Land Use Change and Edge-of-Field Water Quality Impacts of Expanded Biofuels Production

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Research Question

THIS STUDY INVESTIGATES THE impact of the biofuels expansion on cropping patterns and the ensuing sediment and nutrient losses in the midwestern U.S. state of Iowa.

Some 28% of total U.S. ethanol production is located in the state, and rapid shifts in crop production are occurring because of increasing demand for corn as ethanol production feedstock. Between 2006 and 2007, corn production in Iowa increased by 26%, bringing the current Iowa corn crop to 19% of total U.S. production. In response, concern is growing regarding potential negative water quality externalities resulting from the increased corn production.

The expansion of corn production may come from either the acreage transformed from the land that is not currently cropped, such as in the Conservation Reserve Program (CRP) (a land set-aside program instituted by the U.S. federal government) (the extensive margin), or by increasing the incidence of corn in the rotations on the land that is already in row crop production (the intensive margin). We analyze both impacts.

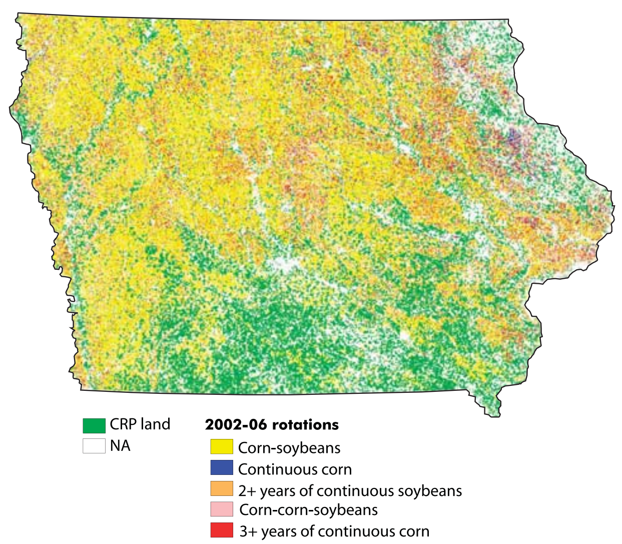
Data & Modeling Framework

U.S. DEPARTMENT OF AGRICULTURE (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Spatial and Tabular Data (SSURGO 2.2) provide information on some 10,637 unique soils for the region. To construct historical rotations (Figure 1), we use USDA National Agricultural Statistics Service (NASS) remote sensing crop cover maps for five years of data, 2002 to 2006. The study focuses on three crop rotations that are currently dominating state cropland: continuous corn, corn-soybeans, and corn-corn-soybeans.

The modeling framework consists of geographical, economic, and physical processes simulation models interlinked via spatially explicit common geographical units of analysis. We use an economic model to simulate farmers' choices of rotations under alternative corn prices, and estimate the resultant changes in edge-of-field sediment, nitrogen, and phosphorus losses using the Environmental Policy Integrated Climate (EPIC) model.

In modeling economic behavior of farmers, we assume that profit maximization is the driving force in farmers' decision-making, and that farmers choose the crop rotations that offer the highest expected net returns. To estimate these net returns, we estimate potential yields from soil maps and build crop rotation budgets. The budgets take into account the bundled nature of the choices farmers make about crops to grow and farming practices. We consider three tillage systems: conventional tillage (moldboard), conservation tillage (chisel), and no-till or ridge-till.

Figure 1. Location of 2002-06 Crop Rotations and CRP Land



Findings

AS CORN PRICES INCREASE, it becomes increasingly profitable for the most productive land to move toward more corn production, because even with the yield losses and the added cost of fertilizer, corn becomes relatively more profitable than soybeans. Even for very high corn prices, the production on the CRP acres or extensive margin would equal only 4% of the total.

Table 1 details the impact of the land use changes on four environmental indicators. On current cropland, sediment losses increase considerably while increases in nitrogen loss increases are limited. These estimates are partly the result of some conservative assumptions, namely, all fertilizer being applied in the spring, and no "insurance" use of fertilizer for the three-year rotation and continuous corn. They also reflect the existing high statewide agricultural production intensity. As cropland in Iowa is already intensively farmed, the impact of increased corn planting on the environment is more obvious on the extensive margin. Figure 2 shows the percentage changes in sediment losses on the current cropland and on CRP land. Figure 3 illustrates the corresponding percent changes in nitrogen losses.

Table 1. Historical and projected environmental indicators on the basis of corn prices

Rotation acreage	Historic baseline	Corn price $2.75/bushel	Corn price $3.60/bushel	Corn price $4.25/bushel
Intensive margin - current cropland (tons)				
Sediment Losses	43,971,672	57,061,555	62,660,601	69,812,462
Nitrogen Losses	696,432	702,907	726,776	759,434
Total Phosphorus	83,773	84,561	86,254	81,811
Soil Carbon	3,633,546,864	3,593,226,219	3,576,810,720	3,584,765,948
Extensive margin - current CRP land (tons)				
Sediment Losses	850,834	2,346,540	4,906,274	6,089,258
Nitrogen Losses	9,779	26,109	41,670	47,580
Total Phosphorus	848	3,283	4,823	5,002
Soil Carbon	195,943,313	185,148,756	179,525,393	177,623,183

Figure 2. Percent Sediment Change with Corn at $4.25/bu

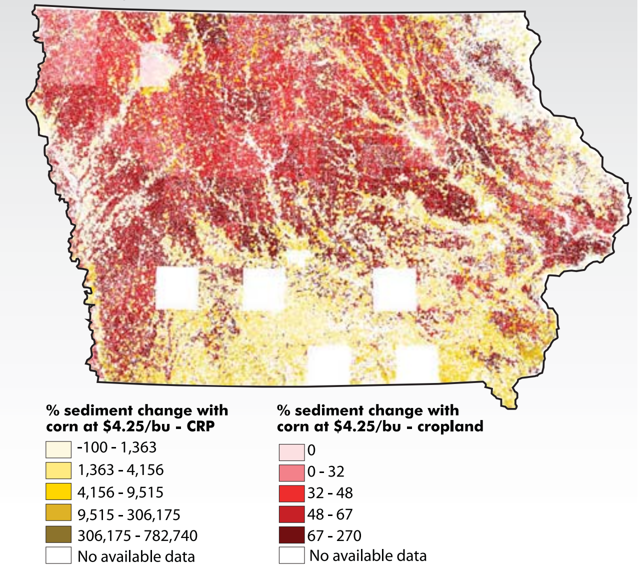
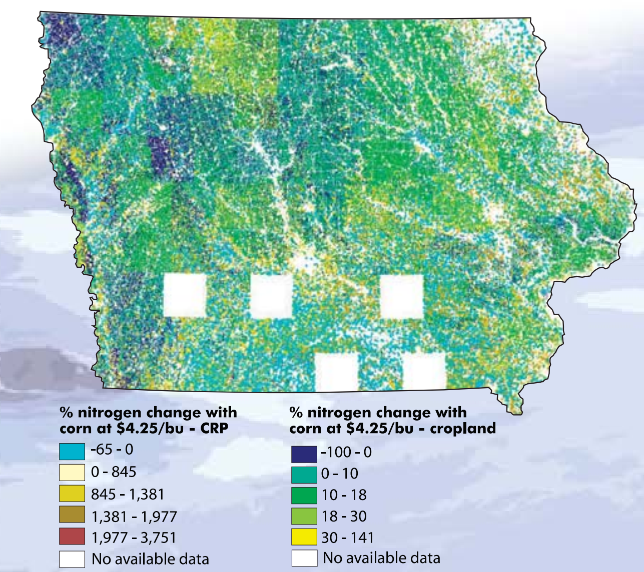


Figure 3. Percent Nitrogen Change with Corn at $4.25/bu



Conclusions

THE VASTLY DISPROPORTIONATE IMPACT of returning CRP land into production illustrates the importance of differentiating between the intensive and extensive margin. This result is likely to be replicated in other intensely cropped areas, while the extensive margin will play a more important role in providing biofuel feedstock outside the Corn Belt.

Our analysis can be used as an input in other studies of land use change assessment. The maps can be overlaid with information on wildlife to estimate some of the impacts on biodiversity. The results can also be used as inputs for both groundwater and surface water modeling to analyze likely water quality and quantity impacts. This is going to be of particular importance in hotspots where the production of biofuel crops requires irrigation, such as the Great Plains area in the United States.

Acknowledgments

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