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ECONOMICS OF RESIDUE HARVEST: REGIONAL PARTNERSHIP EVALUATION

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Economic analyses on the viability of corn (*Zea mays*, L.) stover harvest for bioenergy production have largely been based on simulation modeling. While some studies have utilized field research data, most field-based analyses have included a limited number of sites and a very narrow geographic distribution. This analysis evaluates the biomass prices needed for profitable corn stover harvest for three stover harvest strategies. The analysis utilizes grain and residue yield and associated management information from the Sun Grant Regional Partnership locations associated with the Corn Stover Regional Partnership Team and other long-term ARS studies contributing to the Renewable Energy Assessment Project (REAP). An Iowa case study is developed quantifying costs for delivery of corn stover to a biorefinery using the Biomass Logistics Model. Results show that economics will tend to drive residue harvest toward higher removal rates. However, higher removal rates can degrade soil resources. Limiting harvest quantities to leave sufficient residues to protect against excessive erosion and maintain soil organic carbon levels may provide economic incentives for producers to adopt cropping practices, such as no-till and cover cropping, that allows for higher harvest rates and reduces biomass costs to the biorefinery.

Keywords: corn stover, bioenergy, economics, sustainability

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INTRODUCTION

Economic analyses on the viability of corn stover harvest for bioenergy production have largely been based on simulation modeling (Archer and Johnson, 2012, Graham et al., 2000; Kurkalova et al., 2010). While some studies have utilized field research data, most field-based analyses have included a limited number of sites and a very narrow geographic distribution (Hoskinson, et al., 2007; James et al., 2010). However, field studies are being conducted at sites across the U.S. (Karlen, 2010). By consolidating information from these studies into a common database, there is an opportunity to utilize these data to conduct economic analysis for a wide range of sites based on field research data. Furthermore, these data provide validation points that can help improve the credibility and reliability of model-based analyses. The objective of this analysis is to demonstrate the use of a newly-implemented field research database to analyze corn stover supply. The methodology is demonstrated as a case study for sustainable biomass supply delivered to an Iowa biorefinery.

METHODS AND MATERIALS

The analysis utilized grain and residue yield and associated management information from the Sun Grant Regional Partnership locations associated with the Corn Stover Regional Partnership Team and other long-term ARS studies contributing to the Renewable Energy Assessment Project (REAP). A common database has been implemented as part of REAP to store data for each of the participating research sites. The database includes treatment and location information, weather information; soil, greenhouse gas, plant, and biomass measurements, and detailed management information for each site. Data from the 'Field 70/71' site at Ames, IA, and a stover harvest near Emmetsburg, IA (Karlen et al., 2012) were used to demonstrate the potential use of this database for economic analysis of corn stover supply. These data were used construct crop enterprise budgets for the crop production treatments and as inputs to the Biomass Logistics Model (Jacobson et al., 2010) to evaluate three biomass harvest scenarios: cob-only harvest; rake and bale stover removal; and chop, rake and bale stover removal.

Crop Production Budgets

Management data were retrieved from the database for the 'Field 70/71' site, and were used to construct crop enterprise budgets for the conservation tillage (CT) and no-till (NT) continuous corn treatments, under standard management (Standard) and the no-till corn plus rye cover crop treatment (NT+Rye). The enterprise budgets were constructed based on the machinery operations and inputs used in the field study. Machinery costs were from 2012 projected costs from Iowa State University Extension budgets (Duffy, 2011). Machinery costs include depreciation, interest, taxes, insurance, fuel, lubricants, and repairs. Seed, fertilizer, and pesticide costs were 2011-2012 prices from USDA National Agricultural Statistics Service (USDA-NASS, 2012) or from North Dakota State University Extension (NDSU, 2012) for items where NASS data were not reported. Costs did not include land, labor and management, or crop insurance, drying, hauling, or storage costs. Corn grain gross income was calculated using a corn price of \$184 Mg^{-1}, which was the average price received by Iowa farmers for 2007-2011 (USDA-NASS, 2012).

Biomass Logistics Model

The Biomass Logistics Model (BLM) is part of a simulation toolset developed by Idaho National Laboratory (INL) to estimate delivered feedstock cost, and energy consumed for supply systems delivering biomass to biorefineries for biofuel production (Jacobson et al., 2010). The BLM is engineered to work with various thermochemical and biochemical conversion platforms and accommodates numerous biomass materials (i.e., herbaceous residues, short- rotation woody and herbaceous energy crops, woody residues, algae, etc.). The BLM simulates the flow of biomass through the entire supply chain, tracking changes in feedstock characteristics (i.e. moisture content, dry matter, ash content, and dry bulk density) as influenced by the various operations in the supply chain. By accounting for all equipment that comes in contact with biomass from the point of harvest to the throat of the conversion facility and the change in characteristics, the BLM enables detailed economic costs and energy consumption analysis. As a result of this analysis, high impact areas for improvement (i.e. equipment efficiencies, operational parameters, environmental conditions etc.) can be identified to guide feedstock supply system research and development.

Three feedstock supply system cases are examined for this analysis. The first case is a cob only removal. In this case the harvester is modified to pull a cart that separates and collects cobs directly from the harvester. The removal rate for cobs is assumed to be around 12% of the total biomass available (Ref Doug/Jane study). The second case examines a moderate removal rate of around 50%. In this system a rake is then used to collect the residue into a windrow. The windrow is then baled into 3’x4’x8’ square bales. The third case examines a high residue removal rate. In this system a flail shredder is used to cut the standing stubble and collect the surface residue into a single windrow. In a third pass, the windrow is baled into 3'x4'x8' square bales. WHAT IS THE REMOVAL RATE FOR THIS CASE NOW???

RESULTS AND DISCUSSION

Average grain costs and returns are shown in Table 1. There was no significant difference in net returns between CT and NT. However, CT is much more common than NT in Iowa. Only 18% of the area planted to corn in Iowa in 2010 was NT, and over 87% of NT corn was planted into soybean stubble, not corn stubble (USDA-ERS, 2012). This may indicate that producers would need to see clear advantages, economic or otherwise, before they would be willing to shift toward NT corn production. The NT+Rye treatment had higher production costs than NT Standard due to the added cost of cover crop seed and cover crop planting.

The difference in grain yields between the cases of CT Standard and NT Standard were insignificant, varying from 9.1 to 9.25 Mg ha^{-1} (dry matter), so the logistics analysis assumed a 9.25 Mg ha^{-1} yield for all analyses. The cost of each of the three logistics supply systems are shown in Table 2. The cob only supply system was more expensive due to the low yields which increase the radius of farm acres needed to supply the biorefinery which drove up the transportation costs. The high residue removal case was least expensive due to the cheaper harvesting cost by using the flail shredder to cut the stubble and windrow the residue. So, economics will tend to drive residue harvest toward higher removal rates.

However, the higher removal rates could lead to higher soil erosion and reduce soil organic carbon, and these impacts would be greater under CT than under NT. The minimum amount of residue needed to sustain the soil resource is higher under CT than under NT. Field research indicates that corn cob only harvest would likely meet the minimum residue retention under CT for Iowa corn production levels. However, rake and bale would often not retain sufficient residue under CT (Johnson et al., 2012). Industry partners working toward commercialization have recognized the economic benefits of higher harvest rates while maintaining minimum residue levels and have shifted from corn cob only harvest to removing more biomass, but short of rake and bale removal levels. Shifting to NT would likely retain sufficient residue to allow for rake and bale harvest, and possible chop, rake, and bale harvest (Johnson et al., 2012). Adding cover crops or perennial crop phases may help ensure that higher removal rates could be sustained.

Since higher removal rates reduce feedstock costs to the biomass plant, there may be opportunities for economic incentives to adopt NT or NT+Rye, depending on how contracts and payments to producers are structured. Suppose the biorefinery pays all harvest and logistics costs, and, following the assumption used in the Billion-Ton Update (U.S. Department of Energy, 2011), a grower payment of \$33 Mg^{-1} including nutrient replacement costs. Net returns for residue harvest would be \$15.72, \$56.95, \$67.03 ha^{-1} for cob only; rake and bale; and chop, rake, and bale, respectively. If sustainable harvest limits CT to cob only, while NT or NT+Rye allow for rake and bale, or chop, rake and bale, shifting to NT or NT+Rye could increase biomass harvest net returns by \$41.23 ha^{-1} to \$51.31 ha^{-1}. This may provide additional incentive for producers to adopt NT and would cover much of the added cost for planting a rye cover crop. In addition, the biorefinery could see reductions in biomass costs of \$5.05 to 8.30 Mg^{-1}. An important question is whether the higher net returns for NT would be sufficient to substantially increase NT adoption. Also, it is important to note that grower benefits for adopting NT or NT+Rye only occur if the biorefinery does not accept biomass harvested at rates above sustainability limits. However, short-term biomass cost reductions to the biorefinery occur with higher removal rates regardless of whether harvest rates are sustainable, but higher removal rates could drive up cost in the long run through reductions in productivity and increases in production costs.

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List of Tables and Figures

Table 1. 2008-2011 average production costs, grain gross returns and net returns for each continuous corn treatment

	CT Standard	NT Standard	NT+ Rye
	------------------------------$ ha^{-1}		------------------------------
Grain gross returns	1975.15	1973.87	1973.87[†]
Production Cost	842.61	826.57	874.12
Grain Net Return	1132.54	1147.30	1099.75[†]

[†]A zero residue harvest treatment was not included for NT+Rye in the study, so grain gross returns and grain net return calculations assume grain yield equal to the NT, Standard treatment.

Table 2: Biomass yield, nutrient replacement (N, P, K) costs, and feedstock logistics costs for the three harvest logistics supply systems, cob only, medium residue removal and high residue removal.

Feedstock	Harvest System	Removal Rate	Dry Biomass Yield	Nutrient Replacement Cost	Logistics Cost
			Mg ha^{-1}	\$ Mg^{-1}	\$ Mg^{-1}
Corn Cob Only	Cob caddy	12%	1.0	17.28	47.70
Stover	Rake and Bale	50%	4.1	19.11	42.65
Stover	Chop, Rake and Bale	60%	5.2	20.11	39.40