LAND USE AND ENVIRONMENTAL IMPACTS OF CORN GRAIN VS CELLULOSIC ETHANOL: A GIS APPROACH

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Overview

Demand for biomass-based energy is increasing due to global concerns about climate change and energy self-sufficiency. Foreign oil dependency and its effects on national security are increasing demand for bioenergy research and production in the United States, and the issue found a prominent place in the President's State of the Union Address in both 2006 and 2007. Substituting biomass-based fuels for petroleum in the transportation sector is expected to make the a large contribution to addressing these concerns.

Estimated biomass availability is highest in the Midwest (Milbrandt 2005), and Iowa is among the many Midwest states that are rapidly transforming their economies to embrace increased biofuel production and its support industries. Indeed, Iowa, is the leading biofuels hotspot in the U.S. due to intensive corn production and the high concentration of ethanol plants that comprise 28% of total U.S. production. Public enthusiasm has been focused on the renewability of biomass feedstock (fuelstock) and potential positive environmental and economic impacts. However, less attention has been paid to the sustainability of the biofuel production system as a whole. And, there is growing consensus that grain-based ethanol is a "first-generation biofuel" marking a large-scale transition to a contemporary lignocellulosic carbon-based economy (versus fossil carbon) (OBP 2005).

To determine the feasibility/profitability of engaging in second-generation biofuels supply chains requires estimates of land's productivity in producing dedicated biomass crops and byproducts such as corn stover relative to corn and soybeans. We consider the impact of the biofuels industry both on current cropland and on land in the Conservation Reserve Program (CRP), a land set-aside program. We estimate potential switchgrass yields and corn stover availability in the state of Iowa at a very fine, spatially explicit scale, based on changes in land coverage for switchgrass, corn, and soybeans in response to changes in crop prices. We estimate soil erosion, nutrient loss, and carbon sequestration for each land coverage scenario. The output maps can be used to assess the economic implications of different land use strategies or incentive policies, as an indicator of the potential environmental impacts of these strategies (including carbon footprints) and to determine the optimal location of second generation ethanol plants.

The paper is structured as followed. First, in the method section, we detail the datasets used to construct a baseline land use for Iowa, and baseline environmental indicators. We then construct crop budgets by tillage and rotation and use forecast prices to predict various future land use scenarios. We look at various price-based scenarios, representing a range of future market conditions. The land use change maps of these simulations, and their environmental impacts, are presented in the results section, together with their significance, both for Iowa and within a larger context.

Methods

We use a combination of economic modeling of choice of rotations linked to an environmental model, the Erosion Productivity Impact Calculation (EPIC) model (Williams, 1990; Gassman at al., 2005;, Izaurralde et al., 2006), based on soil characteristics and existing georeferenced land use maps. To construct the baseline land use for Iowa (Figure 1), we use U.S. Department of Agriculture (USDA) National Agricultural Statistics Services (NASS) remote sensing crop cover maps (USDA 2002-2006) and maps of the location of Conservation Reserve Program (CRP) land obtained from USDA. The GIS maps's resolution is 30 m^2.

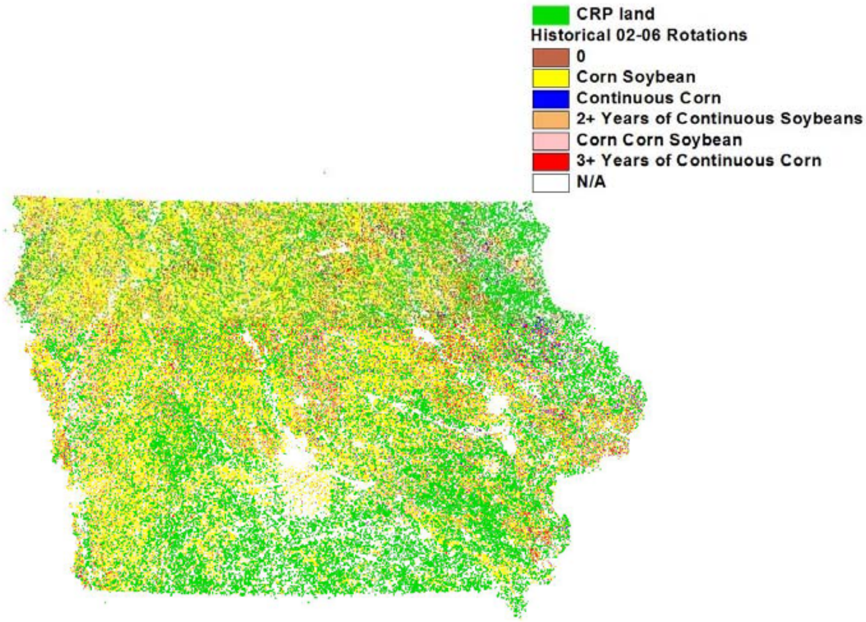
Results

We find that substantial shifts in rotations favoring continuous corn and moving away from the historical corn-soybean rotations (Figure 1) are likely if high corn prices are sustained, as indicated by the current futures market. This also substantially raises the opportunity costs of planting dedicated feedstocks such as switchgrass, and increases the competitiveness of coproducts such as corn stover for cellulosic production.

We find that CRP land is very likely to return to row crop production, unless payments for conservation are dramatically increased. This causes substantial sediment losses, while nitrogen losses increase less.

Returning CRP land into production has a vastly disproportionate environmental impact, as non-cropped land shows much higher negative marginal environmental effects when brought back to row crop production.

Figure 1 - Location of 2002-06 crop rotations and CRP land in Iowa



Note: the CRP area is enlarged and not true to scale to better show its location. CRP areas in Iowa correspond to 7.5% of cultivated cropland.

Finally, we find that switchgrass production, though it has a smaller environmental footprint than corn ansd soybean production, is still quite input-intensive. In particular, yields responses make it optimal for farmers to use high levels of nitrogen fertilizer, comparable with those used on on corn.

Conclusions

Subsidies tied to the carbon footprint of perennial feedstocks for cellulosic ethanol production may be necessary in order to limit the intensification of corn production and the likely reduction in CRP acreage. Alternatively, very productive Corn Belt states such as Iowa may become even more focused in row crop production. This is the likely outcome if externalities such as local water quality and carbon sequestration are not factored in through regulations such as mandates or price-based mechanisms, in the form of government policies or private incentive programs.

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