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Sustainable Crop Removal: Maintaining Soil Quality

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Agricultural biomass, the aboveground plant material that is not grain, is being looked to as a promising renewable energy source for heat and power, ethanol, syngas and bio-oil. When used for these purposes biomass is often referred to being a cellulosic bioenergy feedstock. Currently of particular interest is the use of crop residue—the biomass left on the field after grain harvest. The primary crop residue being considered in the Corn Belt of the United States is corn stover. Perennial grasses such as switchgrass (*Panicum virgatum*) and *Miscanthus giganteus* are also being researched for their potential as cellulosic bioenergy feedstocks.

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Corn stover helps maintain soil quality for future crops.

Production of agricultural biomass for bioenergy offers many potential environmental benefits, but we cannot afford to overlook the production and environmental costs associated with wide-scale removal of biomass from the land.[1] We need to ask *how much crop biomass is needed to protect and maintain the soil resource, and correspondingly, how much can be harvested as renewable fuel?*[2]

Crop residue protects the soil from erosion and adds organic matter. In addition, as Table 1 demonstrates, it provides many other valuable benefits to society, called ecosystem services. Removing too much crop residue will limit these services and affect soil quality. This could have a negative economic impact—lower yields and/or augmented use of external inputs, such as fertilizer, to compensate for decreased soil quality. In addition to field-level effects, unsustainable removal of crop biomass would have negative impacts on a global scale (Table 1). As a society, we need to determine what tradeoffs in ecosystem services we will allow in the emerging bioenergy economy and support research efforts that investigate these issues.

Simple estimates of the amount of stover needed to maintain current soil organic matter levels can be made using our knowledge of current soil organic matter levels, microbial decay, and the amount of aboveground crop residue and roots needed to replace soil organic matter.[3] Residue removal consistently reduces soil organic matter levels across sites, but impacts of residue removal on other soil quality parameters and crop production are site-specific.[4] How residue removal affects soil quality depends on factors such as soil texture, drainage, slope, duration of residue management, rate of residue removal, tillage and cropping system, application of fertilizers, use of organic amendments and climate.[4] Therefore, scientists advise *a cautious approach to harvesting agricultural*

Table 1. Benefits (ecosystem services) provided by crop residue on fields.

Replenish nutrients in the soil, increase soil organic matter levels, conserve soil water, reduce excessive evaporation, promote biological activity, enhance soil aggregation, strengthen nutrient cycling, reduce abrupt fluctuations in soil temperature, improve soil tilth.	→	Maintain agronomic productivity
Reduce soil erosion and non-point source pollution, absorb agricultural chemicals, filter runoff, buffer against the impact of air pollutants.	→	Improve water and air quality
Sequester soil organic carbon, offset emissions of CO_2 and other greenhouse gases.	→	Mitigate global climate change

Adapted from Blanco-Canqui and Lal, 2009.[4]

biomass for energy until research provides answers and guidance to the critical questions of how much biomass to harvest, when to harvest and where.[2] Researchers are currently testing the following practices to mitigate the negative effects of biomass removal on soil quality:

- **Using perennial species** such as poplar trees, miscanthus and switchgrass, which require less soil disturbance and fewer external inputs after they are established than annual crops such as corn.
- **Practicing crop rotation** with small grains such as wheat.
- **Altering** the amount and frequency of agricultural biomass harvested.
- **Implementing conservation techniques** such as contour cropping and use of conservation buffers.
- **Establishing cover crops**, which can help to reduce soil erosion and add organic matter and nutrients. (More information can be found at http://www.mccc.msu.edu.)
- **Adding manure or compost**. Michigan State University researchers have found that adding compost or manure to fields where corn stover is removed can maintain soil organic matter levels.[5]
- **Applying co-products of bioethanol production**, such as biochar, to fields as soil amendments to enhance ecosystem services related to soil quality.

Soil quality is complex and easily affected by management, so it is important for farmers to monitor their soil quality as they harvest bioenergy crops. Resources to help do this include:

- **Soil Quality Assessment**. 2008. S.S. Snapp and V.L. Morrone. Pages 79-96 in S. Logsdon, D. Clay, D. Moore and T. Tsegaye (eds.), *Soil Science: Step-by-step Field Analysis*, Madison, WI, Soil Science Society of America.
- **Cornell Soil Health Assessment Training Manual**. Available at: http://soilhealth.cals.cornell.edu/extension/manual.htm
- **Soil Health Scorecard**. Available at http://www.cias.wisc.edu/wp-content/uploads/2008/07/soilhealth_screen.pdf
- **USDA Soil Quality Assessment**. Available at: http://soils.usda.gov/sqi/assessment/assessment.html
- **Sampling Soils for Fertilizer and Lime Recommendations**. Available at: http://fieldcrop.msu.edu/documents/E0498.pdf

Bioenergy crops can maintain or even improve soil quality and increase ecosystem services, depending on the crop, geographic location and management practices. Perennial bioenergy crops—such as switchgrass—always have roots present, thereby guarding against soil erosion and improving retention of nitrogen fertilizer. In addition, carbon is sequestered belowground in the roots and soil organic matter because there is no further tillage after crop establishment. Because management for these perennial species is less intensive than management for annual grain crops—less tillage, planting and weed control— fuel and carbon dioxide costs are lower.[6]

References:

[1] Sagar, A.D., and S. Kartha. 2007. Bioenergy and sustainable development? Annual Review of Environment and Resources 32:131-167.

[2] Johnson, L.M.F., D. Reicosky, R. Allmaras, D. Archer and W. Wilhelm. 2006. A matter of balance: Conservation and renewable energy. Journal of Soil and Water Conservation 61:120A-125A.

[3] Thelen, K. 2009. Corn crop residue is beneficial for soil organic matter. At: http://www.ipmnews.msu.edu/fieldcrop/fieldcrop/tabid/56/articleType/ArticleView/articleId/746/Ten-fundamentals-every-one-should-know-about-bioenergy-Part-5-corn-crop-residue-is-beneficial-for-soil-organic-matter.aspx.

[4] Blanco-Canqui, H., and R. Lal. 2009. Crop Residue Removal Impacts on Soil Productivity and Environmental Quality. Critical Reviews in Plant Sciences 28:139-163.

[5] Fronning, B.E., K.D. Thelen and D.H. Min. 2008. Use of Manure, Compost, and Cover Crops to Supplant Crop Residue Carbon in Corn Stover Removed Cropping Systems. Agronomy Journal 100:1703-1710.

[6] Robertson, G.P., D.A. Landis and M Khanna. 2008. The Sustainability of Cellulosic Biofuels, Ecological Society of America. At: www.esa.org/pao/policyActivities/Sustainability%20of%20Cellulosic%20Biofuels%20handout%206.11.pdf.

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