In order to contribute to better public understanding of this set of issues, we assessed the consequences associated with different crop residue management options using field-scale research conducted at the Washington State University Cook Agronomy Farm near Pullman, Washington. In particular, we evaluated the impacts of residue removal for energy production on soil carbon sequestration, crop nutrient removal, and soil erosion.

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Trade-offs between Bio-energy and Soil Carbon Sequestration on the Palouse: Evaluating Sustainable Options

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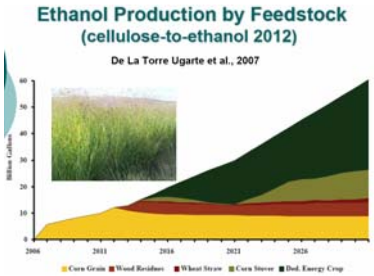
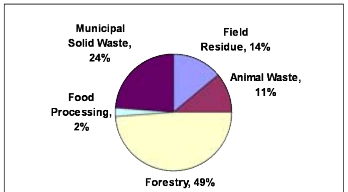


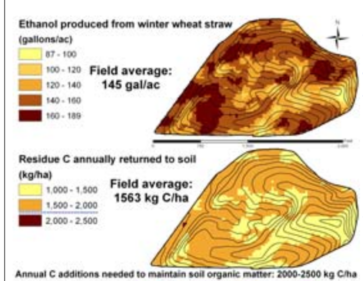
In February 2006, President Bush launched the "Advanced Energy Initiative" that established a goal of replacing 15 percent of the nation's gasoline consumption with 35 billion gallons of renewable and alternative fuels, such as ethanol, by 2017. The US Department of Energy indicates that crop residues are likely to be a key biomass feedstock. Frear, et. al. (2005), indicate that crop residues could provide 14% of feedstocks for biofuels in Washington State. While crop residue utilization represents both an opportunity for energy production, it raises serious concerns for sustaining soil resources.

Crop residues as a portion of biomass feedstocks from biofuels.



Frear, et.al. (2005). Washington Biomass Inventory.

In order to contribute to science-based land management and public policy, we assessed trade-offs associated with different crop residue management options using field-scale research from the Washington State University Cook Agronomy Farm near Pullman, Washington. Here, we assess the impacts of harvesting crop residues for energy production on soil carbon sequestration and nutrient removal.

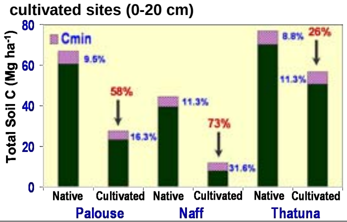


Trade-offs between residue removal for bio-energy and maintenance of soil organic matter are illustrated to the left for the WSU Cook Agronomy Farm near Pullman.

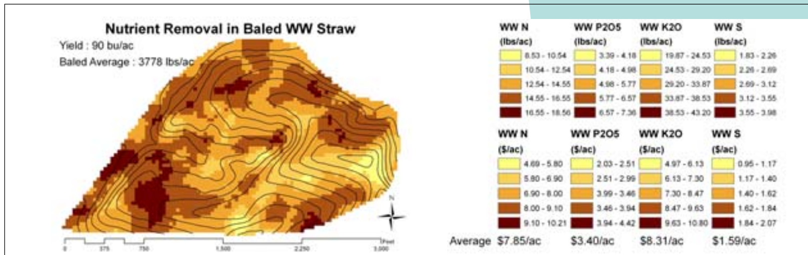
The upper image shows the amount of ethanol (gal per acre) that could be produced from winter wheat straw harvested every other year in a winter wheat-spring pea crop rotation. Average winter wheat yield for the field is 90 bu per acre producing 3.9 Tons per acre of total residue of which 49% or 1.89 Tons per acre of wheat straw can typically be baled and removed. Assuming 77.1 gal of ethanol can be produced from 1 Ton of wheat straw, field average estimates for ethanol are 145 gal per acre. Within field variation, however, is over two-fold ranging from 87 to 189 gal/ac. Further analyses are needed to assess if residue removal is economically viable for all field locations.

The lower image shows the net annual return of carbon in crop residues (45% C) after winter wheat straw is harvested for energy production. Annual returns of residue C needed to maintain soil organic matter levels are between 2000 and 2500 kg C/ha. In this case, removal of crop residues for energy production does not leave sufficient residues to maintain soil carbon levels, much less increase them.

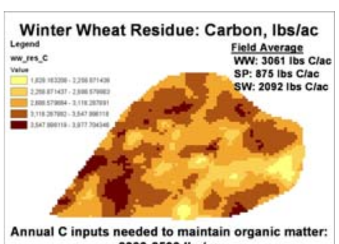
Total soil carbon and portion mineralized (Cmin, 182 day incubations) for Palouse, Naff and Thatuna soils at neighboring native and cultivated sites (0-20 cm)



Agricultural soil management practices (ie. cultivation, fallowing) have led to exponential declines in soil organic matter following the conversion of native prairies to agricultural production. In the dryland cropping regions of the Pacific Northwest, severe soil erosion, which preferentially removes soil organic materials from farm fields, also contributed to declining soil carbon with eroded soils often averaging only 25% of native soil carbon levels. The loss of soil organic matter has seriously degraded the native productivity of many soils by reducing water infiltration, water holding capacity, nutrient supplying power and effective rooting depth. Degraded soils require increased inputs of nutrients, water and pesticides to maintain crop yields and often are more vulnerable to further degradation under normal weather extremes. Further removal of crop residues for energy will increase the pressure on soil resources.



Another trade-off of utilizing crop residues for energy production is the removal of nutrients contained in the residues. We analyzed the value of nutrients contained in crop residues distributed across the field using June 2007 prices. The average value of nutrients per ton of straw was >$13. The DOE's model for cost-effective ethanol feedstock includes only a $10 / ton payment to the farmer.



In the dryland cropping region of the Inland Pacific Northwest, carbon in wheat residues following harvest can be in excess of 4,500 lbs C /ac - equivalent to about 400 gal/ac of ethanol with current technology. Considering that annual carbon inputs of about 2,000 lbs C /ac will sustain current levels of soil carbon in typical agricultural lands, it appears at first glance that residue removal for bio-energy is an attractive option with little down-side. However, crop rotation and large within field variability of residue production complicate this simple analysis. The relatively small residue production from common rotational crops such as peas and lentils or from fallow must be compensated by large residue returns during cereal production. Furthermore, although field averages of residue production may look promising, degraded portions of fields often produce 2-3X less than high producing areas and are more vulnerable to further degradation if residues are removed. Therefore, residue harvest must consider spatial-temporal variations in residue production due to rotation and site characteristics.

While removal of crop residues for energy production will increase the need for synthetic fertilizers and can have negative consequences for soil health, we propose that sustainable options for residue removal are possible with the following considerations in mind:

- First, evaluate crop rotation options, within field variation in residue production and site-specific soil condition to make good, science-based decisions for residue removal in an individual field. Biophysical modeling tools and GIS applications as used in our analyses can provide more complete assessments.
- Second, perennial crops can substitute for and even enhance the agro-ecological functions of crop residues while providing the biomass needed for energy production. Long-term, sustainable strategies for utilizing biomass as an energy feedstock should seriously consider developing viable perennial biomass crops including legumes.