WRI POLICY NOTE

ENERGY: BIOFUELS No. 1

WORLD RESOURCES INSTITUTE

Beyond the RFS: The Environmental and Economic Impacts of Increased Grain Ethanol Production in the U.S.

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Can we increase grain ethanol production without risk to soil and water resources?

Recommendations

1. Evaluate alternative production technologies and feedstocks for ethanol. Cellulosic ethanol production, for instance, has the potential for lower water, soil, and climate impacts than current grain-based ethanol production. Increase federal R&D appropriations for these evaluations and to facilitate the commercialization of new or emerging technological advances.

2. Increase funding for agricultural conservation programs. Savings in federal crop payments resulting from the Renewable Fuels Standard (RFS) should be transferred to conservation programs to reduce the negative water, soil, and climate impacts of increased grain ethanol production. Promoting performance-based approaches more effectively targets conservation funding to farmers who can achieve the least-cost environmental improvements.[1]

3. Promote precision management of nitrogen fertilizer use and conservation tillage in corn production. Potential policies to achieve those goals include incentive payments, nutrient management plan requirements, farmer education programs, and improved access to technology and technical information about nitrogen management.

4. Federal and state agencies should cooperate in the development and implementation of an environmental strategy for agriculture that is robust to increased ag-energy production.

Background

Ethanol advocates dating back to Henry Ford have described ethanol as the "fuel of the future." Others in the ethanol debate question the feasibility and advisability of large-scale ethanol production based on issues ranging from energy efficiency to environmental impact. However, with aggregate demand for energy rising in the United States, per capita demand skyrocketing in rapidly developing countries such as India and China, and energy security issues coming to the forefront of the national debate, attention has increasingly turned to the potential role that ethanol may play in relieving U.S. concerns about energy supply and security. Advocates of biofuels argue that, to the extent that biofuels are able to displace petroleum use, they are also likely to produce benefits associated with greenhouse gas emissions (e.g. CO_2) and air quality. Farrell et al. (2006) estimate that the fuel cycle for energy from grain ethanol requires up to 95% less petroleum than the fuel cycle for an equivalent amount of energy from gasoline, but that its reliance on other fossil fuels results in a more moderate 13% reduction in overall greenhouse gas (GHG) emissions.[2]

The prospect of using ethanol to supplement a nation's energy supply is not unprecedented either in the United States or abroad; during both World War I and World War II vehicle fuels in the United States were regularly mixed with alcohol as a way of stretching the nation's fuel supplies. Brazil, the world's leader in per capita ethanol production, responded to the 1970s oil shocks by creating regulations and incentives to stimulate the ethanol industry, and in that country today all gasoline is comprised of at least a 25 percent ethanol blend. Sweden, also hit hard by the 1970s oil shocks, has been weaning itself off fossil fuels ever since. Although gasoline and diesel are still used in the transport sector, Sweden has pledged to go "fossil-fuel free" by 2020, and is working to provide incentives for consumers, industry, and automakers to shift toward the use of ethanol and other biofuels derived from the country's extensive forests.

The Renewable Fuel Standard

In the United States, support for the ethanol industry has been provided primarily in the form of corn subsidies, research and development dollars dedicated to the development of ethanol production technology, and a tax credit awarded to blenders who mix ethanol into their gasoline. Advocates wishing for a more aggressive commitment to stimulating the ethanol market, however, have called for, and received in the summer of 2005, legislation in the form of a "renewable fuel standard" that mandates the use of a specified amount of renewable fuels in the U.S. transportation fuel supply.

The concept of the renewable fuel standard was first proposed by Senators Daschle (D-SD) and Lugar (R-IN) in 1998. Their original legislation, proposed in 2000, was the first-ever call for mandatory integration of renewable fuels such as ethanol and biodiesel into the nation's transportation fuel supply. That legislation would have required that the volume of ethanol and biodiesel blended with fuel gradually increase from 2.3 billion gallons/year in 2004 to 5.0 billion gallons/year by 2012. The fuel standard became embroiled in a controversial omnibus Energy Bill, however, including a debate over the use of MTBE as an oxygenate in gasoline. As a result, a version of the Renewable Fuels Standard was not signed into law until the summer of 2005.

By the time the Renewable Fuels Standard appeared in the Energy Policy Act of 2005, it was clear to many policymakers that its original objective of 5.0 billion gallons/year by 2012 would be insufficient to stimulate the ethanol industry beyond market forces already in effect. In the final legislation, the target renewable fuel volume was raised from 5.0 billion to 7.5 billion gallons/year by 2012, and a credit trading program is currently being designed to allow refiners, distributors or importers to purchase renewable fuel credits if they are unable to comply with the required renewable fuel volume. This legislation has been widely applauded as a revolutionary commitment to the development of renewable fuels markets in the United States.

Though Congress increased the RFS to a target of 7.5 billion gallons, even this level appears to be overtaken by recent events in energy markets. Using numbers published in the Energy Information Administration's (EIA) Annual Energy Outlook 2006, we estimate that production of 7.5 billion gallons would provide approximately 3% of the projected gasoline energy demand in 2012. That same source, however, suggests that by 2012, production of ethanol in the United States will reach 9.5 billion gallons/year, considerably exceeding the mandated volume in the current RFS. This stimulation of the ethanol market is due to recent and anticipated increases in the price of petroleum, and effectively makes the RFS obsolete.

Potential Impacts

Throughout its history, the concept of an RFS, and of increased ethanol production in general, has encountered vigorous opposition. Criticism has arisen from skepticism about ethanol itself and about the environmental impacts of an agricultural production system geared more heavily toward producing ethanol feedstock. This argument generally concedes that potential climate benefits exist if ethanol reduces petroleum use and the associated GHG emissions, but contends that little attention has been focused on other possible environmental impacts that increased agricultural production might generate, including the degradation of water quality.

Although ethanol itself is fairly environmentally benign, there are other environmental impacts associated with the production of ethanol, and with the production of the feedstock for ethanol, that must also be considered in a life-cycle analysis. If the United States were to restructure its agricultural system to produce the amount of corn necessary to meet demand for food, livestock feed and ethanol, how much land would have to be brought into production? What would be the implications for soil erosion, pesticide use, and nutrient loads in runoff, which affect our rivers, streams, and coastal waters?

Our Analysis

This study addresses these questions by exploring the soil and water quality impacts of large-scale ethanol feedstock production, together with the impacts on agricultural markets stemming from changes in the pattern and composition of agricultural production. Although promising advances are being made in cellulosic ethanol production, and in biorefinery technologies that allow for the joint production of bioproducts and power from cellulosic feedstocks, we focus on the production of ethanol from corn, as any significant ethanol production from cellulose is not likely to occur prior to 2012. We use a national agro-environmental production model to analyze the restructuring of the agricultural sector to provide sufficient corn-based ethanol to satisfy the RFS as well as larger volumes that could be stimulated by factors such as increased RFS requirements or higher oil prices. To measure environmental impacts we look specifically at agricultural GHG emissions, which are often under-represented in the dialogue about greenhouse gas reductions, as well as at nitrogen and phosphorus loads into local waterways and rates of soil erosion, which have been the focus of most existing and pilot agricultural conservation programs.

The baseline scenario for our RFS analysis is one where ethanol production in 2012 reaches 5 billion gallons—the production level specified by the original RFS. Relative to this scenario, we look at the impacts of the current RFS in three areas: (1) key environmental indicators, (2) agricultural structure, such as the pattern and extent of production, and (3) market conditions, such as the price of commodity goods. Our analysis assumes that the mandated 7.5 billion gallons are provided entirely by domestically produced corn-based ethanol, and that two thirds of that amount is produced through the dry mill production process.

As noted, current market conditions are projected to overtake the current RFS of 7.5 billion gallons, so the required production levels will be reached well before their deadlines. We therefore analyze additional scenarios that represent cases in which production exceeds the current RFS, either because future legislation increases the RFS to achieve greater market stimulation or because energy prices propel the ethanol market beyond the mandated level. We examine the relative impacts on the environment and agricultural structure of increasing ethanol production to levels of 10 billion gallons, 12.5 billion gallons, and 15 billion gallons per year by 2012.

TABLE 1 Economic and Environmental Impacts of Increased Ethanol Production

		Baseline	Current RFS			
Billions of Gallons of Ethanol/Year		5	7.5	10	12.5	15
Crop Acreage Planted	Mill. Acres	320.8	324	326.8	329.4	332.5
Corn Acreage Planted	Mill. Acres	80.5	82.5	85.4	87.9	90.7
Crop Acreage under Conservation Tillage	Mill. Acres	83.3	82.7	82.3	82.1	81.9
			Percent Change from Baseline			
Economic Impacts						
Price of Corn	$/bu	$2.40	3.3	7.9	12.1	17.5
Price of Soybeans	$/bu	$5.60	-0.4	-1.6	-2.7	-3.6
Farm Income	($bill/yr)	75	0.7	0.7	1.9	3.3
Cash Receipts	($bill/yr)	208	0.7	1.1	1.9	3.0
Variable Costs	($bill/yr)	133	0.6	1.3	1.9	2.9
Farm Income (Corn)	($bill/yr)	16	3.7	8.5	18.0	30.6
Farm Income (Soybeans)	($bill/yr)	5	-2.2	-7.4	-12.2	-16.3
Farm Income (Livestock)	($bill/yr)	47	0.5	-0.4	-0.9	-2.3
Govt. Payments	($bill/yr)	10	-7.5	-15.9	-17.5	-18.4
Environmental Impacts						
Fertilizer Used	Mill. Tons	9.0	2.1	4.2	6.1	8.4
N Lost to Water	Mill. Tons	5.2	1.5	2.9	4.2	5.6
P Lost to Water	Mill. Tons	0.6	1.8	3.2	4.4	6.0
Soil Erosion	Mill. Tons	1,776	1.5	2.8	4.0	5.3
Ag. GHG Emissions	MMTCE	87	1.9	3.8	5.6	7.7

Projected Ethanol Impacts

The national economic and environmental outcomes of increased grain ethanol production are shown in Table 1.

Degradation of the Environment

Our study corroborates the argument that an expanding market for ethanol from corn grain will exacerbate water and soil quality problems in the United States. The incentive for production provided by the increased value of corn results in an overall increase in cropland acreage, lowered enrollments in the Conservation Reserve Program (CRP), an increase in acreage dedicated to intensively managed continuous corn rotations, and a slight absolute decline in acreage managed using low-till or no-till techniques. Aggregate local nutrient loads and soil erosion increase, contributing to the eutrophication of rivers, streams and lakes, reduced fish habitat, impaired drinking water and hypoxic (oxygen-depleted) zones in coastal waters.

Agricultural GHG emissions in our study are measured as carbon dioxide emitted in the grain production process (fuel use, fertilizer production, etc.), the net carbon flux from the sequestration and release of carbon from agricultural soils (including those in the CRP), and nitrous oxide released from nitrogen fertilizer use. Increased ethanol production results in an increase in all of these agricultural sources of GHGs, as acres are managed more intensively, with greater nitrogen application, and using higher impact tillage techniques. When 15 billion gallons of ethanol are produced, total measured GHG emissions from agricultural production increase by almost 8%.[3]

The increased rates of nutrient and soil loss, as well as of agricultural GHG emissions, are disproportionately larger than the rate at which acreage is brought into production. Stimulated by the ethanol market, the increase in agriculture's environmental impact is due to more than simply increased crop acreage; growers respond to the changing market conditions by moving away from more environmentally benign rotations and tillage practices in favor of cropping practices that are more nitrogen and management intensive and that have greater negative environmental impacts.

Increased Farm Income

Overall, increases in ethanol production levels provide additional financial benefits to the agricultural sector. Due to the increased value of production for key commodity crops, farm income steadily increases as ethanol production increases.[4]

As ethanol production grows, however, there are winners and losers in the agricultural community. Corn growers derive the greatest absolute benefit from the increased demand for their product. The price of corn increases from $2.40/bushel to $2.82/bushel when the current RFS is doubled to 15 billion gallons, subsequently increasing corn-based income by 30%. Soybean prices, on the other hand, decrease from $5.60/bushel to $5.40/bushel, and income in that sector drops by 16%. Despite the loss of product value, soybean production increases slightly; acreage in continuous soybeans declines, but acreage in corn/soybean (and in continuous corn) increases. It is important to note that most soybeans are grown in corn/soybean rotations, so many of the same growers who are suffering the effects of lower soybean prices are more than compensated by the increased corn prices.

Many of the economic impacts of increased ethanol production operate through the livestock feed sectors. In all scenarios, the price of soybeans is depressed by the huge increase in availability of distillers dried grains—a byproduct of ethanol production and a substitute for soybean meal in livestock feed markets. This competition drives the price of soybean meal down by 7%, and exports of soybean meal increase by almost 100%. Because corn is less affordable as a feedstock, other grains—such as sorghum, barley, and oats—are diverted into the feed market. The sorghum market is particularly affected; its price increases by 21%, production increases by 27%, and exports drop to zero.

The livestock sector initially benefits slightly from the increased availability of feedmeals at lower prices. However, the increasing price of corn and other cereals, together with dietary restrictions on the extent to which they can be substituted with lower-priced feedmeals, eventually drives down returns. Income in the livestock sector starts to decline around 9 billion gallons of ethanol, and falls by 2.3% (a loss of over $1 billion annually) at ethanol production levels of 15 billion gallons. At that production level, however, gains to crop producers amount to $3.5 billion annually. At all ethanol production levels the aggregate gains to crop producers are larger than the aggregate losses to livestock producers, but these returns are not uniformly distributed nationwide. In certain regions—most significantly the Southeast and the Delta states—losses to the livestock sector are not compensated by gains to cropping sectors, so reductions in net farm income occur (See Figure 1).

Reduced Government Payments

Stimulating markets for a key commodity crop through value-added processing opportunities results in a steady decline in government commodity crop payments. When 15 billion gallons of ethanol are produced, government payments decline by more than 18% from the baseline, for an expenditure savings of $1.88 billion/year. The vast majority of this decline is due to a reduction in counter-cyclical payments, though a small portion represents a decline in CRP payments, as CRP acreage declines with the increase in corn production.[5]

Our Findings

Ethanol production may be a promising technology to reduce GHG emissions from the production and use of transportation fuels, as well as to diversify the nation's liquid fuel supply. Our study predicts that such a strategy will also have a positive impact on aggregate farm income and result in significant reductions in farm support payments.

Given current grain-based ethanol technology and in the absence of policy intervention, however, these benefits will come at a cost to our nation's water and soil health. An expanded ethanol market is likely to provide an incentive for farmers to revert to more intensively managed rotations and less sustainable management practices, which may have long-term implications for soil and water quality. The benefits gained from displacing petroleum GHG emissions are offset in part by the increased agricultural GHG emissions demonstrated here and by the energy required for producing ethanol.

Tradeoffs among national environmental objectives such as improved soil and water quality and reduced GHG emissions must be recognized in legislative decisions about how far and how fast to push the development of grain-based ethanol markets, and in what policy context. To the extent that developing an ethanol market lies outside policymakers' hands, spurred instead by energy market forces such as high oil prices and consumer demand for non-imported or renewable energy sources, legislators must also be prepared to engage in a dialogue about what sorts of policy incentives can be put in place to mitigate the threats to soil and water quality that increased grain-based ethanol production will bring.

References

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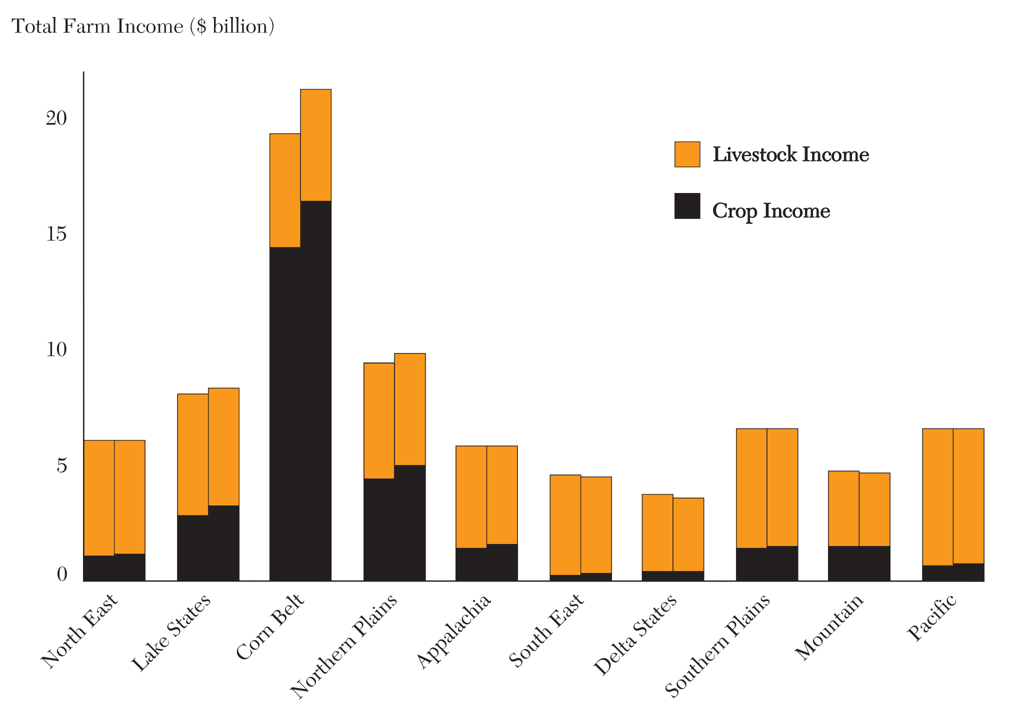
FIGURE 1 Farm Sector Income by Region at Baseline (first column) and at 15 Billion Gallons of Ethanol Production (second column)



Methodology

The U.S. Regional Agricultural Sector Model (USMP) was designed for general-purpose economic, environmental, and policy analysis of the U.S. agricultural sector. USMP is a spatial equilibrium model in which production, consumption and prices within the agricultural sector and selected processing sectors are all mutually determined. Developed by the U.S. Department of Agriculture/Economic Research Service (USDA/ERS), USMP has been extensively modified by World Resources Institute to allow analysis of environmental impacts, a broader array of spatial scales, and a wider variety of agricultural management practices. The model estimates the impacts of changes in policy, demand, or production/processing technology on: regional supply of crops and livestock; commodity prices; crop management; farm income; and environmental indicators such as nutrient and pesticide runoff, soil loss, GHG emissions, and soil carbon fluxes.

The data driving USMP are drawn from the USDA production practices survey, the USDA multi-year baseline, and the National Resources Inventory. The model includes 10 major commodity crops (corn, sorghum, oats, barley, wheat, rice, cotton, soybeans, hay, and silage), a number of livestock enterprises (dairy, swine, poultry, and beef cattle), and a variety of processing technologies used to produce retail products from agricultural inputs. USMP divides the United States into 45 production regions and optimizes over approximately 850 different cropping rotations and tillage practices based on the various crops and regions. Environmental responses to the changes in agricultural production practices that result from policy, demand or technology changes are then derived from a crop biophysical simulation model, the Erosion/Productivity Impact Calculator (EPIC).

Environmental impact data are calibrated using available region-specific information on soils, weather, agricultural production patterns, and yields. Due to the highly aggregated nature of the model and the coarseness of the estimation, USMP results are generally used to evaluate the relative effects of various policy options and not to predict absolute changes in production or environmental parameters.

Notes

1. See Greenhalgh and Sauer (2003) and WRI Policy Notes on environmental markets (www.wri.org/policynotes) for more information.
2. When translated into energy equivalence, this means that the production of 100 MJ of ethanol-based energy requires approximately 5 MJ of petroleum-based energy. Because the production of ethanol requires energy from other GHG-emitting sources, however, particularly coal and natural gas, the impact of ethanol on GHGs is much more moderate. Farrell et al.'s (2006) best estimate is that GHGs are reduced by 13%, but their data range from a reduction of 32% to an increase of 20%.
3. This number represents only the increase in agricultural GHG emissions from increased corn production. We do not estimate decreases in GHG emissions in the transport sector that are likely to occur from displaced petroleum use, as Farrell et al. (2006) do.
4. In our analysis, estimates of cash receipts include only production income and government payments for the commodity crops and livestock sectors covered, not alternative sources of farm income such as off-farm employment.
5. If the federal government continues to offer a tax credit to blenders who mix ethanol into their gasoline, this reduction in government farm support may be offset by increases in tax credits awarded to blenders.

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Acknowledgments

The authors would like to thank the following reviewers for their constructive feedback and suggestions: Andrew Aulisi, Janet Ranganathan, Joseph Cooper (USDA-ERS), and Robert Anex (Iowa State University). For research support we would also like to thank the McKnight Foundation, the Wallace Genetic Foundation, the U.S. Environmental Protection Agency, the U.S. Department of Energy, the U.S. Department of Agriculture, and the National Science Foundation.

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ISBN 1-56973-620-0

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