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Economic and Environmental Impacts of Biofuels Expansion: The Role of Cellulosic Ethanol

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Introduction

Within the past three years, politically, there has been a significant movement towards an energy future with a substantially larger renewable energy component. A major driver for this movement is the perception that importing over 60% of our oil reduces our national security. An ethanol subsidy in place, increased oil demand and, hence, increased gasoline prices, along with the reduction in use of MTBE as an oxygenate, have resulted in ethanol becoming highly profitable. This profitability and perception that independence from foreign oil is a goal for America has resulted in significant growth in the corn-ethanol industry. As the industry grew, so did the demand for feedstocks. With that increased demand, increased commodity prices followed.

The use of bioenergy feedstocks to produce transportation fuels could not only help reduce reliance on foreign oil, but could also provide significant environmental benefits and invigorate rural economies. Agriculture is well positioned as a feedstock source, because the fuels can be utilized with current engine technologies and are compatible with the current distribution infrastructure. Ethanol production increased from 2.8 billion gallons in 2003 to nearly 4.9 billion gallons in 2006 (Renewable Fuels Association, 2007). The rapid buildup in the past three years of ethanol production has increased farm income and rural economic development in certain regions of the United States. Ethanol production has expanded beyond the Midwest region where 17 states have ethanol plants in 1999 to 26 states in 2007.

The Energy Policy Act of 2005 established a renewable fuel requirement for the nation, mandating 7.5 billion gallons of renewable fuels by 2012 (U.S. Congress, 2005). Ethanol and biodiesel are both defined as eligible renewable fuels. A more sweeping renewable fuels standard was proposed as part of The Biofuels Security Act of 2007 (sponsored by Senator Tom Harkin and co-sponsored by Senators Biden, Dorgan, Johnson, Lugar, Obama, and Salazar). This proposal would require 10 billion gallons of renewable fuels by 2010, 30 billion by 2020 and 60 billion by 2030 (U.S. Congress, 2007a). Furthermore, the Governors' Ethanol Coalition has recommended that replacing at least 25 percent of petroleum used as transportation fuels by the year 2025 (Governor's Ethanol Coalition, 2006). Subsequent to the 2005 Energy Policy Act, the Energy Independence and Security Act of 2007 was enacted. A renewable fuel standard schedule is created with applicable volume of renewable fuel increasing from 9.0 billion gallons in 2008 to 36 billion gallons in 2022. By 2016, 22.25 billion gallons of ethanol production is required (U.S. Congress, 2007b).

Numerous profit and non-profit organizations have developed initiatives attempting to move renewable fuel production from its current status toward one that will impact this nation's land resource and rural areas. De La Torre Ugarte *et al*. (2003) and Walsh *et al*. (2003) evaluated the impacts of bioenergy crop production on the agricultural sector. The realized net farm income increased and government payments decreased compared to the USDA baseline as dedicated energy crop production increased. The 25x'25 group set forward a national goal to meet 25% of the energy needs in the year 2025 with renewable energy. In a study conducted by the University of Tennessee, 15.45 Quads of energy would come from renewable and sustainable biomass feedstocks and another 6 quads would come from wind (English *et al*., 2006). In subsequent analysis conducted for the Governors Ethanol Coalition (De La Torre Ugarte, 2006), the estimated impacts resulting from the production of 60 billion gallons of ethanol and a smaller amount of biodiesel were revealed. In another study, an analysis was conducted that examined the impacts of meeting increased biopower, biofuel, and bioproducts demands (De La Torre Ugarte, 2007). Each of these studies used a simulation model called POLYSYS and evaluated the economic and land use pattern changes as a result of various levels of new bioproduct production; however, little attention

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was paid toward the environmental impacts resulting from increased agricultural demands.

Objectives

The goal of this study is to provide not only an economic analysis of agriculture's ability to contribute to the Congressional goal of supplying 18 billion gallons by 2016, but to also evaluate the impact the pursuit of this goal could have on this nation's environment if cellulosic ethanol is not feasible by 2016. The first objective of the study is to evaluate the ability of production agriculture to contribute 18 million gallons of corn-ethanol. The second objective is to estimate the potential environmental impacts on the nation's resources as a result of this emerging industry.

Methodology

Energy targets for ethanol were defined for the years 2006 through 2016. This information, along with the assumption that the ethanol must be produced from corn or other traditional feedstocks, was then introduced into POLYSYS, a regional/national agricultural simulation model, to estimate the quantity of ethanol to be produced from agriculture, as well as the price, agricultural income, and other agricultural sector impacts deriving from producing such a level of energy production. Results from POLYSYS were used to evaluate the environmental implications through the use of indicators. An Environmental POLYSYS Sub-module (EPS) was developed to provide indicators on changes in the environment. Changes in chemical and fertilizer applications were indicated by changes in expenditures for these inputs. Changes in erosion are provided through the Universal Soil Loss Equation assuming current tillage practices are constant. The changes in erosion are placed into the Micro Oriented Sediment Simulator (MOSS) (Alexander and English, 1988) to provide regional estimates of the costs incurred due to sedimentation and deposition. Changes in carbon sequestration and in carbon emissions were estimated using Carbon Management Response (CMR) curves and per unit carbon emissions from direct fuel usage and are embodied in the production of inputs.[2] For further information on POLYSYS and its use in this analysis see De La Torre Ugarte and Ray (2000) and English *et al*. (2007).

The focus of the analysis is on comparing the impacts that producing ethanol will have on the nation's agricultural sector and its environment. To adequately interpret the results coming from POLYSYS, it is important to refer the simulation values to the 2007 USDA baseline (USDABASE). The baseline represents the best estimate of what would occur without meeting pre-specified energy goals. Results under four scenarios were compared to USDABASE. The first three scenarios project the impacts of attaining the ethanol targets of 14 (14BILETH), 16 (16BILETH), and 18 (18BILETH) billion gallons of ethanol and the fourth scenario assumes that the level of ethanol never exceeds 8.6 billion gallons, or the amount of ethanol assumed to be produced in the USDABASE in 2007 (FLATETH) (Figure 1). In all of these

[2]The carbon analysis in this section incorporates changes in carbon emissions and soil carbon as a result of changes in land use. It does not compare the carbon footprint of ethanol to that of gasoline production. Nor does it include the carbon emissions likely to occur as a result of feedstock and product distribution.

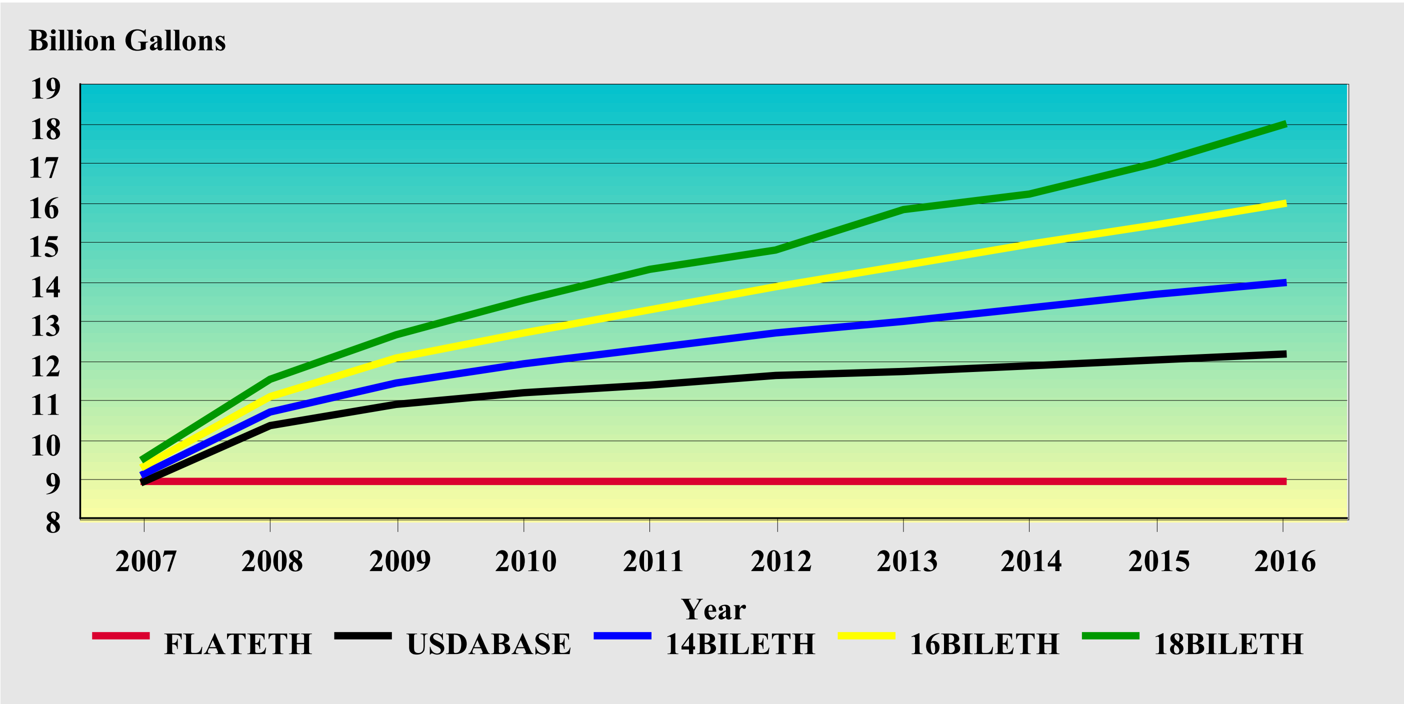

Figure 1. Ethanol Production for the Various Scenarios Analyzed

scenarios, corn grain was the feedstcok assumed through the year 2016. Yields for grain and other crops increased at the USDA expected rate. However, sensitivity analysis was conducted on corn yield as some have indicated much greater yield potential by 2016. Results from a solution that allowed corn yield to increase to 200 bushels by 2016 were also examined in this analysis. Results from these four scenarios are compared with the extended baseline to illustrate how various paths of ethanol industry expansion may influence the agricultural sector. In addition, the results of the 18BILETH scenario was compared to FLATETH in order to discover the impacts that additional growth in the ethanol industry will have compared to 2007's estimated level of ethanol production.

Results

Under each of the scenarios, the desired targeted production of ethanol can be achieved for the years 2007 through 2016. As specified, for each of the scenarios except FLATETH, the use of corn reaches a peak in 2016. With the changes in ethanol demand, major changes occur in the demand for corn, prices in agricultural commodities, land use patterns, and agricultural sector net returns. These economic and land use changes impact the environment through changes in chemical expenditures, fertilizer expenditures, soil erosion and sedimentation, and carbon sequestration and emissions.

Economic and Land Use Impacts

Agricultural Production

In the USDABASE, by 2016, 14.09, 2.24, and 3.08 billion bushels of corn, wheat, and soybeans, respectively, are produced. In addition, 320, 125, and 210 million bushels of sorghum, oats, and barley are produced. Also, 230 million cwt of rice and 22.8 million bales of cotton are produced. If ethanol production were to remain at the 2007 levels by 2016, a reduction in annual corn production of 1.3 billion bushels would result, along with increases in soybeans, wheat, and cotton (Table 1). However, increasing the ethanol production to 18 billion gallons is projected to increase corn production by 1.57 million bushels but decrease soybeans, wheat, and cotton production. As demand for ethanol increases, the production of corn increases in response to this change but the productions of other crops typically decrease.

Estimated Commodity Price Impacts

As expected, increasing the amount of ethanol produced from corn causes increased prices for all commodities. In the baseline, commodity prices are at higher average prices

Table 1. Change in Commodity Production for the Alternative Scenarios, 2007, 2010, 2013, and 2016

Scenario and Crop	Units	Projected for the Year of: 2007	2010	2013	2016
		---- Millions of Units ----			
FLATETH-USDABASE					
Cotton	bales	0	0.17	0.27	0.11
Corn	bushels	0	-457	-19	-1,304
Soybeans	bushels	0	132	-21	362
Wheat	bushels	0	12	12	22
14BILETH-USDABASE					
Cotton	bales	0	-1.83	-2.77	0.19
Corn	bushels	0	320	486	312
Soybeans	bushels	0	-26	-67	-32
Wheat	bushels	0	-29	12	-41
16BILETH-USDABASE					
Cotton	bales	0	0.15	0.02	-2.49
Corn	bushels	0	171	357	1,190
Soybeans	bushels	0	-25	-48	-191
Wheat	bushels	0	-11	-35	-33
18BILETH-USDABASE					
Cotton	bales	-0.49	-0.92	-1.99	-1.53
Corn	bushels	-55	749	1,155	1,567
Soybeans	bushels	21	-147	-297	-186
Wheat	bushels	4	-2	34	-129

than those prices that have occurred during the past 10 years. Corn price is projected to average $3.48/bushel in the USDABASE. As ethanol production increases, all commodity prices increase reflecting the increased demands being placed on land resources. Corn price increases by an average of 5.2 % as we move from 12 billion gallons to 18 billion gallons (Table 2).

Livestock prices are also impacted by changes in ethanol production. In the USDABASE scenario, the farm price for beef ranges from $80.57/cwt to a high of $83.59/cwt with an average price over the ten year time frame of $81.43/cwt. The pork and poultry farm price in the USDABASE scenario averages $45.67/cwt and $43.19/cwt respectively. As ethanol demand increases to 18 billion gallons (18BILETH), the average prices increase for beef, pork and poultry by $1.20, $1.07, and $0.66/cwt respectively.

Agricultural Land Use Changes

Use of agricultural cropland changes when compared to the baseline as agriculture attempts to meet the changes in ethanol demanded. In the USDABASE scenario, 90 million acres are planted to corn in 2016, an increase of 4 million compared to the land needs projected for 2007. To accommodate this increase, a decrease in soybean and wheat acreages are projected. As ethanol demand increases as reflected in the 18BILETH scenario, further increases in planted corn acreage is projected with 100 million acres of corn planted by 2016. This increase in corn land of nearly 10 million additional acres when compared to the BASEUSDA scenario is coupled with decreases in wheat, soybeans, cotton, and rice of 3.64, 2.88, 1.03, and 0.16 million acres respectively. The projected change in planted corn acres is estimated at 18.5 million acres when ethanol production remains flat at slightly over 8 billion gallons (FLATETH scenario) compared to the 18BILETH scenario, a change of 22% in planted corn acres.

Changes in land use occur in most areas of the United States. The increase in corn acreage occurs throughout the United States with concentrations in eastern Colorado, north Texas, southern and eastern Nebraska as well as the traditional Corn Belt. Soybeans leave the Corn Belt and move toward the South and Great Plains. Wheat production shifts from the Great Plains and the Corn Belt and increases in the western states as well as the South and Appalachian regions. Cotton shifts from the South westward into primarily irrigated regions of the country.

Changes in Agricultural Sector Net Returns and Government Payments

Agricultural net farm income in the USDABASE scenario averages $65.2 billion per year over the ten year period. If ethanol production increases to 18 billion gallons per year by 2016, net farm income is projected to increase by over $5 billion per year creating a win for agriculture and agricultural resource owners (Table 3). If the nation maintains production at projected 2007-2008 levels, agricultural net farm income will decrease by $5.5 billion per year on average from the baseline. As ethanol production increases, net farm income increases, and government payments decline.

Table 2. Three Year Average Percent Change in Commodity Prices for the Alternative Scenarios

		Three Year Average Projected for:				
Scenario and Crop	Units	2007-2009	2010-2012	2013-2015	Ending Price	10 Year Average
14BILETH						
Cotton	pound	0.0%	0.6%	4.9%	0.5%	2.4%
Corn	bushels	1.5%	1.4%	3.1%	9.1%	4.5%
Soybeans	bushels	0.0%	0.5%	4.5%	3.6%	2.2%
Wheat	bushels	0.1%	0.7%	1.0%	2.9%	1.3%
16BILETH						
Cotton	pound	0.6%	0.5%	-0.2%	7.1%	1.6%
Corn	bushels	0.4%	0.7%	7.3%	-3.6%	2.8%
Soybeans	bushels	0.3%	1.3%	4.2%	8.7%	3.5%
Wheat	bushels	0.2%	0.3%	3.4%	1.9%	1.7%
18BILETH						
Cotton	pound	0.7%	0.3%	1.7%	-2.5%	1.2%
Corn	bushels	1.1%	3.1%	1.2%	10.4%	5.2%
Soybeans	bushels	0.1%	0.1%	6.6%	-1.2%	2.0%
Wheat	bushels	0.2%	1.4%	1.4%	9.9%	2.8%

Table 3. Realized Net Farm Income over the Ten Year Period of Analysis

Scenario	Projected for the Year of: 2007	2010	2013	2016	Total	Average
	------------------------ Million Dollars ------------------------					
FLATETH	62,300	61,785	58,277	56,084	595,358	59,536
USDABASE	62,300	68,300	65,800	62,800	651,700	65,170
14BILETH	62,592	69,772	68,128	65,545	670,312	67,031
16BILETH	62,986	71,692	70,427	67,284	686,462	68,646
18BILETH	63,580	73,103	74,859	70,897	707,065	70,707

Total payments over the ten year period of analysis are estimated at $115 billion. With only nine percent of the payments in countercyclical and loan deficiency payments, very little change in government payments can occur as a result of increased income. As ethanol production increases, the loan deficiency and countercyclical payments decline. This analysis assumes that the government program stays in place as it was in 2007 and that CRP land does not shift into production. It is likely that CRP program payments would have to increase as contracts expire to maintain the current land base in the CRP program. This is not accounted for in this analysis.

Changes in the Environmental Impact Indicators

In this manuscript, most of the environmental impact indicator comparisons will be conducted using the 18BILETH versus the USDABASE or FLATETH scenarios. Similar comparisons could have been made for the 14BILETH and the 16BILETH scenarios. The comparisons are made on chemical and fertilizer expenditures, along with nitrogen use, soil erosion and sedimentation and the estimated associated costs, plus carbon sequestration and emissions.

Non-Fertilizer Chemical Use

In the year 2016, non-fertilizer chemical use increased by a projected $271 million under the 18BILETH scenario when compared to the USDABASE scenario. The trend over the 10 year horizon is an increase in non-fertilizer chemical expenditures above the changes that occur in the USDABASE scenario. During the entire span of years, an increase above the USDABASE scenario of $487.5 million is projected, or an average increase of $487,549 per year in non- fertilizer chemical expenditures.

Not all regions of the country experience increases in non-fertilizer chemical expenditures however. While the average increase in non-fertilizer chemical expenditures for an ASD is $160,000 each year, in 2016, 90 ASDs out of 305 experience either no change or decreases in non-fertilizer chemical expenditures. The 18BILETH scenario has 88 ASDs with zero or reductions in chemical expenditures when compared to the FLATETH scenario.

Fertilizer Expenditures

In the year 2016, fertilizer expenditures increase nearly $300 million under the 18BILETH scenario when compared to the USDABASE scenario, and increase by over $600 million when compared to the FLATETH scenario. The trend over the 10 year horizon is an increase in fertilizer expenditures as corn acreage expands above the changes that occur in the USDABASE scenario. During the entire span of years, an increase above the USDABASE (FLATHETH) scenario of $1.3 ($2.4) billion is projected, or an average increase of $130 million per year in fertilizer expenditures.

In examining regional changes in fertilizer expenditures, decreases in fertilizer use are projected in parts of the delta, as cotton acreage is reduced, and in the Northern Plains, as corn and soybeans replace wheat. Areas with large increases in nitrogen expenditures fall within the Mississippi River Basin (Figure 2). Though not evaluated in this study, the increase in nitrogen expenditures will elevate concerns regarding nutrient movement leading to a greater likelihood the Gulf might experience additional hypoxia.

Soil Erosion and Sedimentation

Increasing ethanol production from 8.6 billion gallons (FLATETH) to 18 billion gallons in 2016 will result in an increase of 25.8 million tons of erosion. Although this increase in erosion is projected to be distributed throughout the nation, most occurs in the Corn Belt region. Nearly all ASDs in Iowa and Illinois are projected to have increased erosion levels exceeding 100,000 tons/year by 2016.

Increased suspended sediment estimates are projected to exceed 1.7 million tons per year in Illinois, 1.5 million per year in Louisiana, and 1.0 million tons per year in Iowa and Ohio when comparing the 18BILETH to FLATETH. A comparison of annual sediment deposits for these same two scenarios shows increases estimated at 1.2 million tons for Illinois, 0.94 million tons for Iowa, and 0.88 million tons for Ohio. The estimated change in cost damages as a result of these increases in both suspended and deposited sediment range from $36.6 to $150 million per year with an estimated value of $70.48 million per year (2005 dollars).

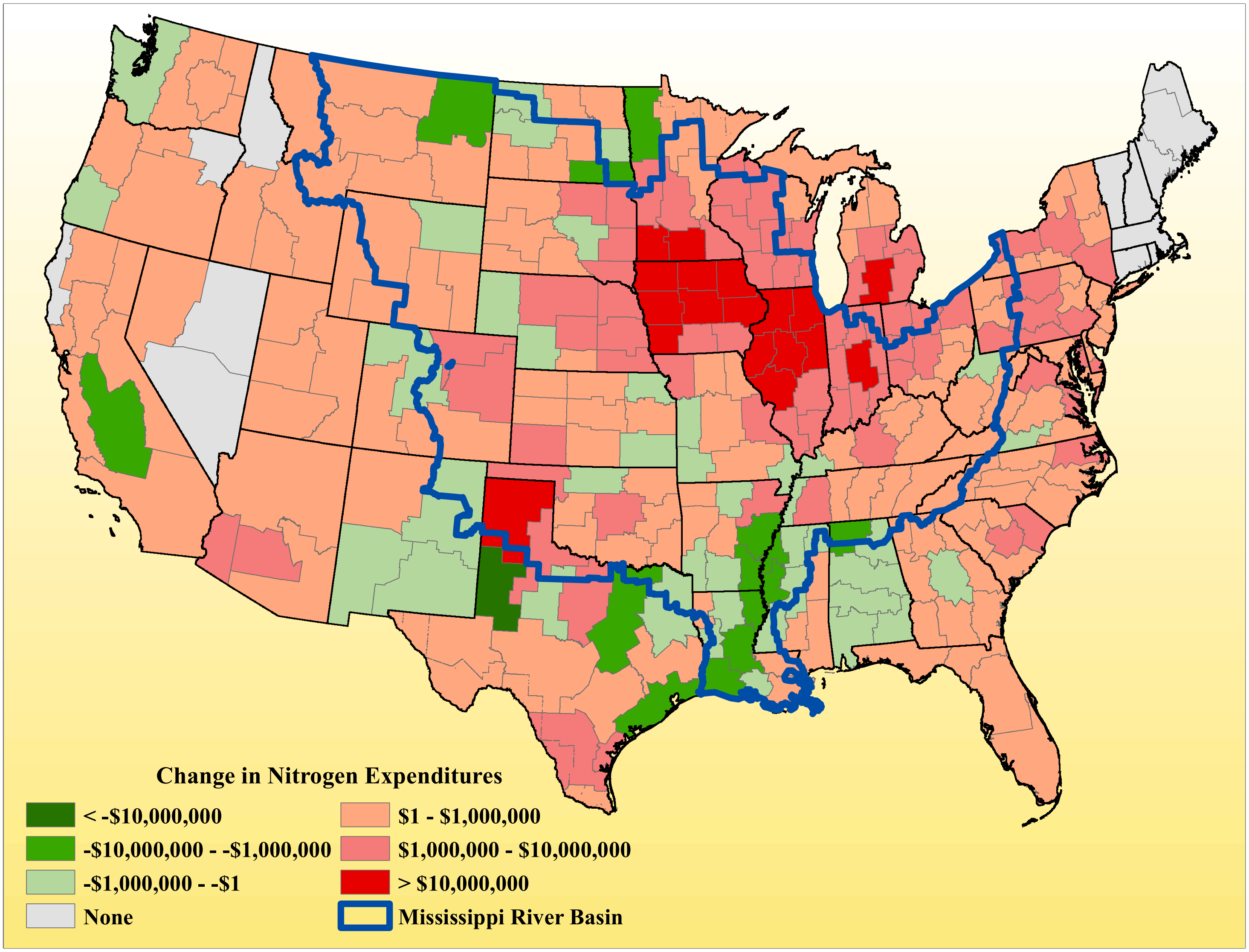

Figure 2. Change in Nitrogen Expenditures, 18BILETH vs FLATETH

Carbon Emissions and Carbon Sequestration

Carbon emissions in producing agricultural commodities, not including livestock, are lowest for the FLATETH scenario and highest for the 18BILETH scenario (Figure 3). The estimated difference between these two scenarios is slightly more than four million metric tonnes over the 10 year period. There is little change in the initial years of the analysis when comparing carbon emissions of the USDABASE, 14BILETH, 16BILETH, and 18BILETH scenarios to the FLATETH scenario. The largest changes appear to take place under the 18BILETH and 16BILETH in the years 2014-2016. When reviewing the data, however, it must be remembered that the analysis is not incorporating the carbon emissions from fuels that are being replaced by ethanol, nor do they include the carbon emissions as a result of transportation of the feedstock or the emissions resulting from distributing the ethanol once it is produced.[3]

Increased Average U.S. Corn Yield Impacts

Compared to the recent past, Monsanto has publicly indicated that future corn yields will increase at a much faster rate. To examine the potential impacts of an accelerated corn yield, corn yield was increased to 200 bushels by 2016 (Figure 4). This increase in yield would result in a 22% decline in corn commodity prices in the 18 billion gallon scenario. On average 3.6% less corn acreage is required to meet expected demands. Total crop acres in production change very little. Realized net farm income declines from a yearly average of

[3]The carbon analysis in this section incorporates changes in carbon emissions and soil carbon as a result of changes in land use. It does not compare the footprint of ethanol to that of gasoline production. Nor does it include the carbon emissions likely to occur as a result of feedstock and product distribution.

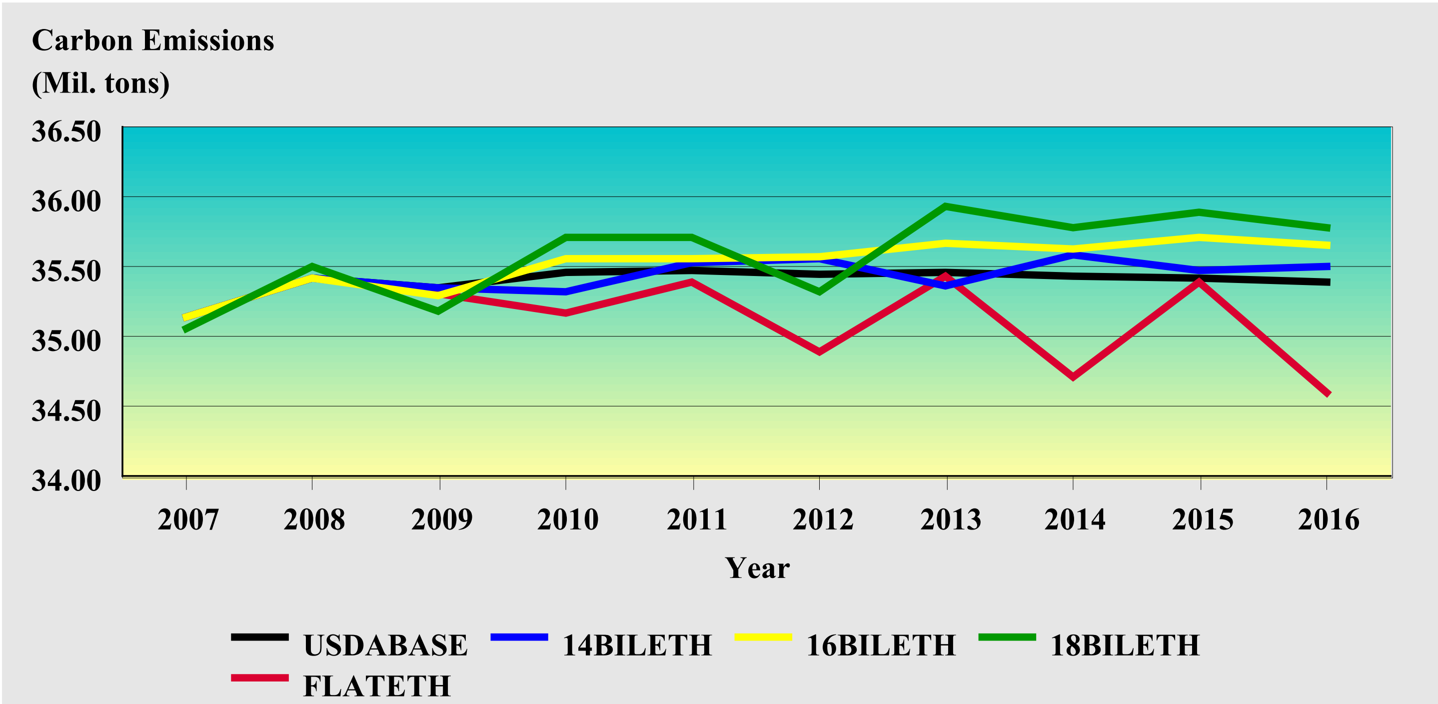

Figure 3. Carbon Emissions in Metric Tonnes for the Five Scenarios

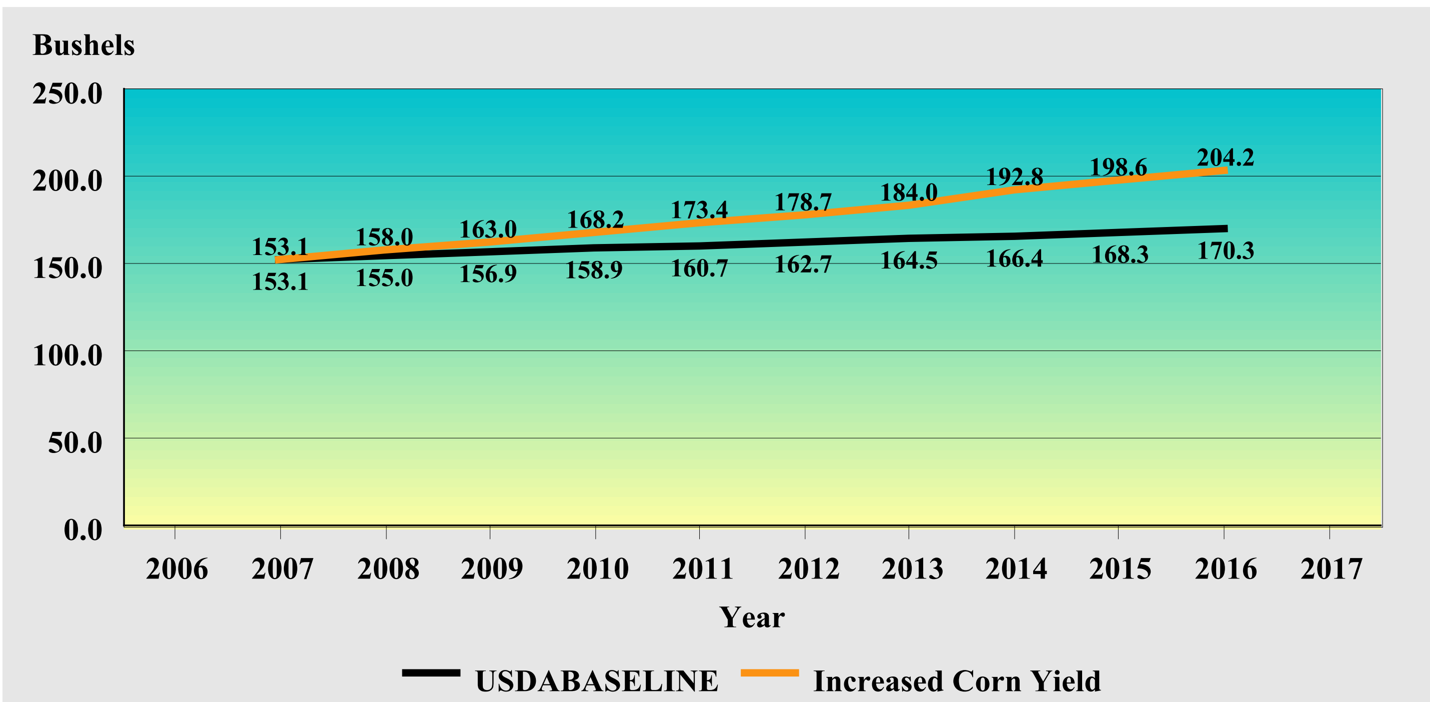

Figure 4. Projected Corn Yields, 2007 through 2016, for the 2006 USDA Baseline and the High yield Sensitivity Alternative

$66.9 billion reflected in the 18BILETH solution to $55.7 billion when corn yields increase.

Conclusions

The analyses performed indicate that U.S. agriculture can increase ethanol production from grains to 18 billion gallons over the next ten years. The analysis provides a comparison of the projected impacts of moving from an agricultural sector that produces sufficient feedstock for an 8.6 billion (FLATETH) gallon per year ethanol industry to an ethanol industry of 12 (USDABASE), 14 (14BILETH), 16 (16BILETH), or 18 billion (18BILETH) gallons. Overall, for the period 2007 to 2016, the estimated accumulated gains in net farm income exceeds $55 billion, with an accumulated potential savings in government payments of 2.4 percent assuming no changes in direct and CRP payments when compared to the USDABASE scenario. Realized net farm income over the ten year period of analysis increases $112 billion as a result of the ethanol industry increasing in scale from 8.6 billion gallons to 18 billion gallons. Increasing corn yields from the 2006 USDA Baseline each year of the analysis culminating in a 19% change by 2016, resulted in decreased acres planted in corn, reduced net farm income primarily as a result of decreased corn prices, and little change in total land in production.

Land use shifts occur as corn production increases as a result of increased returns for this crop. As land moves away from other crops into corn, prices for those crops are bid up. Cotton shifts westward and wheat shifts into the southeast. Corn production increases throughout the United States, but the largest increases occur in the western Corn Belt and eastern Nebraska. Soybeans shifts out of the Corn Belt into the Southeast. By 2016, corn acreage increases to 100 million acres in the 18BILETH scenario, an increase of 10 million acres compared to the USDABASE and an increase of more than 19 million acres when compared to the FLATETH scenario.

Resulting land use shifts and increases in corn acreage significantly impact the environmental indicators in this analysis. Use of both non-fertilizer chemicals and fertilizers increase. Soil erosion and sedimentation increase. Soil carbon sequestered as a result of agricultural production activities decrease and carbon emissions as a result of agricultural crop production activities increase. It is important to note, however, that under the assumptions of the analysis, no change in tillage practices were assumed. Changes toward no-till would reduce the amount of soil erosion, the amount of carbon emitted and the amount of carbon sequestered. However, chemical inputs would likely increase as chemicals are used instead of mechanical means for weed control.

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