Economic and Environmental Impacts of Cellulosic Feedstock Production in Minnesota

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Introduction

Cellulosic ethanol is in the spotlight as the Federal Government plan to increase alternative fuel production. Currently most biorefineries are based on corn grain as a feedstock, cellulosic ethanol has advantages over corn ethanol. Using corn stover or other lignocelluloses does not compete with human food use while large amounts of corn are required for corn ethanol. Cellulosic ethanol is estimated to reduce greenhouse gases more than corn ethanol (Hill et al. 2009). Biofuels from perennials grown on marginal or abandoned cropland can offer immediate and sustained GHG advantages (Fargione et al. 2008).

When corn-stover is harvested for biofuel feedstock, plant nutrients contained in the stover are also removed. Additional fertilizer must be applied to compensate for the nutrient loss. Removal of stover may also lead to significant increases in surface water contamination. This research will focus on the economic and environmental impacts of emerging biofuels economies on Minnesota agriculture.

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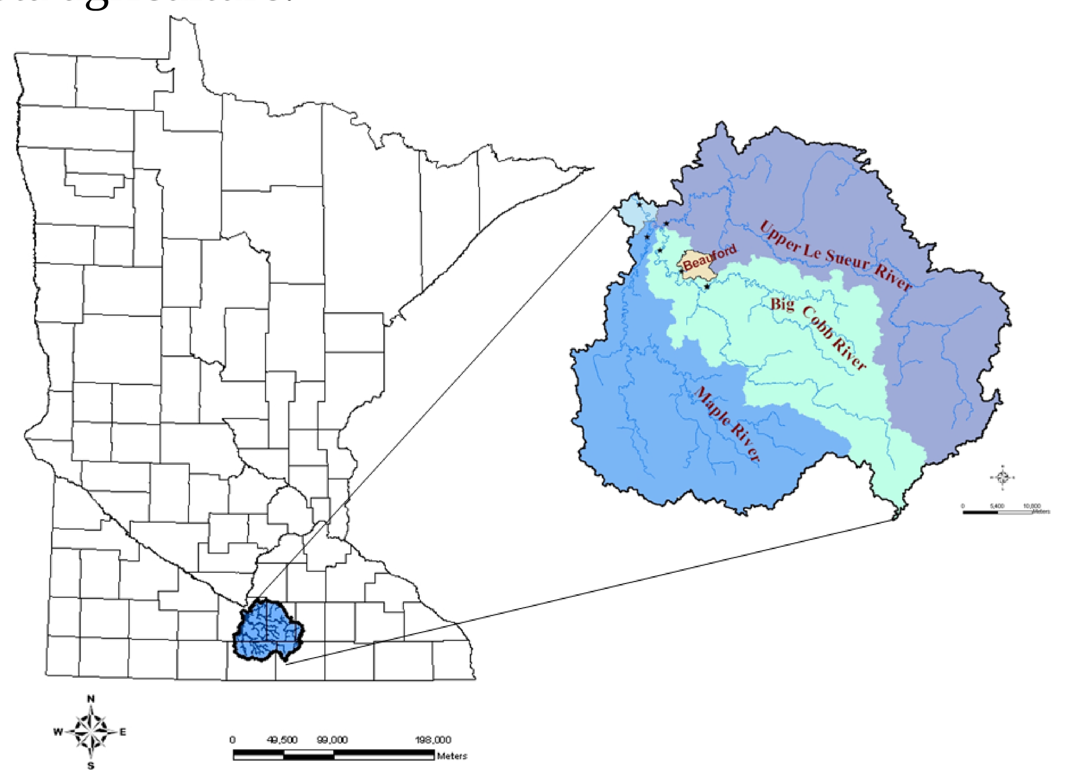

Figure 1: Location of the LeSueur River Watershed

The objective of this study is to analyze the environmental outcomes and crop production activity changes associated with cellulosic ethanol feedstock production. The LeSueur River watershed in southern Minnesota (Fig. 1) has been selected as the study region for this paper. The region is typical of Minnesota and Iowa corn-soybean agricultural production with large potential for biofuel feedstock production.

Model & Data

The Agricultural Sector Model: An economic model of the agricultural sector in the watershed was constructed. This multi-region, endogenous-supply, spatial equilibrium model has a general structure similar to typical mathematical programming models of agricultural sectors, but with a high level of spatial detail. The model is used to estimate feedstock supply at a centrally located biofuel processing plant.

Some general characteristics of the model:

- 47 Townships used as regions, each approx 6 miles by 6 miles.
- Unique production activities defined for each of 84 sub-watersheds.
- Baseline crop production activity a two-year, corn-soybean rotation.
- Alternative production activities include three-year, corn-corn-soybean rotation, and stover harvest at 0%, 10%, 30% & 60% of available crop residue.
- Input coefficients and costs based on empirical data; yields and effluent levels simulated using SWAT – including soybean, corn grain and stover, and sediment, nitrogen and phosphorus effluent levels.
- Fixed stover demand at a central region is parametrically increased from zero to the maximum possible output for the region to estimate feedstock supply for each market, policy and technology scenario.
- The regional economic model is constructed with GAMS; there are 2216 crop production activities and 2087 input supply, product demand and transportation activities; 2039 input and product balance and other constraints.

The Soil and Water Assessment Tool (SWAT)

is a basin-scale simulation model capable of predicting the effects of alternative land management practice. SWAT is used to simulate the effects of corn stover production on soil and water quality. Technical coefficients for the sector model use SWAT simulation results including yield of corn, soybean, stover, and discharges of sediment, nitrogen, and phosphorus in 84 sub-watersheds of the LSW.

Results

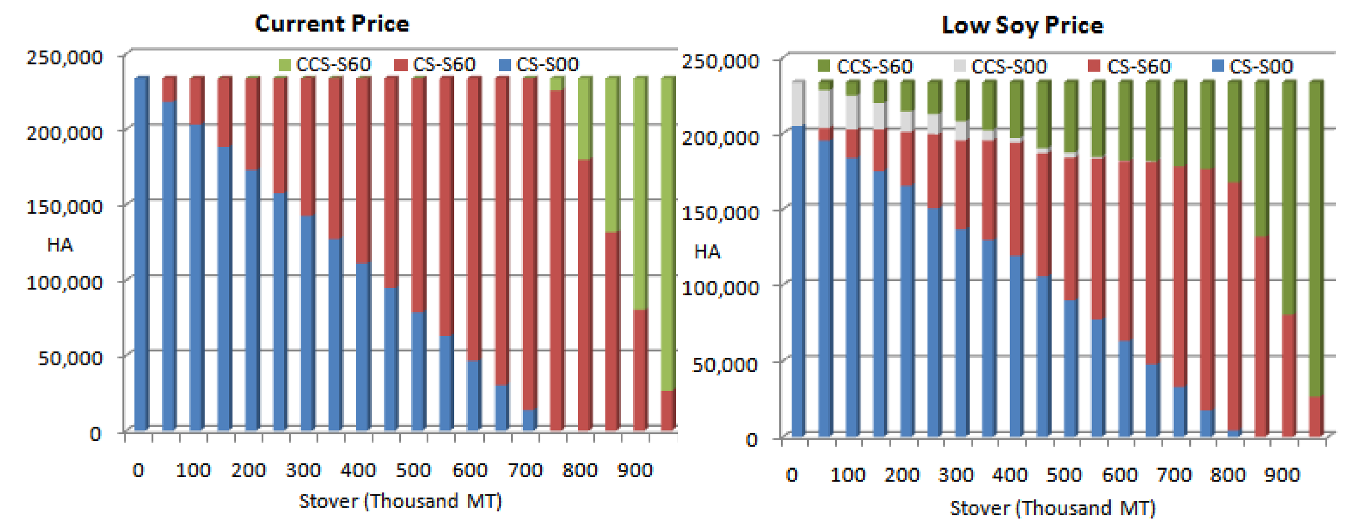

Figure 2: Crop Production Activity Change

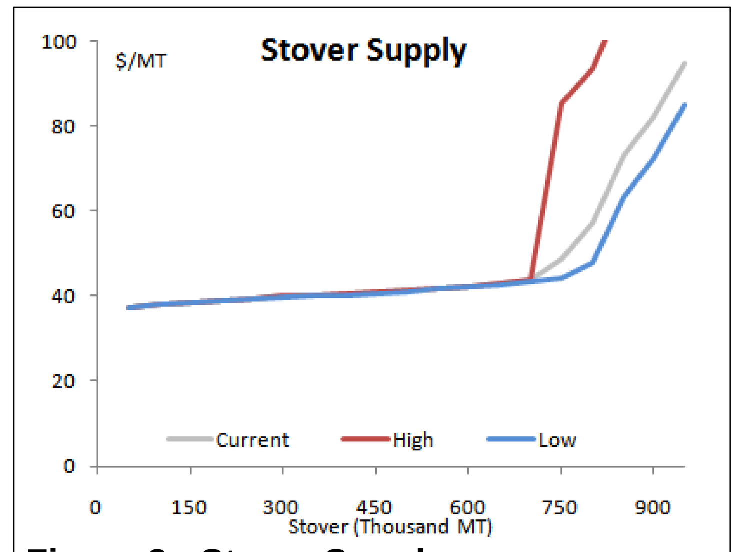

Figure 3: Stover Supply

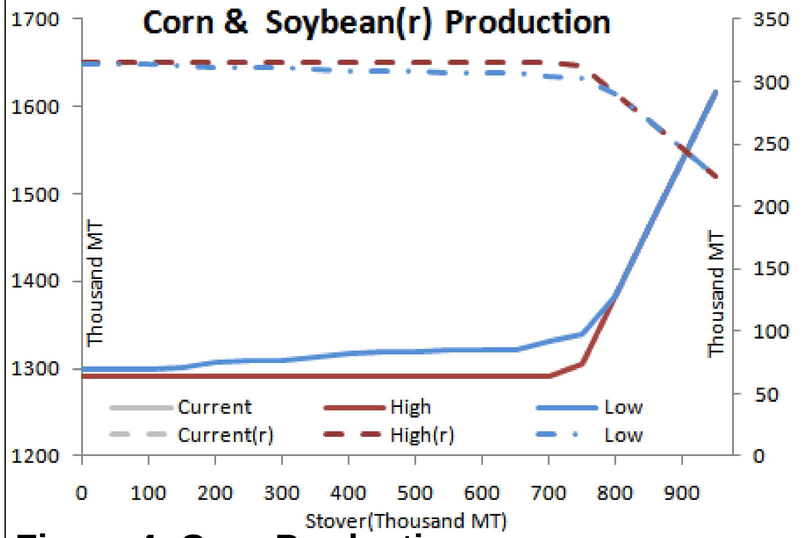

Figure 4: Crop Production

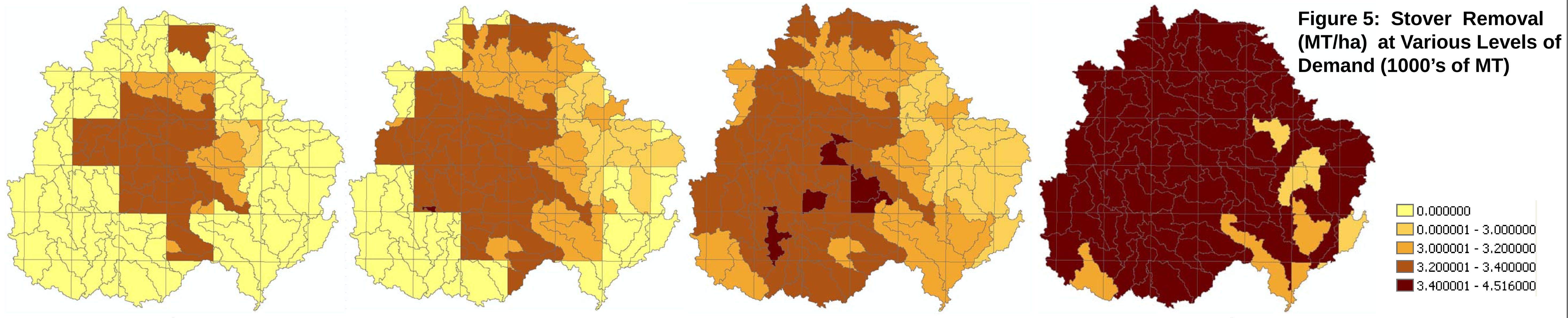

Figure 5: Stover Removal (MT/ha) at Various Levels of Demand (1000's of MT)

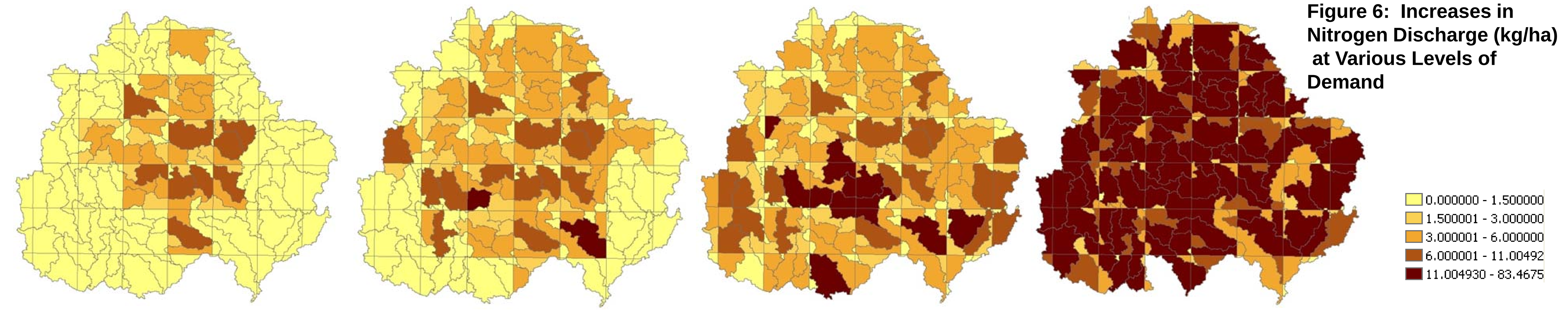

Figure 6: Increases in Nitrogen Discharge (kg/ha) at Various Levels of Demand

- The area in a CCS rotation with 60% stover removal increases as stover demand increases, especially when soybean prices are low (Fig 2). As stover demand and supply price increase, the area planted to corn goes up (Fig. 3 and 4).

- As stover demand increases, stover production becomes more intensive and moves to areas further away from the processing plant (Fig. 5). Increased stover removal results in increasing additions of N fertilizer and losses of nitrate-N to surface waters (Fig. 6).

Conclusions

- As stover demand increases, intensive corn production activities are adopted, especially if soybean prices are low.

- High rates of stover demand/removal accelerate nitrogen losses.

- Future work will examine how ethanol production and environmental outcomes change as switchgrass replaces corn on steep, marginal, or CRP land.