Biofuels as an instrument for carbon dioxide emission reduction: an empirical analysis

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(1) Overview

When burned for energy production, biofules are releasing carbon dioxide (CO_2) that has been removed from the atmosphere through photosynthesis and stored as biomass, thus "recycling" this potent greenhouse gas (GHG). While this feature of biofuels production and use has been among the chief arguments in hailing the expansion of corn-based ethanol production, several recent studies caution against overstating the carbon recycling effect of corn ethanol because as the ethanol production grows, so do the demand for corn, corn prices, and corn acreage.

The expansion of corn production may come from either the acreage transformed from grasslands, pasture, abandoned lands, or forests, or by increasing the incidence of corn in the rotations on the land that is already in row crop production. A few recent economic studies of the GHG mitigation potential of biofuels account for the former way of increasing corn acreage (e.g., McCarl et al 2005), but the latter, corn production intensification effect, has not been adequately addressed. Yet the higher incidence of corn in traditional Midwestern crop rotations, such as a shift from the two-year corn-soybean (CS) rotation towards three-year corn-corn-soybean rotation and continuous corn (CC) usually leads to higher rates of nitrogen fertilizer application and lower corn yields.

More corn in rotations also offers additional challenges for conservation tillage because of the need for higher tillage intensity to counter higher pest pressure and to facilitate preparation of soil for planting after the corn residue, which is heavier than the soybean residue. The greater tillage intensity could negatively affect soil and water resources due to the increased likelihood of nutrient and soil losses. The overall impact on CO_2 emissions is not, however, obvious. On one hand, tillage that is more intensive leads to higher CO_2 emissions from agricultural soils. On another hand, replacing soybean residue with the corn one may result in higher rates of soil carbon sequestration as the former is more fragile and is usually less in quantity on a mass per unit of area basis. Thus, a comprehensive study of the GHG mitigation implications of corn production intensification requires simultaneous consideration of both rotation and tillage effects. Our study quantifies the effect of the growing corn prices on crop rotations, tillage intensity, and soil carbon sequestration rates for a major U.S. crop production region, the 0.5 million-acre Boone River watershed in Iowa.

(2) Methods

We use spatially explicit, GIS-based, 2005 land use data supplemented by the detailed soils data for some 8,300 field-level data points. Using crop production budget analysis, we simulate the effect of an increase in corn prices from the historically average of $2/bushel to $5/bushel. Presently, the majority of the watershed is under row crops in corn-soybean rotation. We find that at $3/bushel, the corn-corn-soybean becomes the predominant rotation, and at $4/bushel, the majority of the study area converts to continuous corn. We use the physical processes simulation model EPIC to estimate the CO_2 emissions attributable to changes in rotations and tillage intensity by comparing soil carbon content under the 2005 baseline with that under the simulated cropping and tillage patterns.

(3) Results

We find a replacement of the CS rotation with CC and a tightly corresponding replacement of the mulch with conventional tillage at corn prices above $3.6 per bushel ($141.73 per ton), with an almost complete (98.6%) switch to continuous corn and conventional tillage at $5 per bushel ($196.84 per t). A corn price increase from $2 to $4 per bushel is predicted to lead to the CO_2 emissions at 63,711 tons per year higher than under the baseline.

(4) Conclusions

By considering the choice between corn-soybean rotation and continuous corn, and taking into account the potential yield reduction effects of alternative tillage systems, we found strong evidence for potential increases of corn in rotations and tillage intensity in the Boone River watershed in central Iowa, U.S., in response to the growth in corn prices. These changes are estimated to lead to sizable increases in CO_2 emissions, both from soil and from farm operations. The study points to the importance of GHG emission life-cycle accounting in estimating the GHG fossil fuel substitution effects of corn ethanol production, especially if GHG offset markets develop or if society chooses to reward biofuel carbon recycling via some incentive payments (McCarl et al 2005).

References

McCarl, B.A., D. Gillig, H.-C. Lee, M. El-Halwagi, X. Qin, and G.C. Cornforth. 2005. “Potential for biofuel-based Greenhouse Gas emission Mitigation: Rationale and Potential.” In J. Outlaw, K.J. Collins, and J.A. Duffield (Eds.), Agriculture as a Producer and Consumer of Energy, pp.300-316