The Impact of Biofuel Production on Crop Production in the Southern Plains

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Introduction and Background

Concern over high petroleum prices, unstable supply, geopolitical issues and environmental issues have all influenced interest in biofuel production. The Energy Policy Act of 2005 includes a provision designed to double the production and use of ethanol in fuels by 2012. The 2005 Act also provides that beginning in 2013, a minimum of 250 million gallons per year of ethanol be produced from cellulosic sources such as corn stover, wheat straw, and switchgrass. Goals for renewable fuels and a number of other incentives at the state level have also attributed to the interest in biofuel production. These factors have risen at a time of significantly low agricultural commodity prices, and have led to a relatively quick expansion in the interest and production of biofuels (Ugarte et. al.). The production of grain-based ethanol, encouraged by a variety of federal and state incentives appears likely to meet or surpass the goals provided in the Energy Policy Act. Cellulose-based ethanol production has not reached commercialization, making it difficult to predict progress toward the 2013 goal of 250 million gallons. The biofuels industry must bid agricultural resources away from current uses. Biofuel production will have major impacts on U.S. land use and the agricultural economies.

Ethanol production has already had major impacts in the grain belt. Ethanol demand for corn has influenced corn basis levels, the demand for storage infrastructure and impacted unit-train loading and river market facilities. The majority of U.S. ethanol production is currently centered in the mid-west grain belt, close to the source of feedstocks. Biodiesel production is more disperse but is also focused near feedstock supplies. However, ethanol production is expanding into the Southern Plains, a typically grain deficit region. The region's advantages in terms of lower natural gas prices (an important input in ethanol production), distance to ethanol markets and demand for distillers grain by-products appear to offset the rail transportation cost for the grain inputs. Ethanol project organizers in the Southern Plains also anticipate increased production of corn and grain sorghum and/or shifts of winter wheat production into winter barley a potential ethanol feedstock.

There is also recent interest in biodiesel production in the Southern Plains region. New varieties of winter canola, both conventional and herbicide resistant have been released. Winter wheat producers are adopting winter canola as a rotational crop to achieve diversification and for the agronomic advantages that can be gained from rotating between grass and broadleaf crops. Canola adoption would be expected to increase dramatically if the crushing and biodiesel production infrastructure is developed. The growth of biodiesel production facility in the Southern Plains region would be expected to increase the demand for both, winter canola production and summer oilseed crops such as soybeans, yet another major agriculture commodity used to produce biodiesel.

The commercialization of cellulosic – based ethanol (ethanol that comes from feedstocks such as switchgrass, corn stover, wheat straw and wood products residues) could have even greater impact on the agricultural industry (Epplin). Researchers in the Department of Biosystems and Engineering at Oklahoma State University have developed pilot-scale equipment for the production of ethanol from switchgrass. Potential conversions of 75 gallons or higher from each ton of switchgrass coupled with expected switchgrass yields of 4-6 tons/acre (estimated to be equivalent to the yield of pasture hay) have led to excitement over the future role of dedicated biofuel crops in the regions agriculture. President George Bush mentioned switchgrass in both his 2006 and 2007 State of the Union speech. A September 8th article appearing in the New York Times included the statement “You could turn Oklahoma into an OPEC member by converting all of its farmland into switchgrass.”

Research and development is ongoing in an attempt to develop economically competitive methods to produce ethanol from cellulose. However, as of this writing no economically competitive commercial size facility exists in the United States (Ugarte et. al.). Technological breakthroughs have not occurred at the rate anticipated. Several competing conversion technologies that would enable use of cellulosic biomass for biorefinery feedstock are under development. Examples include gasification, pyrolysis, liquefaction, fermentation, and anaerobic digestion (Epplin). A number of challenges must be overcome if cellulosic ethanol is to become an economically competitive alternative to corn-ethanol and eventually to gasoline.

If and when an economically competitive bioconversion system is developed, it is anticipated that the agricultural community will be actively engaged in the production, harvest, storage, and transportation of feedstock to biorefineries. Relative to corn grain, cellulosic material such as switchgrass is bulky and difficult to transport. Ethanol plants may post a competitive price and corn grain will be delivered by the existing marketing system. The infrastructure for production, harvest, storage, transportation, and price risk management of corn grain is well developed. Unlike corn grain, a well-developed harvesting and transportation system does not exist for cellulosic biomass such as switchgrass and crop residues.

Objectives

The goal of this study was to investigate the impact of biofuel production on Oklahoma agriculture. While the study focuses on Oklahoma land use, the results provide important insights into the impact of biofuel production on the Southern Plains region. The study has three basic objectives. (1) Determine the current grain-based biofuel feedstock base and its regional dispersion. (2) Project shifts of cropland into grain-based biofuel feedstocks at various biofuel price levels, potential biofuel production and the implications of these land-use shifts. (3) Project potential cellulosic-based ethanol feedstocks including crop residues, converted cropland and conservation reserve program (CRP) at various biofuel prices and the implications of these land-use shifts.

The previously described objectives represent an important first step in identifying and quantifying the potential impacts of biofuel production on Southern Plains agriculture. This study projects when producers would have an economic incentive to convert their current crops into biofuel feedstock crops. The study did not attempt to model the likelihood or time path of such conversions. The time-path for the development of biofuel refining infrastructure is also not considered. Full development of the grain-based biofuel production potential identified in this study could require an investment of up to $1 billion while full development of a celluloic based industry could require $10 billion or more infrastructure investment.

Data and Methods

A mathematical programming model was used to project the potential impacts of biofuel production on the Southern Plains crop production. The model compares the revenues of existing crops in every county in Oklahoma, with the potential revenues earned by converting to alternative biofuel crops. The model allowed land in each county to shift into biofuel production when the returns from the biofuel crop exceeded that of the existing crop enterprise. A wide range of biofuel prices were used, allowing the model to project the sensitivity of biofuel crop adoption to biofuel price levels. Two scenarios were considered. The first scenario considered potential cropping shifts due to grain-based ethanol and grain-based biodiesel production. The second scenario considred cellulosic-based ethanol and grain-based biodiesel production.

County level price and yield data and Oklahoma State University Enterprise Budget production cost estimates were used to reflect revenues and costs for existing crops. Prices and yields for grain-based biofuel crops were based on 5 year historical county averages. The enterprise budget production costs included both a fixed and variable component providing production cost estimates for each crop in each county. Ethanol converstion rates of 2.8 gallons/corn bushel equivalent and 75 gallons/ton of cellulosic material were assumed. Biodiesel conversion was based on standard oil content of 20%, 38%, and 44% for soybeans, winter canola, and peanuts, respectively, and an extraction efficiency factor of 85%. The projected prices of biofuel grain feedstocks were calculated as the residual value above the fixed and variable costs of biofuel production including a 15% return on investment for the owners of the biofuel refinery. The biofuel crop returns therefore represented the maximum available to the crop producer. The cropping changes projected therefore represent an upper limit on the potential biofuel crop adoption.

The impact of cellolosic-based ethanol production, which was considered as a separate scenario, considered three sources of cellolosic feedstocks. These included crop residues (corn stover and wheat straw), the production of switchgrass on CRP acreage and the conversion of existing cropland into switchgrass production.   County level estimates of switchgrass yield were based on the yields of alfalfa hay. Switchgrass yields on CRP acreage were based on data from a previous Oklahoma State University study. Switchgrass production costs were based on OSU Enterprise Budgets for hay production.

Alternative Biofuel Crops

In general, summer crops such as corn, grain sorghum, cotton, alfalfa, peanuts and oats are grown in areas of the state with higher precipitation patterns and/or irrigation capacity. Winter crops such as hard red winter wheat and rye are grown in areas which typically receive lower amounts of precipitation during the summer months. This dichotomy is not complete as some land can be transitioned between winter and summer cropping patterns. Table 1 provides a summary of the major alternative biofuel crops for the major crops produced in Oklahoma.

Table 1. Alternative Biofuel Crops for Oklahoma

Crop	Harvested Acres	Potential Alternative Crop: Ethanol	Potential Alternative Crop: Biodiesel
Wheat	4,000,000	Hulless Barley	Winter canola
Hay	2,920,000	Corn or sorghum	Soybeans, various oilseeds
Corn	290,000	(current ethanol feedstock)	Soybeans, various oilseeds
Grain Sorghum	270,000	(current ethanol feedstock)	Soybeans, various oilseeds
Soybeans	305,000	Corn or sorghum	(current biodiesel feedstock)
Cotton	240,000	Corn or sorghum	Soybeans, various oilseeds
Rye	70,000	Hulless barley	Winter canola
Alfalfa	55,000	Corn or sorghum	Soybeans, various oilseeds
Oats	45,000	Corn or sorghum	Soybeans
Peanuts	35,000	Corn or sorghum	(current biodiesel feedstock)

Results

Current Biofuel Production

Oklahoma currently produces grain based ethanol feedstocks equivalent to 112 million gallons of ethanol production and biodiesel feedstocks equivalent to 16 million gallons of biodiesel (Table 2). Three ethanol plants with a combined capacity of 150 million gallons are currently under construction. A biodiesel plant with a capacity of 15 million gallons has recently begun production. Anticipated biofuel production will therefore exceed currently available feedstocks, even when competing uses for livestock are ignored.

Table 2. Oklahoma's Current Potential Biofuel Production

Crop	Land in Production (acres)	Total Annual Yield (bushels)	Potential Biofuel (gallons)
Corn (ethanol)	200,000	26 Million	75 Million
Sorghum (ethanol)	310,000	13 Million	37 Million
Soybeans (biodiesel)	238,000	9 Million	16 Million

Based on a conversion rate of 2.8 gallons of ethanol per bushel was assumed for the conversion of corn and sorghum and based on a conversion rate of 1.34 gallons of biodiesel from every 60lb. bushel of soybeans.

Potential Biofuel Production from Grain Crops

The potential shift of existing crops into grain-based ethanol at various ethanol prices is shown in Table 3. The results indicated that at ethanol prices above $2.00/gallon cotton and peanut acreage would shift into feed grain production. Ethanol prices of almost $2.90/gallon were required to shift hard red winter wheat acreage into grain sorghum production. Ethanol prices of over $4.00/gallon were required before hard red winter wheat acres began to shift into winter barley. Total ethanol production at $3.00/gallon was projected at 686 million gallons/year, roughly four times higher than currently capacity. At an assumed ethanol price of $5/gallon ethanol production from grain-based feedstocks was projected to be just under 1 billion gallons/year.

Table 3. Ethanol Production (gallons) at Various Ethanol Prices

	Ethanol Price $/Gallon						
Crop	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00
Corn	74,597,699	74,597,699	74,597,699	74,597,699	74,597,699	74,597,699	74,597,699
Sorghum	37,030,759	37,030,759	37,030,759	37,030,759	37,030,759	37,030,759	37,030,759
Alfalfa	35,567,314	56,632,897	60,394,839	60,394,839	60,394,839	60,394,839	60,394,839
AOH	413,711,124	416,127,300	418,711,084	418,711,084	419,352,284	419,352,284	419,352,284
Cotton	5,569,033	12,877,403	19,127,664	19,127,664	19,210,854	19,210,854	19,590,156
Oats	2,793,979	2,834,763	2,834,763	2,834,763	2,834,763	2,834,763	2,834,763
Peanuts	803,874	1,302,752	7,499,436	8,322,992	9,014,452	9,014,452	9,186,524
Rye	0	0	0	1,619,042	2,844,028	2,857,828	2,870,206
Soybeans	61,059,720	64,912,172	66,021,002	66,210,432	66,210,432	66,287,096	66,287,096
Wheat	0	0	0	278,376,527	278,393,124	278,393,124	278,393,124
Total=	631,133,501	666,315,743	686,217,244	967,225,799	969,883,232	969,973,696	970,537,449

The potential shift of existing crop land into biodiesel feedstocks is shown in Table 4. While the model indicated that winter wheat would shift into barley production only at high ethanol prices, winter wheat acres shifted into canola for biodiesel production at biodiesel prices below $2.00/gallon. Summer crops (cotton, peanuts, corn, grain sorghum and alfalfa) shifted into soybean/biodiesel production only at very high (> $5.00/gallon) biodiesel prices. At $3.00/gallon the results indicated that the shift in wheat acreage would be sufficient to produce almost 350M gallons of biodiesel, over 20 times current production capacity. The results indicate that land converts into a biodiesel producing crop at a considerably lower price than converting land into ethanol producing crops. This suggests that the Southern Plains region may have more potential for a niche market in biodiesel production versus ethanol production. The potential conversion of wheat into canola represents the largest single potential source of biodiesel. It should be noted that winter canola has only been recently introduced in the region, making it difficult to assess its long-term adaptability.

Table 4. Potential Biodiesel Production at Various Biodiesel Prices

	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00
Soybeans	15,996,498	15,997,867	15,997,867	15,997,867	15,997,867	15,997,867	15,997,867
Alfalfa	0	0	0	27,260	98,156	2,581,236	3,440,428
All Other Hays	0	0	0	0	0	650,089,799	662,121,154
Corn	2,952,095	3,011,102	3,029,921	3,029,921	3,029,921	3,508,220	4,395,626
Cotton	0	2,448,379	2,448,379	2,448,379	6,845,805	6,954,543	7,032,404
Oats	0	0	0	0	967,436	4,149,952	4,225,391
Peanuts	0	0	0	0	0	995,037	4,329,485
Sorghum	12,461,889	12,698,437	12,906,933	12,989,231	12,989,231	12,989,231	12,989,231
Wheat	354,083,703	354,083,703	354,083,703	354,083,703	354,083,703	354,083,703	354,083,703
Total	385,494,185	388,239,488	388,466,803	388,576,361	394,012,119	1,051,349,588	1,068,615,290

Potential for Production of Cellulosic Feedstocks

The potential cellulosic-based ethanol production from crop residues, CRP acreage and converted crop land is provided in Table 5. As would be expected the addition of cellulosic ethanol substantially increases the projected potential ethanol and crop land shifts into cellulosic ethanol at lower biofuel prices. While the production of switchgrass for ethanol on Conservation Reserve Program land is often touted as a future energy solution, the model results indicated that existing cropland would shift into switchgrass at lower ethanol prices than were required to convert conservation reserve land. Wheat acres were projected to begin shifting into cellulosic ethanol prices of slightly over $2.00/gallon which would lead to substantial production (over 1B gallons/year) at $3.00/gallon and higher prices.

Table 5. Potential Cellulosic Ethanol Production (gallons) at Various Ethanol Prices

	Ethanol Price: $/gallon					
Crop	$2.00	$3.00	$3.50	$4.00	$ 4.50	$5.00
Corn Stover	55,927,522	55,948,274	55,948,274	55,948,274	55,948,274	55,948,274
Wheat Straw	476,474,615	171,074,550	171,074,550	171,074,550	171,074,550	171,074,550
Corn	118,965	16,788,945	35,563,365	35,889,555	35,889,555	35,889,555
Sorghum	23,045,220	50,763,660	50,763,660	50,763,660	50,763,660	50,763,660
CRP	118,136,734	118,136,734	118,136,734	118,136,734	118,136,734	118,136,734
Alfalfa	10,310,250	12,088,245	16,666,995	16,666,995	23,805,855	23,805,855
All Other Hay	23,849,022	227,832,648	227,832,648	227,832,648	227,832,648	227,832,648
Cotton	2,611,530	2,611,530	2,611,530	2,611,530	2,611,530	2,611,530
Oats	167,190	547,410	547,410	868,470	884,895	884,895
Peanuts	8,895,585	8,895,585	8,895,585	8,895,585	8,895,585	8,895,585
Rye	9,413,235	9,549,900	9,549,900	9,549,900	9,549,900	9,549,900
Wheat	104,749,560	638,852,490	638,852,490	638,852,490	638,852,490	638,852,490
Total	833,699,428	1,313,089,971	1,336,443,141	1,337,090,391	1,344,245,676	1,344,245,676

Summary and Conclusion

Oklahoma, like many areas in the Southern Plains is currently a feed deficit region. Even if livestock needs are ignored, the biofuels plants currently under construction in Oklahoma exceed the states total feed grain production. The model results suggest that results biofuel production could provide the incentive for substantial (four-fold) increase in feed grain production. It should be emphasized that this result is based on the optimistic assumption that biofuel profits, in excess of a reasonable return on investment in the biofuel refinery are passed on to the producer. This shift would have major impacts on the livestock industry since much of this production would be the result of land currently used for hay and pasture production shifting into feed grains. The model also indicated that Oklahoma producers would shift land into biodiesel feedstocks, primarily winter canola. This increase in biodiesel feed stocks would come at the expense of reduced winter wheat production. Crop land was projected to convert into biodiesel feedstocks at lower biofuel prices suggesting that the Southern Plains region may have more potential for biodiesel production versus ethanol production.

The commercialization of cellulosic ethanol technologies would greatly expand potential biofuel production and encourage cropping shifts at lower biofuel prices. The results indicated that the major source of cellulosic feedstock production will be from conversion of existing croplands rather than production on marginal (CRP) lands.

While this analysis has a number of limitations it does provide important insights into the impact of biofuel production on feed deficit regions such as the Southern Plains. Biofuel production could provide the incentives for substantial cropping shifts, largely at the expense of hay production. The Southern Plains region which is characterized by limited precipitation, biodiesel production, biodiesel production may have greater impact relative to ethanol. Increases in biodiesel feedstocks are likely to come at the expense of wheat production. Finally, the realization of cellulosic ethanol technologies, while greatly enhancing ethanol production are also likely to impact existing crop and forage production.

References

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