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A Multi-Factor Analysis of Sustainable Agricultural Residue Removal Potential

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Agricultural residues have significant potential as a near term source of cellulosic biomass for bioenergy production, but sustainable removal of agricultural residues requires consideration of the critical roles that residues play in the agronomic system. Previous work has developed an integrated model to evaluate sustainable agricultural residue removal potential considering soil erosion, soil organic carbon, greenhouse gas emission, and long-term yield impacts of residue removal practices. The integrated model couples the environmental process models WEPS, RUSLE2, SCI, and DAYCENT. This study uses the integrated model to investigate the impact of interval removal practices in Boone County, Iowa, US. Residue removal of 4.5 Mg/ha was performed annually, bi-annually, and tri-annually and were compared to no residue removal. The study is performed at the soil type scale using a national soil survey database assuming a continuous corn (*Zea mays* L.) rotation with reduced tillage. Results are aggregated across soil types to provide county level estimates of soil organic carbon changes and individual soil type soil organic matter content if interval residue removal were implemented. Results show interval residue removal is possible while improving soil organic matter. Implementation of interval removal practices provides greater increases in soil organic matter while still providing substantial residue for bioenergy production.

Keywords

Residue removal, Model integration framework, Agricultural residues, Soil organic matter

Disciplines

Agriculture | Energy Systems | Oil, Gas, and Energy | Soil Science

A Multi-Factor Analysis of Sustainable Agricultural Residue Removal Potential

Jared Abodeely¹, David Muth¹, Paul Adler², Eleanor Campbell³, Kenneth Bryden⁴

Abstract

Agricultural residues have significant potential as a near term source of cellulosic biomass for bioenergy production, but sustainable removal of agricultural residues requires consideration of the critical roles that residues play in the agronomic system. Previous work has developed an integrated model to evaluate sustainable agricultural residue removal potential considering soil erosion, soil organic carbon, greenhouse gas emission, and long-term yield impacts of residue removal practices. The integrated model couples the environmental process models WEPS, RUSLE2, SCI, and DAYCENT. This study uses the integrated model to investigate the impact of interval removal practices in Boone County, Iowa, US. Residue removal of 4.5 Mg/ha was performed annually, bi-annually, and tri-annually and were compared to no residue removal. The study is performed at the soil type scale using a national soil survey database assuming a continuous corn (*Zea mays* L.) rotation with reduced tillage. Results are aggregated across soil types to provide county level estimates of soil organic carbon changes and individual soil type soil organic matter content if interval residue removal were implemented. Results show interval residue removal is possible while improving soil organic matter. Implementation of interval removal practices provides greater increases in soil organic matter while still providing substantial residue for bioenergy production.

Keywords: residue removal, model integration framework, agricultural residues, soil organic matter

Introduction

Agricultural residues are the plant material other than grain (cob, stalk, leaves, etc.) produced when commodity grain crops such as corn (*Zea mays* L.), wheat (*Triticum aestivum* L.), and barley (*Hordeum vulgare* L.) are grown. Removing agricultural residues for energy production has received significant attention over the past few decades. However, determining the quantity of agricultural residues that can be sustainably removed from a field is challenging because of the diverse functions that agricultural residues provide within the agroecosystem. Considering this range of functions Wilhelm et al. (2010) identified six environmental factors that can potentially limit the quantity of agricultural residues that can be removed sustainably: soil organic carbon, wind and water erosion, plant nutrient balances, soil water and temperature dynamics, soil compaction, and off-site environmental impacts. The impact of residue removal on soil organic matter has received considerable attention among these six limiting factors because soil organic matter is critical to long term soil productivity. Soil organic matter enables nutrient cycles, helps stabilize soil structure, and facilitates water retention resulting in increased crop productivity. Soil organic matter also helps mitigate soil erosion losses due to wind and water (Johnson et al., 2010). Because of this it is essential to understand how residue removal impacts soil organic matter to determine the long term sustainability of a specific residue removal practice.

This paper utilizes a model integration framework to quantitatively analyze how residue removal practices impact long term soil organic matter levels. There are a wide range of potential residue removal

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practices and each can impact soil organic matter levels differently. Previous efforts have qualitatively considered how changing the removal rates, i.e. the percentage of residue biomass taken off the field, can impact soil organic matter levels (Muth et al., 2012). The challenge with implementing lower removal rates to address soil organic matter constraints, and broader sustainability concerns, is that lower removal rates are often not economically viable (Hess et al., 2009). One way to address concerns about soil organic matter losses and still remove residues at rates which are economically viable is to implement interval removal practices. These practices will remove residues one out of every two or three years that a residue producing crop is grown on a field. Interval removal practices have significant potential but need further analysis. To provide this analysis, this paper extends the previous integrated model developed by Muth and Bryden (2012) to provide quantitative soil organic matter analyses using the DAYCENT model (Parton et al., 1998) to assess the sustainability of interval residue removal practices.

Muth and Bryden (2012) developed an integrated model for determining sustainable agricultural residue removal using the model integration framework VE-Suite (McCorkle and Bryden 2007). The integrated model performs sustainable residue removal assessments considering water erosion, wind erosion, and soil organic matter constraints. Three models were integrated into the framework: The Revised Universal Soil Loss Equation, Version 2 (RUSLE2) (McCool et al. 2004); the Wind Erosion Prediction System (WEPS) (Wagner 1996); and the Soil Conditioning Index (SCI) (USDA-NRCS 2012). In 2012, Muth et al. (2012) performed a county-level national assessment of sustainable residue removal using the model integration framework.

Extension of the integrated model to include DAYCENT provides the ability to quantify the impacts of sustainable residue removal on the soil and environment. DAYCENT is a biogeochemical model that simulates daily fluxes of carbon and nitrogen between the atmosphere, vegetation, and soil (Del Grosso et al., 2001). DAYCENT is comprised of several submodels that together enable assessments of nitrogen-gas fluxes, carbon dioxide flux from soil respiration, soil organic carbon and nitrogen, new primary production, and daily water and nitrate leaching. This study investigates four interval removal practices in Boone County, Iowa, US: no residue, annual, bi-annual, and tri-annual removal. Results were aggregated over 30 soils under a continuous corn rotation and reduced tillage management to provide a county level assessment of soil organic matter impacts.

Methodology

The integrated model is comprised of disparate models and databases that together provide the capability to quantitatively assess the impact of residue removal on soil organic carbon. **Error! Reference source not found.** shows the flow of information within the model integration framework.

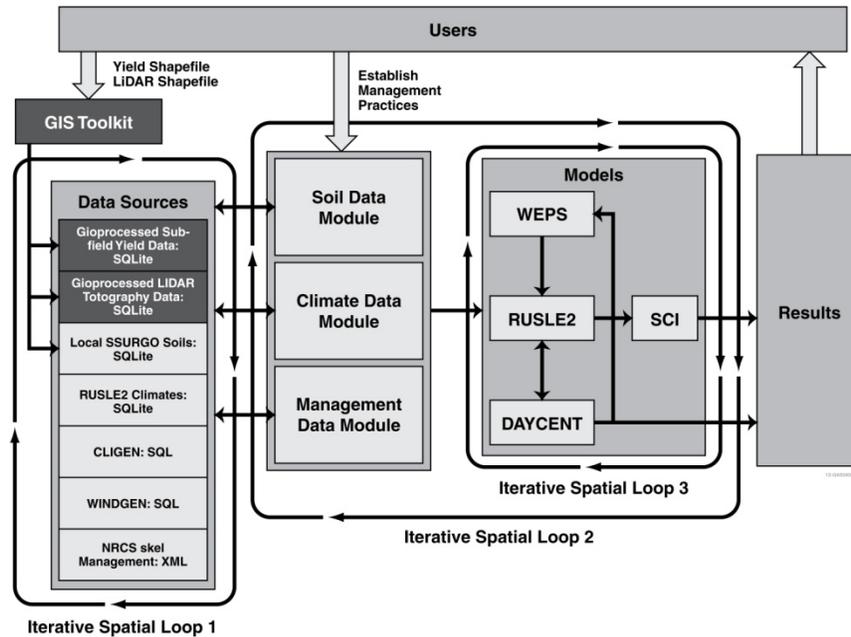


Figure 1. Data flow through the integrated model

Users select the area of interest, crop rotation, land management practices, and residue removal scenario. Soil and climate data are dynamically acquired based upon the selected area. Because the integrated models were developed and maintained by different organizations, file formats, data acquisition, and model execution are different. To address this issue, databases and file converters have been developed to enable consistent data flow across the integrated models.

The model simulation is a two-part process: calibration of the integrated model and scenario simulation. First, model inputs are initialized for a defined scenario. Spatial selection defines the climates and soils for the scenario. Climate and soil databases are loaded and queried to create the respective input files. Management and simulation files are built for WEPS and then the model is executed. Wind erosion results are passed into RUSLE2. RUSLE2 is executed and results are passed into SCI. SCI uses organic matter, field operation, and water erosion results from RUSLE2 and wind erosion results from WEPS to determine the soil conditioning index. Sustainability is defined as total erosion being less than the t-factor for the soil and a SCI greater than or equal to zero. If sustainable, DAYCENT is then initialized with soil, climate, and management data consistent with previous models. Erosion results are passed to DAYCENT and the crop is calibrated against the yield input. Once the calibration process is completed, the scenario is simulated considering soil, climate, and land management practices using the same sequence of execution.

The integrated model is utilized to assess an interval residue removal scenario for a continuous corn rotation under reduced tillage land management practices in Boone County, Iowa, US. The 2010 Billion Ton Update (US DOE, 2011) yield scenario is the basis for calibration of the integrated model. The climate inputs utilize stochastically generated data for a single year allowing the simulation to run without considering any climatic stress events that may actually occur over a 20-year weather cycle. Interval residue removal practices are run across each soil to determine the impacts on soil organic matter for the major soil types used in row crop production in Boone County.

Results and Discussion

This study investigated the long-term impact of interval removal practices on soil organic carbon under a continuous corn rotation and reduced tillage management practices (Figure 2).

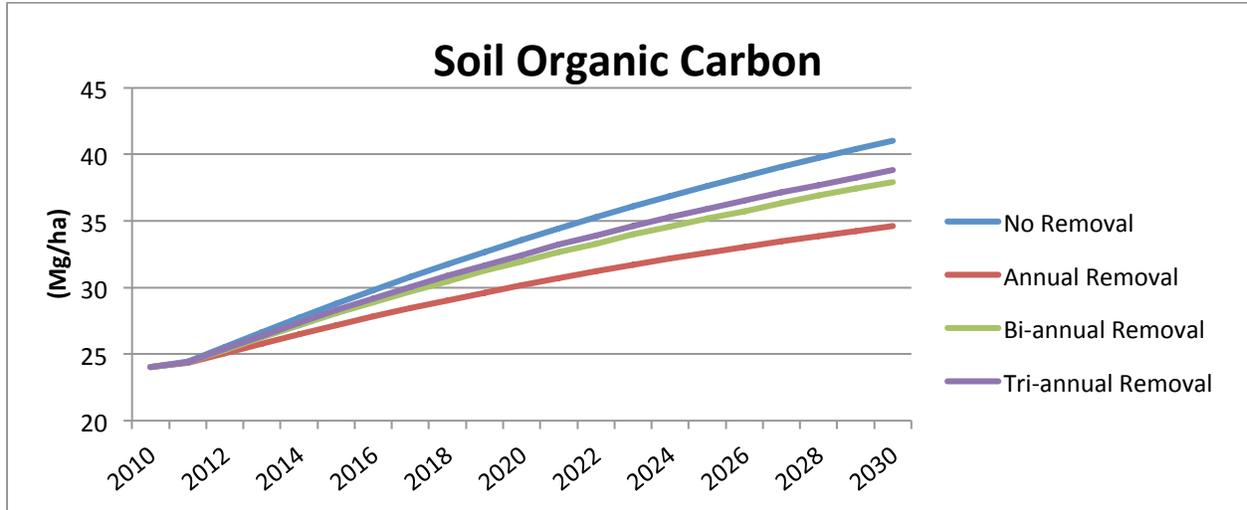


Figure 2. Changes to soil organic carbon per interval harvesting scenario

Annual removal of nearly 4.5 Mg/ha increases soil organic carbon under each scenario but over the 20 year simulation soil organic carbon is reduced more than 7 Mg/ha relative to the no removal scenario. shows the predicted changes in soil organic matter.

Table 1. Predicted changes to soil organic matter in the top 6 soils in Boone County considering interval residue removal practices.

Soil Type	Map Unit Acres (%)	% Organic Matter (SSURGO)	Predicted levels of SOM (%)			
			No Residue Removal	Annual Residue Removal	Bi-annual Removal	Tri-annual Removal
Canisteo silty clay loam, 0 to 2 percent slopes	24.54	6.5	9.22	8.52	8.92	9.01
Clarion loam, 2 to 5 percent slopes	19.74	3.5	4.96	4.59	4.80	4.85
Nicollet loam, 1 to 3 percent slopes	14.2	5.5	7.81	7.21	7.55	7.62
Webster silty clay loam, 0 to 2 percent slopes	9.64	6.5	9.14	8.44	8.81	8.94
Harps loam, 0 to 2 percent slopes	4.49	5.0	7.11	6.57	6.87	6.94
Clarion loam, 5 to 9 percent slopes, moderately eroded	4.49	2.7	3.81	3.50	3.67	3.70

The results show that some soils could potentially reach over 9% soil organic matter under no residue removal management. Two key conclusions result from this analysis. First, for each of these soils and residue removal practices the long term soil organic carbon increases. This is a very positive conclusion suggesting that residue removal at the modeled rates will be sustainable for energy production. Second, the interval removal schemas provide an agronomic strategy which will result in less soil organic matter stress than annual removal. This is important for considering best management practices for residue removal on land which is potentially at risk.

References Cited

- U.S. Department of Energy (2011). "U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry." Oak Ridge National Laboratory, Oak Ridge, TN.
- U.S. Environmental Protection Agency. (2012). "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2010." *EPA 430-R-12-001*, U.S. Environmental Protection Agency, Washington, DC.
- Del Grosso, S. J., Parton, W. J., Mosier, A. R., Hartman, M. D., Brenner, J., Ojima, D. S., and Schimel, D. S. (2001). "Simulated interaction of carbon dynamics and nitrogen trace gas fluxed using the DAYCENT model." Modeling carbon and nitrogen dynamics for soil management, S. Hansen, M. J. Shaffer, and L. Ma, eds., Lewis Publishers, Boca Raton, FL, 303-332.
- Hess, J., Kenney, K., Wright, C., Perlack, R., and Turhollow, A. (2009). "Corn stover availability for biomass conversion: situation analysis." *Cellulose*, 16(4), 599-619.
- Johnson, J. M.-F., Papiernik, S. K., Mikha, M. M., Spokas, K. A., Tomer, M. D., and Weyers, S. L. (2010). "Soil Processes and Residue Harvest Management " Soil Quality and Biofuel Production, R. Lal and B.A. Stewart, eds., Taylor and Francis, LLC., Boca Raton, FL, 1-44.

- McCool, D. K., Foster, G. R., and Yoder, D. C. (2004). "The Revised Universal Soil Loss Equation, Version 2." 13th International Soil Conservation Organisation Conference, Brisbane, Australia, 1-4.
- McCorkle, D., and Bryden, K. (2007). "Using the Semantic Web technologies in virtual engineering tools to create extensible interfaces." *Virtual Reality*, 11(4), 253-260.
- Muth, D. J., and Bryden, K. M. (2013). "An integrated model for assessment of sustainable agricultural residue removal limits for bioenergy systems." *Environmental Modelling and Software*, 39, 50-69.
- Muth, D. J., Nelson, R. G., and Bryden, K. M. (2013). "Sustainable Agricultural Residue Removal for Bioenergy: A Spatially Comprehensive National Assessment." *Applied Energy*, 102, 403-417.
- Parton, W. J., Hartman, M., Ojima, D., and Schimel, D. (1998). "DAYCENT and its land surface submodel: description and testing." *Global and Planetary Change*, 19, 35-48.
- USDA-NRCS. (2012). "Soil Conditioning Index."
- Wagner, L. E. "An Overview of the Wind Erosion Prediction System." *Proceedings of the International Conference on Air Pollution from Agricultural Operations*, Ames, IA.
- Wilhelm, W. W., Hess, J. R., Karlen, D. L., Johnson, J. M.-F., Muth, D. J., Baker, J. M., and al., e. (2010). "Balancing limiting factors and economic drivers for sustainable Midwest agricultural residue feedstock supplies." *Industrial Biotechnology*, 6(5), 271-287.