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Synergies between cover crops and corn stover removal

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ABSTRACT

The potential harvest of corn stover as a feedstock for biofuels to meet government mandates has raised concerns about the agronomic impacts of its removal from fields. Furthermore, in order to meet these mandates, larger quantities of stover will be required. As a result, increased attention has been placed on sustainable agronomic practices, such as cover crops. While cover crops may offer desirable benefits, adoption comes at a cost. The objective of this study was to determine the extent to which cover crop costs could be compensated by additional stover removal and additional agronomic benefits from the use of cover crops.

To meet the objective, we took three distinct approaches: (1) benefit-cost analysis, (2) integrated model analysis, and (3) representative farm analysis using the linear programming model PC-LP. Each approach was a different take on the same issue; however, each provided different information. First, we estimated cover crop costs and agronomic benefits and employed benefit-cost analyses, including stochastic analysis in @RISK. Second, we tested cover crops with stover removal for 24 Indiana farms using PC-LP. Cover crop costs ranged from \$81.76/ha to \$172.50/ha, with variability being driven by differences in the seeding rate and seed cost. Agronomic benefits included reduced erosion, which was calculated using a newly created integrated modeling system.

The mean estimated reduced soil erosion with a cover crop and no residue removal was 0.72 metric tons/ha. An analysis of cover crop agronomic benefits resulted in private benefits (on-site) ranging from \$91.45/ha to \$192.07/ha, and \$97.63/ha to \$198.27/ha from society's perspective. These benefits were highly influenced by added or scavenged nitrogen (N) from the cover crop. For sensitivity we eliminated the benefit from added N and reevaluated the results. Without the N credit, benefits ranged from \$74.72/ha to \$134.62/ha. Benefit-cost analyses when considering the agronomic benefits of cover crops resulted in a range of a net loss of \$11.09/ha to a net benefit of \$87.32/ha for the private perspective.

The integrated modeling system results indicated that, on average, while holding soil erosion constant, an additional 4.01 metric tons/ha of stover could be removed if a cover crop were used. Accounting for cover crop costs and stover removal, a benefit-cost analysis suggested that at a farm-gate stover price of \$66.14/metric ton, net benefits ranged from a loss of \$3.78/ha to a net benefit of \$86.93/ha. At a farm-gate stover price of \$88.18/metric ton, mean net benefit ranged from \$158.81/ha to \$249.52/ha.

Results from the farm model (PC-LP) indicated that cover crops, along with increased stover removal, impacted crop rotations, increased the total amount of stover harvested, and had the potential to increase farm profits.

1. Introduction

As concerns with global warming increase, alternative energy sources are continually being sought. The Energy Independence and Security Act (EISA, 2007) established that by 2022, 36 billion gallons (144 billion liters) of biofuel are to come from renewable fuel sources. More specifically, the mandate requires the production of cellulosic biofuels to increase to 16 billion gallons (64 billion liters) ethanol equivalent annually by 2022 (EISA, 2007). Cellulosic biofuels are derived from several sources including corn (*Zea mays* L.) residue, or corn stover. Of the 16 billion gallons mandated by 2022, 7.8 billion gallons (31.2 billion liters) are estimated to come from corn stover (EPA, 2009). It is also favored due to the fact that it is readily available and has a high cellulosic content (Blanco-Canqui and Lal, 2009).

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Corn stover (also interchangeably referred to as ''residue'', ''stover'', and ''biomass'' throughout this study) is a crop residue which is identified as the ''above ground material left in fields after corn grain harvest'' (Karlen et al., 2011). The components of corn stover were found to be 30% husks, shanks, silks, and cobs, and the rest stalks, tassels, leaf blades, and leaf sheaths (Hoskinson et al., 2007). Crop residues, such as corn stover, which typically remain on the field, are responsible in numerous ways for preserving the soil (Huggins et al., 2011). While corn stover could be a promising source of biofuels, several concerns have risen about its removal from the fields. This has brought new attention to conservation practices, such as planting cover crops. While it has been observed that moderate removal of stover may actually be beneficial (Swan et al., 1994), increased removal can have many adverse effects (Blanco-Canqui and Lal, 2009; Blanco-Canqui and Lal, 2007; Meki et al., 2011; Wilhelm et al., 2004). Acceptable removal rates of corn stover vary across studies, but there is evidence to suggest that rates of removal may be limited to around 33% of total available stover due to the potential negative effects on soil quality and productivity (Blanco-Canqui and Lal, 2009; Graham et al., 2007; Kim and Dale, 2004; McAloon et al., 2000; Nelson, 2002; Petrolia, 2006; Thompson and Tyner, 2011; Thompson and Tyner, 2014). Over the years, much research has been conducted to show the agronomic advantages and disadvantages of using various cover crops (Frye and Blevins, 1989; Dapaah and Vyn, 1998; Stivers-Young and Tucker, 1999; Kinyangi et al., 2001; Andraski and Bundy, 2005; Snapp et al., 2005). More recent research has shown that in addition to agronomic benefits associated with cover crops, there may also be an opportunity for economic gains if cover crop residue could reduce subsequent fertilizer application and even more so if it can be sold as forage (Gabriel et al., 2013). Given the known benefits of cover crops, it is believed that these benefits could mitigate the potentially adverse impacts of stover removal. Furthermore, the use of cover crops may allow corn stover to be removed at higher rates, which could potentially increase farm revenues.

While the Midwest Corn Belt region is seen as a major supplier of corn stover, cover crops have not been widely adopted. The aim of this study is to analyze the economic and agronomic impacts of stover removal when done in combination with cover crops in the Midwest. Specifically, to what extent would it pay for famers to establish a cover crop if it were possible to increase stover removal rates from 33% to 50% or higher. This analysis considers data from several sources in order to quantify the benefits and costs of cover crops. Additionally, we evaluate the extent to which cover crops allow for increased stover removal without adverse agronomic consequences. Ultimately, the combination of information on stover removal and cover crops is used to determine if the additional revenue from stover removal will compensate farmers for the costs of establishing cover crops.

2. Materials and methods

The data used (or applied) in this study comes from several sources including the Midwest Cover Crop Council (MCCC) Cover Crop Decision Tool, farmer interviews, and anecdotal evidence. We consider six pure cover crops and two cover crop mixes for our analysis: (1) annual ryegrass (*lolium multiflorum*), (2) cereal rye (*secale cereal*), (3) crimson clover (*trifdium incarnatum*), (4) hairy vetch (*vicia villosa)*, (5) oats (*avena sativa*), (6) oilseed radish (*raphanus sativus*), (7) annual ryegrass/crimson clover mix, (8) annual ryegrass/oilseed radish mix. Because of paucity of data, and in some cases poor understanding of how management practices affect soils, we employ several methods and models to analyze the costs and benefits of cover crops coupled with corn stover removal. Each method allows us to approach our objective from a different angle. In doing so, each approach brings something to the overall picture and helps us confirm our results.

First we estimate the cost of cover crops. Next we quantify the benefits of cover crops. Quantifying cover crop benefits involves two separate cases, both of which involve the use of an integrated model: one for agronomic benefits, and another for additional stover removal. Once costs and benefits are quantified and estimated, a benefit-cost analysis with risk distributions is conducted. Finally, cover crop costs are used in a linear programming model to simulate the impacts of cover crops and corn stover removal at the farm level based on real data for 24 Midwest farmers.

2.1. Cover crop cost estimates

We develop a method of cover crop cost estimation which breaks down costs into three components: (1) establishment, (2) termination, and (3) unexpected costs. Establishment costs assumed in this analysis are those costs that are required to aerially inter-seed the cover crop in the fall into the standing cash crop. The components of the establishment cost therefore include the recommended cover crop seeding rate, seed cost, and the cost of aerial application.

Recommended aerial seeding rates for each cover crop come from the MCCC Cover Crop Selector (MCCC, 2012) (available at www.mccc.msu.edu) as a range and are measured as pounds of pure live seed (PLS) per acre. This measure is adjusted to account for the percent purity and the percent germination of a cover crop. The percent purity for seeds is usually about 98–99% and percent germination ranges from 85% to 90% (E. Kladivko, personal communication, September 4, 2012). Since an actual plot is not being tested, we increase the recommended PLS rates for each cover crop provided by the MCCC by 10%. Given the recommended aerial seeding rate for each cover crop and taking into account the cost of seed, it is possible to estimate the seed costs of cover crops. Using quotes from seed suppliers listed in Clark (2007) and prices stated by several farmers, a range of seed costs for each cover crop or cover crop mix is generated. The final component of the establishment cost is the cost of aerial application, which is often done at custom rates. Data for this component comes from anecdotal evidence (Vollmer, 2011) and farmer interviews. The mean estimated aerial application cost is $30.39/ha, the minimum is $24.71/ha and the maximum is $37.06/ha.

Termination costs assumed in this analysis are those costs associated with chemically killing the cover crop in the spring before planting a cash crop, which very often is also done at a custom rate. Using estimated custom rate costs from anecdotal evidence (USDA, 2011a) and farmer interviews, the estimated mean termination cost is $15.76/ha. The minimum is $11.12/ha and the maximum termination cost is $22.24/ha. It should be noted that in some cases, this chemical application would occur regardless of the presence of cover crops or not. Therefore, since we cannot differentiate the proportion of this cost that could be attributed to the use of cover crops or standard field operations, the full cost is used in our analysis.

Due to the inherent risk that planting cover crops carries to a farmer, a cost item has been included to account for an unexpected negative event, such as needing more than one pass of cover crop termination (chemical or mechanical) if it does not kill initially, untimely termination, the cover crop becoming a weed issue in the following cash crop and/or the need to disc an area twice in the spring. Snapp et al. (2005) reports on similar events as ''indirect on-farm costs'' where the establishment of a cover crop may interfere with the following cash crop or where the cover crop has excessive growth or becomes a weed. For this analysis, the total unexpected cost is the probability that the unexpected cost will be incurred multiplied by the associated cost per acre. Based on