Sustainable Corn Stover Harvest for Biofuel Production

Cellulosic ethanol

- Lignocellulose is a structural component of plant matter.
- Because it is abundant in nature, has high energy value, and is not used directly for human consumption, it holds great promise for renewable energy production.
- The primary plant materials being considered for large-scale cellulosic ethanol production include crop residues, “energy crops” developed specifically for fuel, and forest and wood processing residues.
- Of these, crop residues, and particularly those of corn, hold the greatest potential.

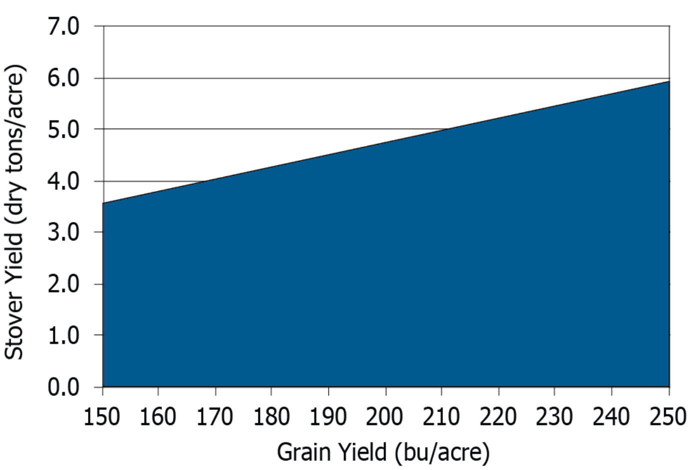
Corn stover as an ethanol feedstock

- Corn produces the highest volume of residue of all the major crops in the U.S.
- Volume has increased in tandem with corn grain increases and will likely continue to do so.

- Several “second-generation” ethanol plants that will use corn residue as a feedstock are planned for production

Higher levels of corn residue

- In recent years, the level of corn residue remaining in the spring has increased significantly in many fields due to:
  - Higher plant populations
  - Use of foliar fungicides and *Bt* traits resulting in improved corn stalks that resist decomposition
  - Reduced tillage practices resulting in less residue breakdown

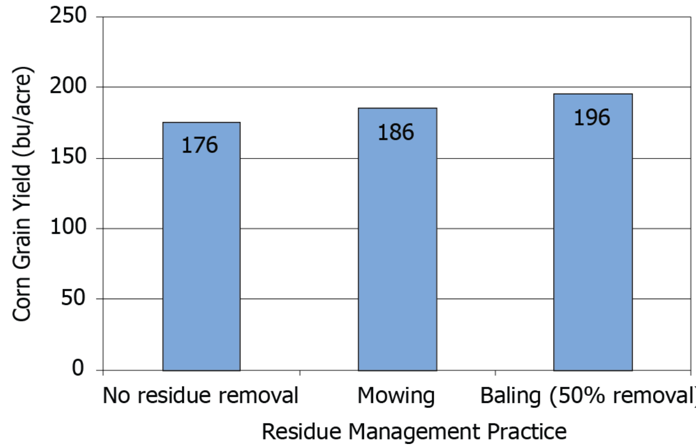


Corn stover dry tons/acre based on a harvest index of 0.5.

In many highly productive systems, particularly under continuous corn, corn stover production exceeds the minimum amounts needed to maintain soil health and productivity, making sustainable stover harvest viable.

Advantages of removing excess residue include:

- Less interference with planting and stand establishment
- Expanded rotation and management options
- Reduced tillage
- Lower inoculum levels for corn pathogens
- Reduction in nitrogen immobilization
- Increased soil temperature and a faster rate of soil drying



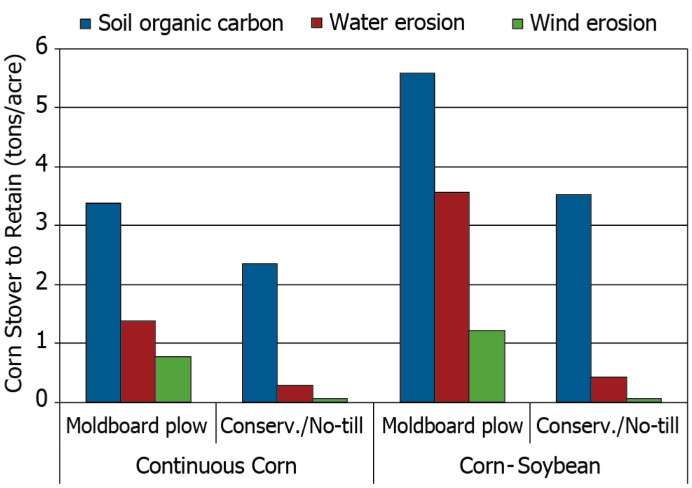
Effect of residue management practices on grain yield in no-till continuous corn in a Univ. of Missouri study conducted in 2008 and 2009 (Wiebold 2010)

How much residue can be harvested?

- Excessive levels of corn residue in many fields make residue harvest a viable, sustainable option.
- In these fields, the important question is how much of the residue can be removed.
- Factors that determine how much residue needs to remain in the field include:
  - soil erosion prevention
  - soil organic carbon maintenance
  - soil fertility management

Soil Erosion Prevention

- Any stover harvest program must leave enough residue on the soil to mitigate water and wind erosion.
- Tools such as RUSLE2 and WEPS are available to assist in developing a soil conservation plan.
- The amount of corn residue needed to manage erosion can vary greatly according to field characteristics and management practices, but is often considerably less than the total quantity produced.



Average amounts of corn residue needed to maintain soil organic carbon (Johnson et al. 2006; Wilhelm et al. 2007) and manage water and wind erosion (Wilhelm et al. 2007) across multiple sites.

Soil Organic Carbon Maintenance

- Soil organic matter levels are determined by the rate of loss through erosion and mineralization and the rate of gain through return of plant residue and other organic material.
- Soil organic matter plays many critical roles in producing high grain yields, creating an economic incentive for ensuring that corn stover harvest is done in a sustainable manner.
- Soil organic matter is frequently measured according to its carbon fraction, or soil organic carbon.
- Research indicates that maintenance of soil organic carbon is likely to be the most limiting factor on the amount of corn stover that can be sustainably removed.
- The amount of residue needed to maintain soil organic carbon will be greater than the amount needed to mitigate erosion in most cases.

Effects of yield level and crop rotation on amount of corn stover available for continual harvest while maintaining soil organic carbon. (Estimates based on research data from multiple sites; actual sustainable removal rates will vary).

Grain Yield	Stover Production[1]	Stover Available for Harvest: Continuous Corn[2]	Stover Available for Harvest: Corn-Soybean[3]
	------ dry matter tons/acre ------		
150	3.5	1.2	0.0
170	4.0	1.7	0.5
190	4.5	2.2	1.0
210	5.0	2.7	1.5
230	5.4	3.1	1.9
250	5.9	3.6	2.4

[1] Based on a harvest index of 0.5
[2] Estimated 2.3 tons/acre dry corn stover needed to maintain soil organic carbon under continuous corn with conservation or no-tillage (Johnson et al. 2006, Wilhelm et al. 2007).
[3] Estimated 3.5 tons/acre dry corn stover needed to maintain soil organic carbon under corn soybean rotation with conservation or no-tillage (Johnson et al. 2006, Wilhelm et al. 2007).

Soil Fertility Management

- Stover harvest increases the total amount of plant material removed from a field which means that greater quantities of nutrients are also removed.
- Nutrient removal tables are useful as a general guide, but determining the actual impact of stover removal on soil fertility is a complex issue that can be affected by factors such as:
  - Soil nutrient levels
  - Growing conditions
  - Hybrid
  - Time of stover removal
- Rainfall can leach nutrients out of corn stover, particularly K, which exists in a soluble form in the plant (Sawyer and Mallarino 2007).

Johnson, J.M.-F., R.R. Allmaras, and D.C. Reicosky. 2006. Estimating Source Carbon from Crop Residues, Roots and Rhizodeposits Using the National Grain-Yield Database. Agron. J. 98:622-636.

Johnson, J.M.F., W.W. Wilhelm, D.L. Karlen, D.W. Archer, B. Wienhold, D.T. Lightle, D. Laird, J. Baker, T.E. Ochsner, J.M. Novak, A.D. Halvorson, F. Arriaga, N. Barbour. 2010. Nutrient Removal as a Function of Corn Stover Cutting Height and Cob Harvest. Bioenerg. Res. 3:342-352.

Sawyer, J.E. and A.P. Mallarino. 2007. Nutrient removal when harvesting corn stover. IC-498(22) Iowa State University Extension.

Wiebold, W.J. 2010. Mitigation of Stover Effects on Yield in Continuous Corn Planted without Tillage. Pioneer Crop Management Research Awards Update.

Wilhelm, W.W., J.M.F. Johnson, D.L. Karlen, and D.T. Lightle. 2007. Corn Stover to Sustain Soil Organic Carbon Further Constrains Biomass Supply. Agron. J. 99:1665-1667.

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