2.21	1.51	2.52
Harvested Stover[2] (dry tons/acre)	1.13	1.88	1.29	2.14
Storage Loss	7%	7%	7%	7%
Marketable Stover[2] (dry tons/acre)	**1.05**	**1.75**	**1.20**	**1.99**
Nutrient Replacement				
Nitrogen	$2.76	$4.61	$3.15	$5.25
Phosphorus	$0.90	$1.50	$1.03	$1.71
Potassium	$5.14	$8.57	$5.86	$9.77
Total Nutrient Replacement	**$8.81**	**$14.68**	**$10.04**	**$16.73**
Harvesting and Storage				
Mowing	$14.91	$14.91	$14.91	$14.91
Raking	$4.73	$4.73	$4.73	$4.73
Baling	$21.66	$26.09	$22.59	$27.63
Staging and Loading	$8.77	$14.61	$9.99	$16.64
Storage	$4.65	$7.75	$5.30	$8.83
Interest	$0.62	$1.03	$0.70	$1.17
Total Harvesting and Storage Costs	**$55.33**	**$69.11**	**$58.21**	**$73.91**
Total Additional Costs	**$64.14**	**$83.80**	**$68.25**	**$90.64**
Breakeven Stover Price ($/dry ton)	**$61.13**	**$47.92**	**$57.10**	**$45.50**

[1]Stover is assumed to be harvested at a moisture content of 15%. Harvested yield used to determine variable harvest and storage costs.

[2]Adjusted for zero moisture content. Dry basis harvested yield used to determine nutrient replacement needs.

[3]Dry basis marketable yield is adjusted for storage losses; breakeven stover price determined on a dry yield basis.

Table 2. Break-even Stover Prices with Low Productivity

	Continuous Corn		Corn-Soy Rotation	
	Conventional Tillage	No Till	Conventional Tillage	No Till
Corn Yield (bu/acre)	112	112	127	127
Stover Yield (tons/acre)	3.14	3.14	3.56	3.56
Removal Rate	30%	50%	30%	50%
Harvested Stover[1] (tons/acre)	0.94	1.57	1.07	1.78
Harvested Stover[2] (dry tons/acre)	0.80	1.33	0.91	1.51
Storage Loss	7%	7%	7%	7%
Marketable Stover[2] (dry tons/acre)	**0.74**	**1.24**	**0.84**	**1.41**
Nutrient Replacement				
Nitrogen	$1.96	$3.27	$2.22	$3.70
Phosphorus	$0.64	$1.07	$0.73	$1.21
Potassium	$3.65	$6.08	$4.13	$6.89
Total Nutrient Replacement	**$6.25**	**$10.41**	**$7.08**	**$11.80**
Harvesting and Storage				
Mowing	$14.91	$14.91	$14.91	$14.91
Raking	$4.73	$4.73	$4.73	$4.73
Baling	$19.73	$22.87	$20.36	$23.92
Staging and Loading	$6.21	$10.36	$7.05	$11.74
Storage	$3.30	$5.49	$3.74	$6.23
Interest	$0.44	$0.73	$0.50	$0.83
Total Harvesting and Storage Costs	**$49.31**	**$59.08**	**$51.27**	**$62.35**
Total Additional Costs	**$55.55**	**$69.49**	**$58.35**	**$74.16**
Breakeven Stover Price ($/dry ton)	**$74.70**	**$56.06**	**$69.20**	**$52.76**

[1]Stover is assumed to be harvested at a moisture content of 15%. Harvested yield used to determine variable harvest and storage costs.

[2]Adjusted for zero moisture content. Dry basis harvested yield used to determine nutrient replacement needs.

[3]Dry basis marketable yield is adjusted for storage losses; breakeven stover price determined on a dry yield basis.

The breakeven stover price for each tillage practice for the continuous corn rotation are shown to be $61.13 per dry ton with conventional tillage and $47.92 per dry ton under no till. The higher removal rates suggested when using no till practices more than offset the greater costs, implying a more than $13 per acre advantage with no till. These results suggest that farmers who have the opportunity to market corn stover to a bioprocessing facility may have incentives to use no till over conventional tillage practices.

Comparing the continuous corn rotation to a corn-soy rotation assumes higher corn and, therefore, stover yields. This also increases the variable costs associated with stover harvest, but ultimately result in lower breakeven stover prices. Similar to the continuous corn rotation, no till practices imply a $12 or more per acre advantage in terms of the minimum stover price needed to make harvest and collection profitable for the farmer. However, under both tillage practices the breakeven stover price is lower with the corn-soy rotation. This suggests that the ability to sell stover may not provide incentives to farmers to switch to crop rotations that are more corn intensive.

Table 2 summarizes the same scenarios for a lower productivity farm with expected corn yields of 127 bushel per acre in a corn-soy rotation and 112 bushels per acre in a continuous corn rotation. Here, the lower corn yields reduce the amount of stover that is harvested and available to sell by the farmer. While the lower stover yields result in lower variable costs of nutrient replacement and harvest, the net effect is an increase in the breakeven stover price in all four management scenarios.

Similar to the high productivity case, no till practices are associated with a lower breakeven price for stover. The reduction in breakeven stover price in comparing conventional tillage to no till is larger in the low productivity scenario, in the range of $17 to $18 per dry ton. Again, this suggests that the ability to sell stover may incentivize farmers to adopt no till practices over more conventional tillage. Also similar to the high productivity case, the breakeven price of stover is higher for the continuous corn rotation compared with the corn-soy rotation, suggesting that stover removal may not lead to more intensive corn rotational practices among farmers.

Conclusions

The use of corn stover for bioenergy is appealing since it does not divert land from food crop to fuel production or require investment in dedicated feedstocks by farmers and biorefineries. However, its production does require additional costs of harvesting, baling and storage and additional fertilization expenses to replace nutrients removed with the residue. The profitability of harvesting corn stover will depend on whether the price of biomass is high enough to cover these additional costs.

Our estimates show that total production costs decline as the harvestable yield increases, implying lower break-even stover prices. This can create incentives for harvesting stover from fields that use no-till systems where residue removal rates can be higher, and may even create incentives for farmers to switch from conventional tillage to no-till systems if the costs associated with switching tillage practices are lower than the potential for more profitable stover removal. Higher potential profits can also create incentives to increase residue removal rates above those considered here. However, this could have adverse consequences for long term soil fertility as well as contribute to loss of soil organic matter and soil erosion.

In contrast, our estimates do not suggest a financial incentive for farmers to switch from corn-soy rotations to more intensive continuous corn rotations. The yield drag typically experienced for continuous corn, relative to a corn-soy rotation, results in lower stover yields and higher costs associated with stover removal on a per ton basis.

The estimates provided here are based on stover harvest costs typical for Illinois. To examine scenarios for other areas and individual scenarios, a Corn Stover Budget FAST tool has been made available. Default values are provided to generate corn stover production budgets similar to what is presented in tables 1 and 2, and users can adjust variables such as their location, corn yield, stover removal rate, nutrient replacement amounts and prices, and harvest costs to tailor their analysis to their specific situation. The latest version of this Biomass Crop Budget Tool for Corn Stover is available for download here.

References

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