ECONOMIC AND ENVIRONMENTAL TRADEOFFS FROM SWITCHGRASS AND ETHANOL PRODUCTION (A CASE IN OKLAHOMA)

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ECONOMIC AND ENVIRONMENTAL TRADEOFFS

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CHAPTER I

INTRODUCTION

The United States has faced a wide range of interrelated and complex economic, social and environmental problems over the last century. However, climate change has put the nation's environmental sustainability into jeopardy. Various policy measures to address this problem have raised conflicting interests among entities which has slowed down the emission reduction objective to the extent it's envisaged by both the U.S. and the rest of the world.

The search for environmentally friendly renewable energy sources that will lessen or eventually eliminate the United States' dependency on foreign fossil fuels dates back to the 1970s' energy crisis which led to the National Energy Act of 1978 (U.S. Energy Information Adminstration [EIA], 2005). Despite promising results from solar, geothermal, wind and biomass alternative renewable energy sources that have been pursued, fuel ethanol outshines the rest in gaining remarkable attention over the years. The history of ethanol further extends back to the 17th century with the invention of an engine by Samuel Morey in 1826 and the quadricycle by Henry Ford in 1896; both operated with ethanol. Even if ethanol was widely used for various purposes until the end of World War II, its availability was halted by the existence of other, cheaper fuel alternatives until it regained its fame when the Energy Research, Development, and Demonstration Act of 1974 initiated research and development in the field. Since then U.S. has introduced multiple forms of government intervention to support the ethanol sector. 1978 marks the first 40 cent subsidy per gallon of ethanol blended in E10 (10% ethanol mixed with gasoline).

The subsidy continued, despite minor fluctuations, for 33 years until Congress ended the 45 cent subsidy on December, 2011 (U.S. Energy Information Adminstration). In addition, a 2.5% ad valorem import tariff on the import of ethanol, loan guarantees for small ethanol producers, grant funding for biofuels research, etc. have been used to promote the growth of ethanol production in the country (U.S. Department of Energy, 2012).

The very recent Energy Independence and Security Act of 2007 (EISA) extended the initial Renewable Fuel Standard (RFS1) which required 7.5 billion gallons of renewable fuel to be blended with fossil fuel in 2012 to 36 billion gallons of ethanol by year 2022; out of which 16 billion should be produced from cellulosic feedstocks like switchgrass (Luchansky & Monks, 2009; Sissine, 2007). Following the repeal of the 45 cent Volumetric Ethanol Excise Tax Credit (VEETC) and the absence of large scale commercial cellulosic ethanol production, there a skepticism that there may not be enough incentive for cellulosic ethanol producers to meet the 16 billion ethanol production requirement by year 2022.

Even if corn-based ethanol had been found to be economically viable (McLaughlin et al., 2002) and environmentally friendly in terms of a positive energy conversion ratio (Hill, Nelson, Tilman, Polasky, & Tiffany, 2006; Shapouri et al., 2010), other researchers found ethanol production had the following negative impacts: food price increase, high degree of land shift from other uses (Attenberg & United States., 2009; Fargione, Hill, Tilman, Polasky, & Hawthorne, 2008), and energy conversion inefficiency (Pimentel et al., 2010). But most research suggested that advances in ethanol production technology could overcome these undesirable impacts and bring the nation closer to its energy independence.

In the last several years, research on ethanol conversion methods in the U.S. have advanced from starch based conversion, using corn and sugarcane as feedstocks, to cellulosic conversion methods using corn stover, switchgrass and woody biomass. Cellulosic ethanol conversion yields more ethanol per acre of feedstock, and it can use a wide range of resources as inputs. Furthermore, cellulosic feedstocks currently have few alternative uses (McLaughlin & Walsh, 1998). This begins to address the questions of energy conversion efficiency. However, the question of whether switchgrass based ethanol production has positive economic and environmental benefits for the local and surrounding communities still needs more thorough research.

Most of the discussions on the benefits of ethanol production revolve around the economic impact the distillation plants have in the locations where they are built in terms of new employment, labor income and output. This approach only shows one side of the story, because industries are interrelated to each other in their backward linkages through acquiring their inputs and in their forward linkages in delivery of final goods for consumption. It is not clear from the literature, however, that switchgrass and ethanol production create additional jobs in the community, or if there are opportunity costs that need to be considered. Switchgrass production may be less labor intensive than existing agricultural production, so that as land is converted from its current production to switchgrass production jobs may be lost locally. Additionally, the nutrient requirements of switchgrass, a native grass of Oklahoma, may be significantly less than that of existing agricultural production, such that local farm supply outlets might suffer lower sales and local manufacturing of fertilizer and/or herbicides may decline due to switchgrass production. Thus, understanding the local economic impacts of the production cycle is important to assessing the merit of cellulosic ethanol production in Oklahoma. Additionally, Oklahoma is a leading producer of wheat and cattle, and eighty percent of the state's land area is used in agriculture. Conversion of crop and pasture land to switchgrass production could potentially impact agricultural employment and output directly, as well as the shift in input requirements mentioned previously.

There remains, also, the question of environmental benefits from ethanol. While it is known that burning ethanol generates less greenhouse gas (GHG) emissions than conventional gasoline, ethanol production is very energy intensive. Depending on the energy source utilized to produce ethanol, the level of greenhouse gas emissions generated to create ethanol can exceed the benefit of reduced GHG emissions during its consumption. This impact may be intensified if one considers the environmental impacts associated with the production of the switchgrass. Thus, more scrutiny of the environmental impacts of ethanol is warranted, and a comparison of the economic and environmental impacts is needed to assess the desirability of ethanol as an alternative fuel source.

Thus, this paper will compare the existing land uses for agricultural production with projected increases in switchgrass and ethanol production to determine the economic and environmental impacts on the local community. It may be that communities face a difficult choice of choosing economic benefits (e.g., new jobs and income) over environmental costs (e.g., increased pollution of GHG). This information is crucial for communities to fully understand how the Renewable Fuel Standard under EISA might impact and enable them to appropriately assess the tradeoffs between economic and environmental impacts.

Objectives

The general objective of this paper is to determine the overall economic and environmental impact of projected cellulosic ethanol production from switchgrass feedstock in Oklahoma resulting from compliance with the Energy Independence and Security Act's mandate of 36 billion gallons of ethanol to be produced nationally by year 2022.

The specific objectives are;

- Determine long term impact of ethanol production on output, employment, and value added in Oklahoma.
- Determine the economic effect of land shift to switchgrass from the production of other crops and livestock in the state.
- Determine the size and type of pollution caused by switchgrass and ethanol production.
- Determine if ethanol production pollutes less than the status quo agricultural production.

CHAPTER II

LITERATURE REVIEW

Ever since Leontief suggested that input-output (I-O) models can be extended for environmental applications, many studies with different approaches have been carried out. The environmental problems that are discussed have also diversified from energy consumption in the 1960s to global warming in recent years. Despite an increase in number of studies which use environmentally-enhanced input-output models, few studies have focused on the U.S. economy over the past 15 years (Hoekstra, 2010). But the I-O model still remains one of the most commonly used approaches to study both economic and environmental problems. Furthermore, questions remain about the ability of ethanol to accomplish its primary justifications in the U.S., which are to minimize energy dependence and reduce greenhouse gas (GHG) emissions. However, these objectives have been heavily debated issues from economic, environmental and ethical perspectives because there is not a consistent message found in the academic literature.

Ever since the commercialization of ethanol began in the U.S., numerous studies have been conducted to assess its economic and environmental significance to local communities. However, mixed results have been reported, depending upon what impact was measured. The diversity of impacts, from job creation to food prices, has created confusion over the economic benefits of ethanol. English, Menard, and De La Torre Ugarte (2001) selected 10 Midwestern States, analyzed state wide impacts of construction and operation of ethanol plants, and found that a plant that processes 2000 metric tons of corn stover per day creates 1,104 to 2,107 jobs annually during the operation phase. Another study by Renewable Fuels Association adopted a similar methodology using IMPLAN, a commonly used input-output software and data package, and looked at the overall economic impact of ethanol production for U.S. economy. This study concluded that the ethanol sector created over 400,000 jobs across the nation in 2009 by producing 10.6 billion gallons of ethanol. The study also showed that the sector led to a substantial increase in labor income and value added (Urbanchuk, 2011). Other studies found that corn-based ethanol leads to higher food prices by decreasing the supply of corn available for human and animal consumption and by indirectly causing additional land to shift from other crops (Attenberg & United States., 2009).

Ethanol production requires very complex decisions at each level of its processes; nonetheless these contradicting results about whether ethanol production is beneficial in terms of economic considerations do not give sufficient information for local decision makers. Low and Isserman (2009) argue that ethanol production sustainability is heavily dependent on peculiar characteristics of the locality in which they operate. This implies that care should be taken in interpreting studies, because an ethanol plant studied in one county may not give similar outcomes in a different county. In addition, they also inquired into what lies behind the inconsistent findings and concluded that the predominant difference revolves around the assumptions made regarding the characteristics of ethanol and agricultural production in the study area (P. 86). To prove this claim, they created four scenarios by taking four different counties in Illinois with different population size, corn production, and proximity to interstate and found that the total output and employment impact varied because of the assumptions made regarding the land ownership, livestock industry in the counties, rental rates, etc. Another interesting point raised by Justus (2007) is that opportunity costs should be considered when conducting such analyses. Building upon Low and Isserman (2009) and Justus (2007), I compare the current land use and production schemes with estimated ethanol production in Oklahoma to approximate the opportunity cost of pursuing ethanol production in the state. This will avoid the potential bias of recommending ethanol production based on minimal positive impact without considering its opportunity cost.

In addition to assessing the potential economic benefits of ethanol to U.S. communities, life-cycle analysis has been used to identify the environmental benefit of ethanol production. Life-cycle analysis is a technique which attempts to calculate the total environmental impact from the production and consumption of a product by adding together the pollution generated throughout the production process of a good. Hill et al. (2006) used life-cycle analysis for the U.S. economy and found that ethanol will lead to a net energy gain of up to 25%. This means ethanol has more energy content than the energy used in its production process. A similar result was also found by Shapouri et al. (2010). However, other studies showed that corn-based ethanol production requires 46% more fossil fuel consumption during its production process than the energy content that will be gained from ethanol (Pimentel et al., 2010). The emission efficiency argument also becomes suspect if one considers the shift in land use that is required to produce sufficient corn supplies; more specifically, carbon is released when new land is cleared for crop production and additional carbon is lost in the removed vegetation. Fargione et al. (2008), for example, determined that it takes around 93 years to repay the carbon debt caused by shifting native grass lands to ethanol production from corn feedstock in the Central U.S.

From an environmental stand point, the wide range of results in life-cycle analyses (LCA) stem from the difference in efficiency measuring units and also the resolution at which the production processes are analyzed. The efficiency measures reported by various LCA studies include: fuel energy ratio, net energy value, fuel energy ratio, GHG fluxes, GHG displacement, etc. The difference in units hinders comparison of results across studies (Davis, Anderson-Teixeira, & DeLucia, 2009). On the same note, Feng, Rubin, and Babcock (2010) found that the emission reduction potential of ethanol will be constrained when the study area of analysis is extended from Iowa to other states. Another significant difference in the LCA literature is the number and type of environmental interventions considered. Most studies apply LCA to trace back the carbon footprint, GHGs or the net energy gain or loss from ethanol production. However, it's evident that CO_2 is not the only emission caused by ethanol production. Feedstock production requires consumption of fertilizers, herbicides, insecticides and different types of fuel. Similarly, ethanol production also uses chemicals, enzymes and energy as input (Pimentel & Patzek, 2008).Thus, unless all types of pollutants are considered in LCA over its entire production process, ethanol can hardly be considered a green energy source despite its potential to reduce CO_2. In this paper I eliminate this problem by using the academic version of Comprehensive Environmental Data Archive (CEDA 4.41) database which contains a wide variety of environmental impact variables, so my results include many pollutants.

CHAPTER III

METHODOLOGY

Input-Output Model Overview

The input-output model was developed by Wassily Leontif in the late 1930's. This framework has been acclaimed for its breakthrough approach in laying down a system of linear equations that show the economic interdependence of industries (Miller & Blair, 1985). Originally, the model was developed to show the flow of an industry's output throughout the economy via inter-industry transactions and final demand purchases. Due to difficulty in handling complex manual matrices computations and shortage of data, the model's application was limited to a single region and its implementation was also constrained during the early periods. However, over the recent years, the development of high speed computers and advanced software packages has enabled modeling multiple regions. Various modeling approaches have also been developed by many economists over the years.

I-O model is based on three important assumptions. First, the model assumes that the economy represented by the model is in an equilibrium state. This implies that there is no excess input or output in any markets in the model. Therefore, every increase in output by an industry requires additional production from input supplying industries. Since the market clears, the total output produced by an industry is equal to the total purchases by other industries for this sector plus exports and institutional demand. Second, industries face constant returns to scale. Doubling all inputs in an industry will lead to a doubling of its final outputs. Third, the model assumes fixed factor prices for all goods; any change in final demand can be met using existing technology and additional input supplies without affecting the market prices. Under the above assumptions, the model can be used to assess an impact on output, employment and value added components in any sector due to a certain change in final demand at the national, regional, state or county level. These impacts can be measured by the direct, indirect and induced effects.

The direct effect represents the change in final demand itself. However, from the equilibrium assumption, we know that other sectors have to increase their production as well to provide inputs for the initial direct effect. The indirect effect measures this secondary impact in which input suppliers have to provide additional output to satisfy the demand created by the direct impact. Households will get wages and salary from the increased direct and indirect impacts. The induced effect measures the overall increase in output due to increased spending by households due to the initial increase in final demand (Miernyk, 1965). Thus, the key feature of the input-output model is this capability to measure these three impacts for a given change in final demand.

Model Structure

Economic Impact

To determine the total economic and environmental impact of cellulosic ethanol production from switchgrass feedstock in the Oklahoma, I have adopted an input-output model using IMPLAN V3 software package. Nine scenarios with varying number of ethanol plants and switchgrass supplying counties are modeled to accomplish this objective. Tembo (2000) created a mixed integer mathematical programming model to determine the optimal ethanol refinery locations, plant size and biomass requirements in Oklahoma by making different assumptions towards plant size, construction cost, project life (10 and 20 years), transportation cost, breakeven ethanol price, and discount rates and maximizing net present value to the industry. Haque (2010) built upon his model by refining his assumptions regarding switchgrass production. Using Haque's model, assuming an ethanol plant with 50 million gallon capacity (reflective of the technology most likely to be commercialized), and restricting land conversion for switchgrass production to 10% of cropland and 10% of pasture land in each county, nine ethanol plant locations and the total area of crop and pasture land need for each plant were determined and are presented in Table 1.

A typical I-O analysis assesses an impact of new industry production, cellulosic ethanol production in my case, by creating an Industry Change Activity for the direct impact amount for the appropriate sectors on IMPLAN. Then IMPLAN would identify input producing industries to meet the final demand change and determine the direct, indirect and induced impacts. However, this common procedure will not work for my analysis, because the sectoral classification in IMPLAN does not exactly fit the characteristics of both cellulosic ethanol and switchgrass production. No IMPLAN sector matches the production technology and value-added components of cellulosic ethanol, so ethanol production is modeled using analysis-by-parts method. Additionally, switchgrass is not commercially produced and therefore not represented by one of IMPLAN's existing sectors. However, I modified IMPLAN Sector 9, sugarcane and sugar beet farming, to model switchgrass production because sugarcane is not produced in Oklahoma, which gives me the flexibility to introduce the new switchgrass production in my models without affecting the existing industrial mix in the state. I assumed that all switchgrass produced will be consumed for ethanol production. The impacts of switchgrass production and ethanol production are run in separate models to isolate their impacts to different regions. The ethanol production impact is limited to the county in which the plant is located and the switchgrass production impact incorporates all counties producing switchgrass supplied to the ethanol plants in each scenario.

The analysis-by-parts (ABP) method enables me to capture the indirect impact of all inputs purchased by ethanol plants by running the model as if they were direct impact components. This

Table 1: Ethanol plant locations and switchgrass supplying counties under scenarios 1- 9

Scenarios	Biorefinery location	Biomass harvested (tons)			Acres harvested			Yield (tons/acre)
		Cropland	Pasture land	Total	Cropland	Pasture land	Total	
1 ethanol plant	Grady	467,495	137,825	605,320	94,499	38,640	133,139	4.5
2 ethanol plants	Grady & Garfield	1,037,593	173,595	1,211,188	223,140	48,820	271,961	4.5
3 ethanol plants	Grady, Garfield, & Okmulgee	1,464,610	353,474	1,818,083	304,034	96,933	400,967	4.5
4 ethanol plants	Grady, Garfield, Okmulgee, and Pontotoc	1,750,016	673,266	2,423,282	365,132	189,651	554,783	4.4
5 ethanol plants	Grady, Garfield, Okmulgee, Pontotoc, and Woods	2,311,779	717,660	3,029,439	503,177	204,126	707,302	4.3
6 ethanol plants	Grady, Garfield, Okmulgee, Pontotoc, Woods, and Washington	2,673,915	960,547	3,634,462	575,949	277,054	853,002	4.3
7 ethanol plants	Canadian, Comanche, Garfield, Okmulgee, Pontotoc, Washington, and Woodward	3,180,013	1,059,529	4,239,542	711,912	311,303	1,023,216	4.1
8 ethanol plants	Blaine, Garfield, Grady, Jackson, Okmulgee, Pontotoc, Washington, and Woodward	3,656,138	1,190,007	4,846,144	850,375	373,578	1,223,953	4.0
9 ethanol plants	Blaine, Grady, Garfield, Jackson, Okmulgee, Pontotoc, Texas, Woods, Washington	3,988,675	1,466,305	5,454,980	965,725	484,833	1,450,558	3.8

Source: Unpublished estimates from a model developed by Tembo (2000) and modified by data from Haque (2010) and different technology assumptions.

Figure 1: Locations of switchgrass and ethanol production in scenarios 1-9

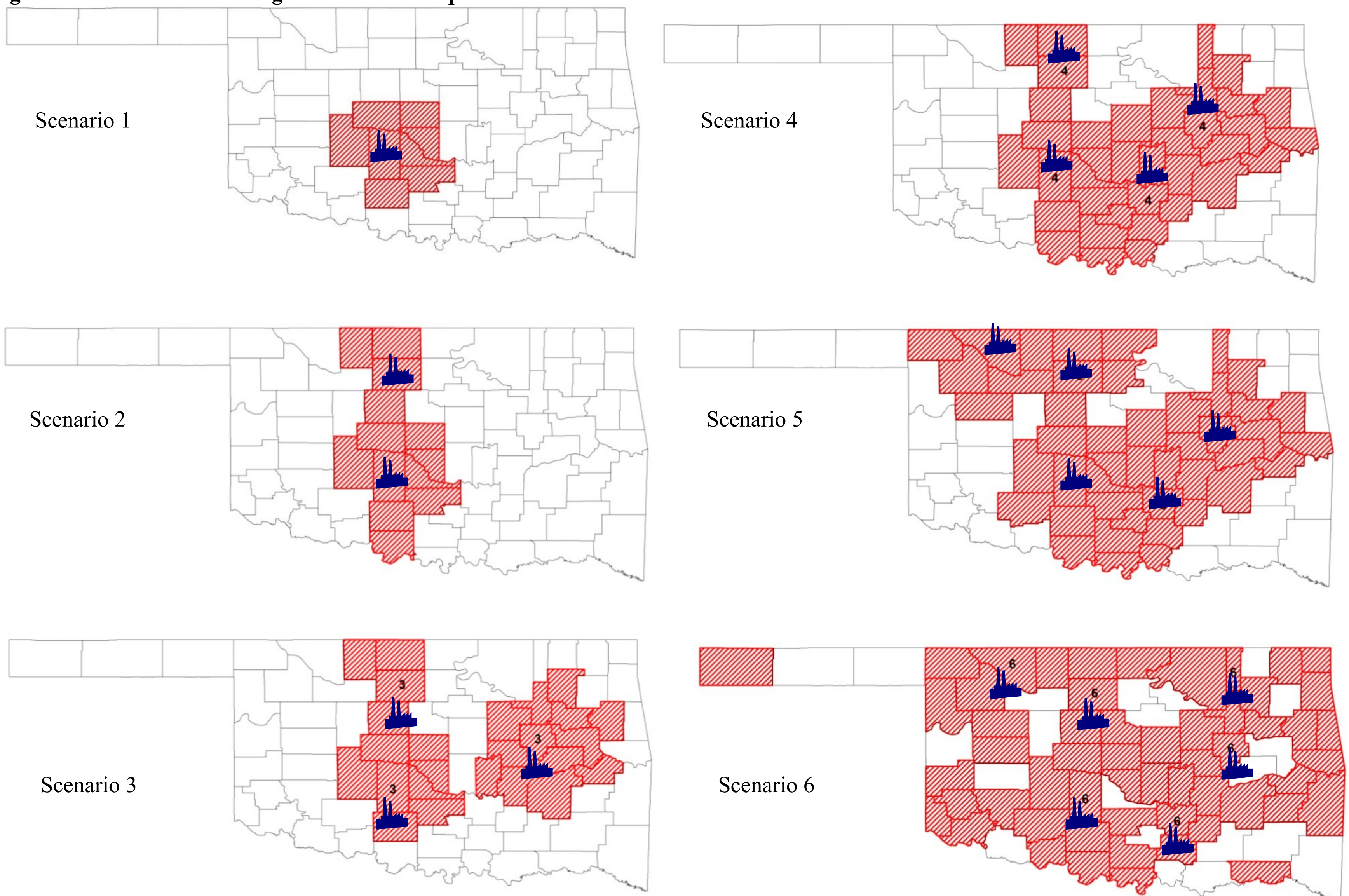
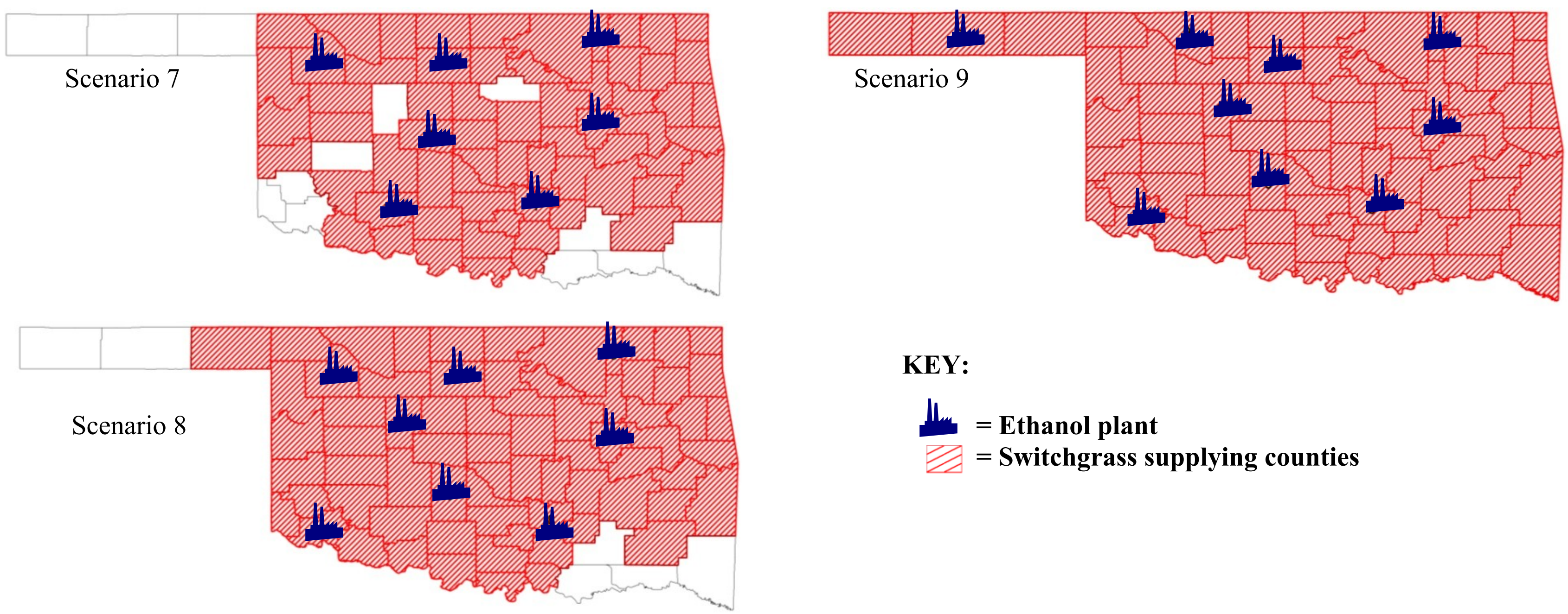


Figure 1: Locations of switchgrass and ethanol production in scenarios 1-9 (cont'd.)



means instead of using the impact of ethanol production on the economy directly, we start from the impact of purchasing the inputs used by the ethanol plants. By running an additional impact to capture the value added portion, one can add the two impacts (ABP and value-added) to give similar results as with starting with the direct impact of ethanol production on the local economy, as if the industry had existed in the IMPLAN industry list.

Ethanol production Modeling

To assess the impact from ethanol production using ABP method, I have taken three steps. First, I created models that contain hypothetical ethanol refinery locations. This will allow me to single out the overall economic impact of cellulosic ethanol production on these counties where the ethanol plants are located. All other counties in Oklahoma are categorized with the Rest of the World, and all goods and services imported into the counties in which the plants are located are considered as leakage from the model. Second, I created Events for ethanol production input levels and entered the dollar value of inputs required to produce a given ethanol production level on a given model. Input values were modified from the annual operating budget under University of Tennessee ethanol production budget (De La Torre Ugarte et al., 2006). I have scaled the original budget that was for 63.5 MMG annual ethanol production to 50 MMG ethanol production per year to match the assumptions in my scenarios regarding the capacity of ethanol producing plants in Oklahoma. The production function for ethanol production was laid down taking the IMPLAN's previous 509 sectors schematic. Thus, I have changed it to the current 440 IMPLAN sectors and reallocated the original expenditure to the new sectors. However, not all sectors required in the ethanol production function exist in the counties under the nine scenarios (see Table 39 in the appendix). That means some inputs will be imported from outside the models' regions. Since all required inputs are not produced in the counties where the plants are located, I have adjusted the Local Purchasing Percentage (LPP) to the Social Accounting Matrix (SAM) level to avoid overestimating the local impact by the imported inputs value. Using the

SAM local purchasing levels will make adjustment for the actual production of inputs that will occur in the ethanol production locations.

Table 2: Annual operating expenditure for a 50 MMG ethanol plant from switchgrass feedstock

Input Producing Industries (IMPLAN Sector Number)	Expenditures ($)
Electric power generation, transmission, and distribution (31)	4,721,595
Water, sewage and other treatment and delivery systems (33)	299,333
Construction of new nonresidential manufacturing structures (35)	36,602
Alkalies and chlorine manufacturing (123)	175,636
Carbon black manufacturing (124)	215
Other basic organic chemical manufacturing (126)	6,621,177
Fertilizer manufacturing (130)	154,856
All other chemical product and preparation manufacturing (141)	1,115
Lime and gypsum product manufacturing (164)	1,132,949
Power boiler and heat exchanger manufacturing (188)	764,257
Metal tank (heavy gauge) manufacturing (189)	650,421
Metal can, box, and other metal container (light gauge) manufacturing (190)	42,170
Other fabricated metal manufacturing (202)	36,534
Farm machinery and equipment manufacturing (203)	122,576
Other industrial machinery manufacturing (207)	640,789
Other commercial and service industry machinery manufacturing (213)	107,267
Air purification and ventilation equipment manufacturing (214)	1,036,833
Heating equipment (except warm air furnaces) manufacturing (215)	73,307
Air conditioning, refrigeration, and warm air heating equipment manufacturing (216)	220,336
Turbine and turbine generator set units manufacturing (222)	829,566
Pump and pumping equipment manufacturing (226)	490,206
Air and gas compressor manufacturing (227)	80,202
Material handling equipment manufacturing (228)	1,493,933
Other general purpose machinery manufacturing (230)	21,563
Industrial process variable instruments manufacturing (251)	42,852
Insurance carriers (357)	485,112
Accounting, tax preparation, bookkeeping, and payroll services (368)	484,498
Waste management and remediation services (390)	1,500,216
Commercial and industrial machinery and equipment repair and maintenance (417)	1,714,125
Total	**23,980,239**

Source: (De La Torre Ugarte et al., 2006)

Although switchgrass is the primary input for ethanol production, I have analyzed its impact in separate models. I set the LPP for switchgrass to zero; which implies there will not be any switchgrass production in the ethanol plant models, since I model this impact separately. All imported levels of inputs are leakage from my model and do not contribute to the local impact of ethanol production.

Third, during the process of ethanol production and the indirect impact of increased production by other industries, households receive salary and they spend it on purchasing goods and services which in turn induce further production. Therefore, I used $2.7 million annual employee compensation estimated by Leistritz et al. (2009) for a 50 MMG ethanol plant and created a Labor Income Change Activity on my model to account for the induced impact. Proprietor's income portion was not included here; due to the assumption of external private equity ownership of the ethanol plants, proprietor income is considered as leakage from the model. Thus, it does not affect the induced impact and the overall economic impact. Finally, using IMPLAN I have generated value added values, direct, indirect and induced effects of producing cellulosic ethanol production in Oklahoma. I have ignored the ethanol plant construction costs to highlight my focus on the long term impact of ethanol plant operation. Similar procedure has been used for the remaining scenarios under Table 1 which identifies the varying number of ethanol plants and their locations.

Switchgrass production modeling

To analyze the impact from switchgrass production I have utilized the following procedure. First, I created models that contain counties that supply switchgrass for a certain number of ethanol plants in corresponding scenarios. IMPLAN will treat other counties as the Rest of World. This will enable me to see the overall economic impact that will occur on switchgrass producing counties.

The second and crucial step I have taken is customizing a sector on IMPLAN to match the characteristics of switchgrass production. In order to do this, I customized the Study Area Data for IMPLAN Sector 9 using the employment, value of switchgrass production, employee compensation and proprietor's income I computed for the total switchgrass needed to meet for the feedstock requirement of the corresponding ethanol plant in scenarios one to nine.

Third, since switchgrass input requirements are different from crops listed under IMPLAN Sector 9, I have adjusted the industry production function in IMPLAN using the estimated input requirements presented in Table 4. This entailed modifying absorption coefficients (intermediate expenditure divided by total value of production) for Sector 19 (Support activities for agriculture and forestry), Sector 130 (Fertilizer manufacturing), Sector 319 (Wholesale trade businesses), Sector 335 (Transport by truck), and Sector 354 (Monetary authorities and depository credit intermediation activities). The sum of the coefficients is equal to the total absorption coefficient in line with the study area data. I eliminated byproducts associated with this sector and set the commodity Local Purchasing Coefficient (LPC) to zero so that other sectors that use sugarcane as an input will be forced to continue importing because sugarcane is not currently produced locally. Switchgrass establishment and maintenance enterprise budgets on Table 3 and Table 4 were taken from Haque (2010). Switchgrass establishment cost has been amortized over 10 years and allocated to appropriate IMPLAN Sectors. In addition, I assumed that switchgrass will be produced under private land ownership. Thus, the land rental value (per acre) will approximate proprietors' income that the switchgrass producers will keep. I used the switchgrass establishment and harvesting machinery hour estimates (Table 6) computed by Haque (2010) and a wage rate of $11.63 from (De La Torre Ugarte et al., 2006) to estimate employee compensation. Thus, value of switchgrass production is the sum of input costs, employee compensation and proprietor income multiplied by the corresponding acres of switchgrass production in every county included in my scenarios. Even if the original data separates the number of acres that will be used to produce switchgrass into cropland and pasture land, I have used the total acres to compute the value of switchgrass production.

Table 3: Estimated Switchgrass Establishment Costs

Item	Units	Quantity	Price/unit ($)	Value ($/acre)
Machinery operation				
Tillage				
Moldboard plow	Acre	1	15.93	15.93
Tandem disk	Acre	2	10.47	20.94
Chemical and fertilizer application				
Spraying herbicide	Acre	1	4.94	4.94
Applying nitrogen	Acre	1	4.14	4.14
Planting				
Cultipack	Acre	1	8.96	8.96
Seeder	Acre	1	13.26	13.26
Operating input				
Switchgrass seed	lbs.	6	7	42.00
Herbicide (2,4-D)	pt.	1.5	1.9	2.85
Nitrogen	lbs.	30	0.46	13.80
Annual operating capital a	$	126.82	0.07	8.88
Land rental	Acre	1	60	60.00
Total machinery, input and land rental cost	$			195.70
Establishment cost, amortized for 10 years at 7%	$		0.07	27.86

Source: (Haque, 2010)

Table 4: Estimated Annual switchgrass Maintenance and Harvesting Costs

Item	Units	Quantity	Price/unit ($)	Value ($/acre)
Establishment cost amortized over 10 years at 7%	$		0.07	27.86
Fertilizer application	Acre	1	4.14	4.14
Operating inputs				
Nitrogen[2]	lbs.	66.78[1]	0.46	30.72
P_2O_5[2]	lbs.	10	0.53	5.3
Machinery operation				
Mowing	Acre	1	10.11	10.11
Raking	Acre	1	3.88	3.88
Harvesting (baling) 1,148 lb DM rectangular bale	Bale	1	14.64	140.02
Land rental[3]	Acre	1	60	60
Total production cost				**222.03**

Source: (Haque, 2010)

[1] Since application varies per harvest strategy, annual average level has been used.
[2] Phosphorus is budgeted for July harvest strategy.
[3] Land rental value is considered as proprietor's income due to the private equity ownership assumption

Table 5: Machinery labor requirement for establishing switchgrass

Machinery Description	Times over	Hrs/Acre[4]
Plow	1	0.1799
Disk	2	0.0818
Spray	1	0.0390
Apply Fertilizer	1	0.0390
Field Cultivator	1	0.0603
Drill	1	0.0786
Total		**0.68**

Source: (Haque, 2010)

Table 6: Switchgrass establishment and harvest labor requirement

Machinery Description	Times over	Hrs/Acre[a]
Establishment	1	0.068[5]
Fertilizer Application	1	0.039
Mowing	1	0.125
Raking, Baling, stacking	1	0.385
Total		**0.617**

Source: (Haque, 2010)

Existing crops considered in this study (All hay and alfalfa, all wheat and soybean) include a ‘Transport by truck’ sector in their production function in IMPLAN. This means truck transportation service is part of their total expenditure. Since the ethanol production enterprise budget I used in my models does not include this sector and because switchgrass is bulky in nature, I have considered transportation cost in my models to make comparison with other crops consistent. However, since switchgrass does not exist currently, IMPLAN does not provide this information. Thus, I have computed an average cost per truck ($79.98) by dividing the expenditure of IMPLAN sector 2 (Grain production) on ‘Transport by truck’ sector by number of trucks used by IMPLAN Sector 2 to transport the total output. The number of trucks was

[4] Acres per Hour estimate taken from (Lazarus, 2009) as cited by (Haque, 2010)
[5] Establishment machinery labor amortized over 10 years.

computed by dividing total wheat production in the state in 2009 by legal truck capacity. (See Table 39 in the Appendix for details of this calculation.)

Finally, I created events on IMPLAN for the total value of switchgrass production in the model for the corresponding ethanol plants. Value of switchgrass is computed by adding input costs of purchased inputs and value added components (employee compensation based upon the values in Table 6 and rate of $11.63 plus proprietor's income determined by the land rental value presented in Table 4. LPP has been set to 100% to imply all switchgrass will be produced in the counties included in the model. This procedure was used for all nine switchgrass producing scenarios, corresponding to the nine ethanol plant location scenarios. The value of switchgrass produced in each scenario is presented in Table 7. Employment numbers were generated by converting the total employee hours to full-time equivalents (by dividing by 2,000 hours) and adjusting this value using an IMPLAN provided factor to calculate full and part time jobs.

Determining the economic impact of ethanol production and the required level of switchgrass feedstock production on the local economies where the hypothetical refineries will be located and on the counties which produce switchgrass does not recognize the fact that switchgrass production used land currently producing other agricultural products. This will overestimate the net impact because it overlooks the loss from the previous land use. My scenarios are based on 10% cropland and pasture land conversion to switchgrass production from their previous uses. This means crop production and cattle farming sectors will be negatively impacted because there will be less acreage in the current land use pattern. Thus, I have made adjustments for crop and cattle loss as follows.

Table 7: Value of switchgrass production and value-added components

Scenarios	Total Acre	Total biomass harvested in tons	Purchased inputs	Labor Cost	Proprietor Income	Employment	Total value of production
1	133,139	605,320	31,328,621	955,364	9,125,676	47.9	41,409,661
2	271,961	1,211,188	63,873,215	1,951,511	18,640,904	97.8	84,465,630
3	400,967	1,818,083	94,327,232	2,877,224	27,483,354	144.2	124,687,811
4	554,783	2,423,282	130,069,630	3,980,961	38,026,293	199.5	172,076,884
5	707,302	3,029,439	165,539,902	5,075,398	48,480,388	254.3	219,095,688
6	853,002	3,634,462	199,548,821	6,120,898	58,467,051	306.7	264,136,770
7	1,023,216	4,239,542	238,399,407	7,342,300	70,133,920	367.9	315,875,626
8	1,223,953	4,846,144	284,557,680	8,782,728	83,892,950	440.1	377,233,359
9	1,450,557	5,454,980	335,857,182	10,408,775	99,425,011	521.6	445,690,968

Modeling crop loss

First, to determine the value of crops that will be lost, I have assumed that acreage that will be used to produce switchgrass will be taken from the major crop (determined by most acres planted) in each county. Making this assumption helps me to have a consistent criterion that applies for all counties, because the type and amount of crops that are produced is varied across counties in the state. Thus, the value of crop lost due to switchgrass production is computed by multiplying the total cropland acreage shifted in each switchgrass supplying county by average yield in that county and the average annual crop price taken from OSU Enterprise Budget (Table 11) of the major crop. Employment was computed by multiplying the per acre machinery labor hours for each crop from OSU Enterprise Budget (Table 8-10) by the converted cropland acres in each county and dividing it by 2000 hours per year. Here I assumed an employee works 40 hours per week and 50 weeks per year. Since IMPLAN agricultural data has a big margin of error, I have updated the study area data with the total value of production from the Oklahoma Agricultural Statistics 2011 provided by USDA National Agricultural Statistics Service (NASS). Finally, I created events with total value of crop lost on IMPLAN to generate the direct, indirect and induced impacts of the lost crop production. Similar procedures have been taken for each of the nine scenarios considered in this study. The value of crop production estimated to be displaced by switchgrass, and its associated employment, for each scenario is presented in Table 12.

Table 8: Dryland Wheat Enterprise Budget - Grain and Graze
1000 acres farmed, 160 acres for this budget

Machinery Description	Times over	Hrs/Ac
Offset Disc	1	0.18
Anhy. App.	1	0.08
Field Cultivator	1	0.06
Drill	1	0.08
Sprayer	3	0.04
Dry Fert. Spdr.	1	0.04
Combine	1	0.1
Total		**0.79**[6]

Source:("OSU Enterprise Budget Software," 2012)

Table 9: Dryland Soybean Enterprise Budget
1000 acres farmed, 160 acres for this budget

Machinery Description	Times over	Acres/hr[a]	Hrs/Ac
Tandem Disk	1	12.22	0.0818
Drill	1	12.73	0.0786
Sprayer	2	25.61	0.0390
Combine	1	7.42	0.1348
Total			**0.45**

Source:("OSU Enterprise Budget Software," 2012)

Table 10: Machine Hours for Prairie Hay

Machinery Description	Times over	Acres/hr[a]	Hrs/Ac
Mow	1	8.73	0.1145
Rake	1	26.18	0.0382
Bale	1	9.45	0.1058
Total			**0.31**

Source:("OSU Enterprise Budget Software," 2012)

Table 11: Annual crop price (in 2009 dollars)[7]

Crops	($ /per acre)
All Hay	280.57
All Wheat	217.19
Soybean	239.70

Source: ("OSU Enterprise Budget Software," 2012)

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[6] Machinery hour is multiplied by 1.21 to obtain an estimate of operator labor hours.
[7] 2012 dollar values converted to 2009 using BLS calculator. Available online http://www.bls.gov/data/inflation_calculator.htm

Table 12: Value of crop lost due to switchgrass production

Scenarios	Cropland acres	Employment	Value of production
1	94,499	35.4	22,221,798
2	223,140	94.0	50,247,907
3	304,034	124.5	68,710,575
4	365,132	142.9	83,938,649
5	503,177	206.2	113,910,457
6	575,949	226.0	132,401,809
7	711,912	286.4	162,267,340
8	850,375	332.9	196,226,294
9	965,724	370.8	224,502,512

Modeling cattle production loss

To estimate the value of the lost cattle from the pasture land shift to switchgrass, first, I have to identify whether beef cattle or dairy cattle farming will be affected significantly. Since only non-lactating cattle graze pasture, dairy sector will not be significantly affected. Thus, I have estimated the number of beef cow head by dividing the number of pasture land acres that will be shifted in each county by 9.55 acres per cow estimate based on the OSU Cow-Calf Enterprise budget. Then, I computed the value of beef cattle by multiplying the number of head by the average annual cattle price of $715.32 (in 2009 dollars) per head taken from Oklahoma Agriculture Statistics 2011. The loss in employment in beef cattle sector is calculated by multiplying the total number of head by the labor hour requirement per head under Table 13 and dividing it by 2000 hours. Total employment was converted to full time equivalent using IMPLAN conversion factors. I have also modified the study area data for IMPLAN sector 11, cattle ranching and farming, using the 2009 value of cattle production estimates taken from the Oklahoma Agricultural Statistics 2011. Lastly, I created an event in IMPLAN for the value of beef cattle lost to determine the direct, indirect and induced impact. Similar procedures have been taken for each of the nine scenarios considered in this study. The value of cattle production estimated to be displaced by switchgrass, and its associated employment, for each scenario is presented in Table 14.

Table 13: Labor requirement for beef cattle

Description	Unit	Price	Quantity	$/Head
Machinery/Equipment labor	Hrs.	10.25	2.65	27.16
Other labor	Hrs.	10.25	3	30.75
Total			5.65	57.91

Source:("OSU Enterprise Budget Software," 2012)

Table 14: Value of beef cattle lost due to switchgrass production

Scenarios	Pasture land acres	No. of head	Employment	Value of beef cattle
1	38,640	4,046	13.3	$ 2,894,224
2	48,820	5,112	16.8	$ 3,656,776
3	96,933	10,150	33.4	$ 7,260,517
4	189,651	19,859	65.4	$ 14,205,343
5	204,126	21,374	70.4	$ 15,289,549
6	277,054	29,011	95.5	$ 20,752,062
7	311,303	32,597	107.3	$ 23,317,440
8	373,578	39,118	128.8	$ 27,981,972
9	484,833	50,768	167.2	$ 36,315,261

Environmental Impact modeling

In line with the basic I-O model assumptions, production of commodities by industry X_i equals the inter-industry consumption plus the final demand consumption. Mathematically, the model structure I used looks as follows;

$$\begin{aligned}
X_1 &= a_{1,1}X_1 + a_{1,2}X_2 + \cdots a_{1,n}X_n + Y_1 \\
X_2 &= a_{2,1}X_1 + a_{2,2}X_2 + \ldots a_{2,n}X_n + Y_2 \\
\cdots &= \cdots \quad \cdots \quad \cdots \quad \cdots \\
X_n &= a_{n,1}X_1 + a_{n,2}X_2 + \ldots a_{n,n}X_n + Y_n
\end{aligned} \tag{1}$$

$$\begin{bmatrix} X_1 \\ X_2 \\ \cdots \\ X_n \end{bmatrix} = \begin{bmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,n} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n,1} & a_{n,2} & \cdots & a_{n,n} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ \cdots \\ X_n \end{bmatrix} + \begin{bmatrix} Y_1 \\ Y_2 \\ \cdots \\ Y_n \end{bmatrix} \tag{2}$$

In matrix notation,

$$X = AX + Y \Leftrightarrow (I - A)X = Y \Leftrightarrow X = (I - A)^{-1} Y \tag{3}$$

Where: X_i is the production of good *i*

$X_{i,j}$ is the use of good *i* in the production of good *j*;

$a_{i,j} = \frac{X\,i,j}{Xi}$ is the direct requirement coefficient

Y_i is the final demand consumption of good *i*

The second major paradigm of this study is to delineate the environmental impact of both switchgrass and ethanol production. The first big step in input-output model application to environmental problems is to figure out how to augment the traditional I-O table with the emissions data. The economic data on the I-O framework is laid down taking the dollar value of outputs of the industries on the row sector to the industries on the column sector. On the contrary, the environmental data is mainly available in weight or volume units, and these units are not consistent across environmental interventions. Thus, summing the inter-industry transactions data with the pollution data directly is not possible (Richardson, 1972). In this regard, will use a similar approach used by (O'Doherty & Tol, 2007) and (Grainger & Kolstad, 2010). This representation links the output of industries with emission coefficients to compute total emission associated with an industry's final demand change. Total emission *E* of a given substance is the sum of emissions from the production of a unit output for emitting industries in an economy.

Thus, E equals,

$$E_I = b_{i,1}X_1 + b_{i,2}X_2 + \ldots b_{i,n}X_n \tag{4}$$

Where: $b_{l,i}$, emission of substance I per unit of production of industry i

In matrix notation,

$$E = BX = B\,(\mathrm{I} - \mathrm{A})^{-1}\,\mathrm{Y} \tag{5}$$

Equations taken from (O'Doherty & Tol, 2007)

In line with this approach, I took the total output impact of switchgrass and ethanol productions results I generated for each of the scenarios I run on the previous section and multiplied it with the emission coefficients I found under the academic version of Comprehensive Environmental Data Archive (CEDA 4.41). Since CEDA 4.41 data contains the amount of environmental intervention that will be caused per dollar increase in output of 440 industries, I have been able to compute the total emission caused by ethanol and switchgrass production over their entire supply chain (to the extent the industries are present in the county) for all of the nine scenarios I included in the study. Since the sectors in IMPLAN and CEDA data were not exactly the same, I have aggregated IMPLAN sectors in my models as well as the on CEDA data to get consistent results.

Data Sources

Currently there is no commercial ethanol or switchgrass production in Oklahoma. Thus, the State's potential in producing ethanol and switchgrass has to be estimated. Such estimates should include information on where the optimal location for constructing the ethanol refineries' will be given the transportation cost, utility capacity, infrastructure availability and feedstock availability based upon estimates of county switchgrass production. Therefore, my analysis mainly depends on such estimated data as hypothetical production of both cellulosic ethanol and switchgrass production as described in the Model Structure: Economic Impact section above.

IMPLAN

I used 2009 IMPLAN economic data published by MIG Inc. to provide the majority of the data required by the input-output model. I also used IMPLAN V3 software to conduct the impact assessments included in this study. The data is structured at the county level and contains 440 industries categorized by North American Industrial Classification System (NAICS) codes. Since IMPLAN's agricultural data is has a wide margin of error, I have augmented IMPLAN data with actual production data for all hay and alfalfa, all wheat, and soybean production, as well as cow and calves inventories, from Oklahoma Agricultural Statistics 2011 published by NASS. Despite the data's significance for conducting this study, its primary limitation is it does not include any kind of environmental data. Thus, I have used a separate data set: The Comprehensive Environmental Data Archive 4.41 (CEDA 4.41).

CEDA 4.41

CEDA 4.41 environmental data is compiled for the U.S. by Climate Earth for year 2002. The data is designed to facilitate life-cycle analysis by providing a wide range of environmental data in units per dollar of output by industry sector, making it compatible with IO results. What makes CEDA data very crucial to my study more than any other publicly available data sources is it contains over 1,300 different types of environmental interventions that range from GHG to other hazardous wastes and particulate matter. In addition, the data was collected from various sources and adjusted for data inconsistencies and missing values (Sangwon, 2005). Furthermore, it converts the environmental data from physical quantities to quantities per one dollar output of all industries consistent with my IMPLAN output. This data will enable me to get a more in-depth look into the environmental impact on local economies caused by ethanol production. It is important to note, however, that the pollution values generated in this research do not represent a complete life-cycle analysis. Instead, the output values that will be multiplied by the CEDA coefficients only represent local production. Therefore, the numbers presented in the next chapter represent the local, net environmental impact from switchgrass and ethanol production, including pollution generated by local suppliers and induced by household consumption.

CHAPTER III

RESULTS AND DISCUSSION

In line with my objective of delineating the economic and environmental impacts from switchgrass and ethanol production, the results will be presented as follows: first, I will present the economic impact from switchgrass production on the current land use pattern. Second, the opportunity cost of producing switchgrass expressed in terms of lost crop and beef cattle production will be provided. Third, the economic impact of cellulosic ethanol will follow. Lastly, the net impact from both switchgrass and ethanol production will be provided. The environmental impacts will be presented using a similar pattern.

Economic impact from switchgrass production

The economic impact of switchgrass production for each scenario is presented in Table 15. One will recall that the direct impact is the value of switchgrass production previously estimated in the methodology section of this study. For the first scenario, the direct impact on output due to switchgrass production is $41,409,661. There will be an additional $12,972,151 worth of output production in other industries in order to meet the input requirements of switchgrass sector, the indirect impact. Furthermore, when households spend the wage and salary they earned from the direct and indirect effects, it may induce an additional $19,121,763 worth of output across all industries. The total economic impact of switchgrass production in the first scenario, then, is estimated to be $73,503,575 in the local economy, which is comprised of eight counties in scenario one. Since all switchgrass supplying counties in each scenario are modeled together, the output impacts presented in Table 15 reflect the total production increase across all sectors caused by the initial increase in switchgrass production region.

Reading down the columns of Table 15, the direct, indirect, induced and the total output impacts consistently increase for all scenarios except scenario 9 where the indirect effect decreased from $161,746,936 in scenario 8 to $137,794,975 in scenario 9. This is because the output per worker in scenario 9 decreased from the previous scenarios since the yield of biomass per acre considered in the scenario is smaller (see Table 1); this, in turn, led to a relatively smaller indirect effect because more labor and less purchased inputs are used in this scenario. In general, the result suggests that given the 10% cropland and pasture land conversion, switchgrass production generates positive output impact for local economies. Table 16 provides the employment generated by switchgrass production. The total employment created by switchgrass production also ranges from 373 up to 4,277 across all industries included in the scenarios 1 up to scenario 9 respectively.

Table 15: Direct, indirect and induced output effect from switchgrass production (in 2009 dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	41,409,661	12,972,151	19,121,763	73,503,575	73,503,575
2	84,465,630	26,150,334	37,705,681	148,321,645	74,160,822
3	124,687,811	46,081,288	67,297,018	238,066,117	79,355,372
4	172,076,884	58,942,094	86,603,287	317,622,265	79,405,566
5	219,095,688	72,267,100	105,386,992	396,749,780	79,349,956
6	264,136,770	86,464,275	125,637,254	476,238,299	79,373,050
7	315,875,626	135,555,185	139,974,369	591,405,181	84,486,454
8	377,233,359	161,746,936	166,406,642	705,386,937	88,173,367
9	445,690,968	137,794,975	200,699,922	784,185,866	87,131,763

Typically value added on IMPLAN includes; employee compensation, proprietor's income, indirect business taxes and other property income. However, for switchgrass the value added value only includes employee compensation and proprietor's income, since we do not have data on the other categories. Thus, the direct value added (Table 17) and the direct labor income are equal. Value added for switchgrass production also increased consistently across all scenarios. The total value added effect ranges from $29,977,934 in scenario 1 up to $314,787,761 for scenario 9.

Table 16: Direct, indirect and induced employment effect from switchgrass production (in 2009 dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	48	138	188	373	373
2	98	285	372	755	377
3	144	615	652	1,411	470
4	200	727	845	1,772	443
5	254	921	1,030	2,205	441
6	307	1,159	1,235	2,701	450
7	368	973	1,373	2,714	388
8	440	1,190	1,641	3,270	409
9	522	1,770	1,986	4,277	475

Table 17: Direct, indirect and induced value added effect from switchgrass production (in 2009 dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	$10,081,040	$7,705,680	$12,191,213	$29,977,934	$29,977,934
2	$20,592,411	$15,385,526	$23,982,260	$59,960,197	$29,980,099
3	$30,360,578	$27,060,415	$42,098,244	$99,519,237	$33,173,079
4	$42,007,248	$33,948,524	$53,919,180	$129,874,952	$32,468,738
5	$53,555,786	$41,967,110	$65,847,720	$161,370,617	$32,274,123
6	$64,587,938	$50,090,172	$78,207,571	$192,885,680	$32,147,613
7	$77,476,230	$73,636,091	$86,886,543	$237,998,864	$33,999,838
8	$92,675,693	$87,894,510	$103,376,556	$283,946,759	$35,493,345
9	$109,833,784	$80,244,021	$124,709,957	$314,787,761	$34,976,418

Impact from lost crop production

The results in the previous section overestimate the impact associated with switchgrass production because it did not consider the opportunity cost or the previous uses of the 10%

cropland and pasture land acreage used for switchgrass production. Thus, I have estimated the value of crops and beef cattle productions. For instance, for the first scenario there would have been $22,221,798 worth of output produced in other crops (all hay, all wheat, and soybean). This crop production would have created 30 direct jobs with an estimated value-added of $1,662,215 (see Table 18-20). Overall, the total economic impact of current crop production that would be displaced by switchgrass is estimated to be $36,021,178 of output, $10,213,541 in value-added and 157 jobs. Similarly, all direct, indirect, induced and total effect consistently increases for scenarios one up to nine.

Table 18: Direct, indirect and induced output effect from crop production (in 2009 Dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	$22,221,798	$8,529,978	$5,269,402	$36,021,178	$36,021,178
2	$50,247,907	$19,388,179	$10,952,654	$80,588,741	$40,294,371
3	$68,710,575	$39,599,052	$22,427,471	$130,737,097	$43,579,032
4	$83,938,649	$45,028,679	$27,677,885	$156,645,213	$39,161,303
5	$113,910,457	$59,579,063	$32,983,111	$206,472,630	$41,294,526
6	$132,401,809	$67,338,020	$38,254,035	$237,993,864	$39,665,644
7	$162,267,340	$81,537,134	$44,017,860	$287,822,334	$41,117,476
8	$196,226,294	$98,546,237	$53,621,889	$348,394,420	$43,549,303
9	$224,502,512	$109,904,988	$61,926,620	$396,334,120	$44,037,124

Table 19: Direct, indirect and induced employment effect from crop production

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	30.4	73.7	52.9	157.0	157.0
2	80.7	167.8	110.7	359.1	179.6
3	106.8	285.2	220.0	612.1	204.0
4	122.5	330.2	274.3	727.0	181.8
5	176.9	435.3	328.5	940.6	188.1
6	193.9	505.1	383.4	1,082.4	180.4
7	245.7	601.3	442.2	1,289.2	184.2
8	285.7	740.5	541.8	1,568.0	196.0
9	318.0	823.1	626.6	1,767.7	196.4

Table 20: Direct, indirect and induced value added effect from crop production (in 2009 Dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	$1,662,215	$5,143,329	$3,407,997	$10,213,541	$10,213,541
2	$3,038,010	$11,593,793	$7,079,664	$21,711,467	$10,855,734
3	$6,141,410	$22,157,781	$14,166,381	$42,465,571	$14,155,190
4	$9,743,297	$24,899,352	$17,396,478	$52,039,127	$13,009,782
5	$10,676,952	$32,748,203	$20,850,235	$64,275,390	$12,855,078
6	$13,188,486	$36,743,587	$24,091,293	$74,023,366	$12,337,228
7	$13,783,011	$44,498,400	$27,705,896	$85,987,307	$12,283,901
8	$16,695,124	$53,744,572	$33,794,964	$104,234,659	$13,029,332
9	$21,719,913	$59,764,599	$39,006,637	$120,491,149	$13,387,905

Economic impact of the loss in beef cattle farming

The second half of the opportunity cost of producing switchgrass is the loss in cattle that would have been produced on the 10 % pasture land which is converted to switchgrass production. As we can see from Table 14 the value of beef cattle estimated to be lost is $2,894,224 directly in the beef cattle farming sector, IMPLAN sector 11. This direct impact stimulates an additional $1,716,714 indirect output effect and $461,183 induced effect. Thus, the total loss in output across the study area in scenario one is estimated to be $5,072,121. The total output impact increases to $67,419,049 for scenario nine. Table 21 presents the impacts of lost cattle production across all nine scenarios.

In terms of employment, 13 jobs will be lost directly in beef cattle industry and an additional 15 jobs will be lost through indirect and induced impacts in scenario 1(Table 22). The direct employment impact increases consistently for all scenarios ranging from 13 to 167 jobs. Overall, the total employment effect on the study area in the scenarios from decreased beef cattle production is estimated to be between 29 to 380 jobs for scenarios 1 and scenario 9 respectively.

Table 21: Direct, indirect and induced output effect of cattle production (in 2009 dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	$2,894,224	$1,716,714	$461,183	$5,072,121	$5,120,842
2	$3,656,776	$1,924,687	$799,457	$6,380,920	$3,190,460
3	$7,260,517	$4,506,107	$1,913,633	$13,680,257	$4,560,086
4	$14,205,343	$8,609,756	$3,587,919	$26,403,018	$6,600,754
5	$15,289,549	$9,301,375	$3,689,363	$28,280,286	$5,656,057
6	$20,752,062	$12,513,399	$4,870,307	$38,135,769	$6,355,962
7	$23,317,440	$14,386,259	$5,492,989	$43,196,688	$6,170,955
8	27,981,972	17,666,399	6,584,439	52,232,811	6,529,101
9	36,315,261	22,547,543	8,556,245	67,419,049	7,491,005

Table 22: Direct, indirect and induced employment effect of cattle production

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	13.3	9.5	6.5	29.3	29.3
2	16.8	11.9	8.1	36.8	18.4
3	33.4	25.8	18.8	78.0	26.0
4	65.4	49.3	35.7	150.5	37.6
5	70.4	53.3	36.9	160.5	32.1
6	95.5	71.2	49.0	215.8	35.9
7	107.3	80.8	55.4	243.5	34.8
8	128.8	99.5	66.8	295.2	36.9
9	167.2	126.3	86.9	380.4	42.3

Table 23: Direct, indirect and induced value added effect of cattle production (in 2009 Dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	248,762	594,720	416,771	1,260,253	1,260,253
2	313,493	729,330	517,152	1,559,975	779,987
3	620,535	1,764,606	1,211,327	3,596,468	1,198,823
4	1,216,385	3,286,201	2,262,621	6,765,207	1,691,302
5	1,296,325	3,478,114	2,339,461	7,113,901	1,422,780
6	1,751,693	4,581,733	3,077,354	9,410,781	1,568,463
7	1,967,004	5,201,641	3,468,323	10,636,968	1,519,567
8	2,357,992	6,307,360	4,163,801	12,829,153	1,603,644
9	3,141,987	8,002,267	5,407,092	16,551,345	1,839,038

Net Switchgrass Impact

The net impact from switchgrass production is presented in Table 24-26. The net impact is the difference between the switchgrass impacts and the sum of cattle and crop impacts. As one can see from the Table 25, the total employment effect of switchgrass production, 4,277, is reduced to 2,129 for scenario 9 when adjusted for crop and cattle losses. Thus, this result shows that considering the opportunity cost of producing switchgrass will decrease the total employment impact by roughly 51 percent. However, the net direct employment does not increase consistently across our scenarios. For instance the direct employment effect for scenario one is 4.3, while for scenario 2 the directly employment is only 0.46. There are two parts to this explanation. First, one will note from Figures 1 and 2 that crop and livestock production are not evenly distributed across the state, so that the location of the ethanol plants and supporting switchgrass production regions offset varying degrees of crop and pasture land. Given differences in input costs between these land uses, indirect costs will fluctuate by scenario depending upon whether proportionately more crop or pasture land is converted to switchgrass. Also, labor productivity differs between the crops and cattle production. Therefore, when proportionately more crop land is converted, a larger employment loss is likely to be realized. Second, each scenario captures a different geographic region, some of which contain metropolitan and micropolitan counties. These counties will have more dense economies than their non-core counterparts, and consequently the indirect and induced effects will likely be higher for those scenarios with more metro- and micro-politan counties in them. However, the net total employment effect is still positive. It ranges from 187 up to 2,129 jobs between scenario 1 to scenario 9.

Unlike employment, the direct effects for net value added and output increase consistently across scenarios, but the indirect and induced effects do not consistently increase across scenarios. This fluctuation reflects the issues described above. If one compares the total net effects of employment, value-added and output to the switchgrass production impacts, one realizes that the switchgrass production values are overstated by 51, 59 and 41 percent respectively (for scenario 9).

Table 24: Net output impact from switchgrass production (in 2009 dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	$16,293,639	$2,859,111	$13,208,805	$32,361,555	$32,361,555
2	$30,560,946	$4,837,469	$25,953,570	$61,351,984	$30,675,992
3	$48,716,719	$1,976,129	$42,955,915	$93,648,764	$31,216,255
4	$73,932,892	$5,303,659	$55,337,483	$134,574,034	$33,643,509
5	$89,895,682	$3,386,662	$68,714,518	$161,996,863	$32,399,373
6	$110,982,899	$6,612,856	$82,512,911	$200,108,666	$33,351,444
7	$130,290,846	$39,631,792	$90,463,520	$260,386,159	$37,198,023
8	$153,025,093	$45,534,300	$106,200,314	$304,759,706	$38,094,963
9	$184,873,195	$5,342,444	$130,217,057	$320,432,697	$35,603,633

Table 25: Net employment impact from switchgrass production

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	4.3	54.5	128.3	187.1	187.1
2	0.5	105.6	252.8	358.9	179.5
3	3.8	304.0	412.8	720.5	240.2
4	12.1	347.4	534.7	894.2	223.6
5	6.7	432.5	664.9	1,104.3	220.9
6	17.6	582.3	802.8	1,402.7	233.8
7	14.9	291.1	875.3	1,181.4	168.8
8	25.5	349.5	1,032.1	1,407.1	175.9
9	36.8	820.2	1,272.1	2,129.1	236.6

Table 26: Net value added impact from switchgrass production (in 2009 dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	8,170,063	1,967,631	8,366,445	18,504,140	18,504,140
2	17,240,907	3,062,404	16,385,444	36,688,755	18,344,378
3	23,598,633	3,138,028	26,720,536	53,457,198	17,819,066
4	31,047,566	5,762,971	34,260,081	71,070,618	17,767,654
5	41,582,509	5,740,793	42,658,024	89,981,326	17,996,265
6	49,647,759	8,764,851	51,038,924	109,451,534	18,241,922
7	61,726,215	23,936,050	55,712,324	141,374,589	20,196,370
8	73,622,577	27,842,578	65,417,791	166,882,947	20,860,368
9	84,971,884	12,477,155	80,296,228	177,745,267	19,749,474

Economic Impact from ethanol production

Our result shows that ethanol production has a positive economic impact in terms of employment, value added and output in the counties where the refineries are located in each scenario. Total employment caused by ethanol production ranges from 90 jobs in the first scenario with one ethanol refinery to 905 jobs in scenario 9 with 9 ethanol plants. While the 9 ethanol plants are identical in size and technology, so that one might expect the direct impacts to be proportional across the scenarios, the direct effects vary due to our use of ABP. Since each scenario, which reflects different locations, will capture different supplying industries as being present in the model, the direct impact values will fluctuate; similarly, the value-added component, modeled as a labor income shock, will reflect different local spending patterns and will reflect the different industrial linkages of each scenario.

The total output effect is estimated to be $9,431,933 in scenario one, and reading down the column of Table 27, we can see that the total output effect reaches $112,540,417 in scenario nine.

Table 27: Direct, indirect and induced output effect of ethanol production (in 2009 dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	$5,223,728	$636,826	$3,571,380	$9,431,933	$9,431,933
2	$12,596,867	$1,732,165	$9,426,285	$23,755,316	$11,877,658
3	$19,210,598	$2,527,082	$13,845,619	$35,583,300	$11,861,100
4	$27,185,390	$3,618,593	$18,345,523	$49,149,505	$12,287,376
5	$33,995,550	$4,525,885	$22,806,570	$61,328,006	$12,265,601
6	$40,421,570	$5,299,423	$27,646,160	$73,367,153	$12,227,859
7	$43,215,936	$5,560,145	$28,077,020	$76,853,102	$10,979,015
8	$57,397,956	$7,364,005	$34,355,730	$99,117,691	$12,389,711
9	$65,257,314	$8,280,248	$39,002,856	$112,540,417	$12,504,491

Table 28: Direct, indirect and induced employment effect of ethanol production

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	51.8	6.7	40.5	99.0	99.0
2	94.8	16.4	100.1	211.3	105.6
3	138.9	24.0	150.7	313.7	104.6
4	184.6	34.0	202.5	421.2	105.3
5	236.6	42.6	253.4	532.6	106.5
6	255.3	50.3	304.0	609.5	101.6
7	241.3	52.1	295.4	588.9	84.1
8	349.3	67.7	375.4	792.4	99.0
9	400.2	76.8	427.9	905.0	100.6

Table 29: Direct, indirect and induced value-added impact of ethanol production (in 2009 dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	$3,233,637	$334,746	$2,281,919	$5,850,301	$5,850,301
2	$7,992,299	$911,770	$6,036,702	$14,940,771	$7,470,386
3	$12,146,418	$1,311,551	$8,842,428	$22,300,397	$7,433,466
4	$17,257,170	$1,852,866	$11,740,883	$30,850,919	$7,712,730
5	$21,521,912	$2,308,525	$14,606,486	$38,436,924	$7,687,385
6	$25,669,927	$2,716,689	$17,616,871	$46,003,488	$7,667,248
7	$27,227,931	$2,873,401	$18,294,688	$48,396,020	$6,913,717
8	$36,249,369	$3,730,037	$21,953,951	$61,933,357	$7,741,670
9	$41,038,256	$4,204,968	$24,992,260	$70,235,484	$7,803,943

Net economic impact from production of switchgrass and ethanol

The results in Table 30-32 show that the net economic impact from production of cellulosic ethanol production using switchgrass feedstock, the sum of ethanol impacts and the net impact from switchgrass production, is positive in terms employment, value added and output. However, the majority of the net total effect is caused by switchgrass production. For instance, the impact from switchgrass makes up, on average, 67%, 72% and 74% of total employment, value added and output effects respectively. After accounting for the opportunity cost of converting crop and pasture land to switchgrass production, the results suggest that cellulosic ethanol production has a positive net economic benefit to Oklahoma by increasing output, employment and value-added. The results suggest that cellulosic ethanol production using Oklahoma grown switchgrass would result in more than 3,000 jobs, almost $250 million in value-added, and over $430 million in output to the state's economy if nine plants were operational.

Table 30: Net output impact of ethanol production (in 2009 dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	$21,517,367	$3,495,937	$16,780,185	$41,793,488	$41,793,488
2	$43,157,813	$6,569,633	$35,379,855	$85,107,300	$42,553,649
3	$67,927,317	$4,503,211	$56,801,534	$129,232,064	$43,077,354
4	$101,118,281	$8,922,252	$73,683,006	$183,723,539	$45,930,884
5	$123,891,232	$7,912,547	$91,521,089	$223,324,869	$44,664,973
6	$151,404,469	$11,912,279	$110,159,072	$273,475,819	$45,579,303
7	$173,506,782	$45,191,937	$118,540,540	$337,239,261	$48,177,037
8	$210,423,048	$52,898,305	$140,556,044	$403,877,397	$50,484,674
9	$250,130,508	$13,622,692	$169,219,913	$432,973,114	$48,108,123

Table 31: Net employment impact of ethanol production

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	56.1	61.2	168.8	286.1	286.1
2	95.2	121.9	352.9	570.2	285.1
3	142.7	328.0	563.5	1,034.2	344.7
4	196.7	381.4	737.2	1,315.4	328.9
5	243.3	475.1	918.3	1,636.9	327.4
6	272.8	632.6	1,106.8	2,012.2	335.4
7	256.3	343.2	1,170.7	1,770.2	252.9
8	374.8	417.2	1,407.5	2,199.4	274.9
9	437.1	897.0	1,700.1	3,034.1	337.1

Table 32: Net value added impact of ethanol production (in 2009 dollars)

Scenarios	Direct Effect	Indirect Effect	Induced Effect	Total Effect	Per Plant
1	$11,403,700	$2,302,377	$10,648,364	$24,354,441	$24,354,441
2	$25,233,207	$3,974,173	$22,422,146	$51,629,527	$25,814,763
3	$35,745,051	$4,449,579	$35,562,964	$75,757,595	$25,252,532
4	$48,304,736	$7,615,837	$46,000,964	$101,921,537	$25,480,384
5	$63,104,421	$8,049,318	$57,264,510	$128,418,250	$25,683,650
6	$75,317,686	$11,481,541	$68,655,795	$155,455,022	$25,909,170
7	$88,954,146	$26,809,451	$74,007,012	$189,770,609	$27,110,087
8	$109,871,945	$31,572,615	$87,371,742	$228,816,304	$28,602,038
9	$126,010,140	$16,682,123	$105,288,488	$247,980,751	$27,553,417

Net environmental impact from switchgrass based ethanol production

So far we have determined the net economic impact of converting from current land use patterns to producing switchgrass and ethanol in terms of output, employment, and value added parameters. In this section, the environmental impact from the net cellulosic ethanol production has been presented. Although there are around 190 regulated hazardous air pollutants, I have presented the six common pollutants under National Ambient Air Quality Standard (U.S. Environmnetal Protection Agency [EPA], 2012). In addition, I have also determined GHG, Volatile Organic Compound (VOP) and ammonia emission levels (see

Table 33-34). Since CEDA 4.41 data provides emission levels per dollar of production by industry, the environmental impacts follow the pattern of total output effect of switchgrass, crop, cattle and ethanol production as explained in the previous section. As we can see from Table 33, greenhouse gas emissions caused by the net output value of switchgrass based ethanol is positive for all gasses except methane (CH_4). This implies that ethanol production contributes to environmental degradation. However, the result shows that CH_4 emission will decrease from the current land use pattern. This is because cattle production decreases due to the pasture land shift to switchgrass production. Carbon dioxide and nitrous oxide are the highest GHG emissions. Reading down the column, we can see the as the emission increases across scenarios. Criteria pollutant and VOC emissions will also increase with the production of cellulosic ethanol production. Particulate matter (PM_{10} and PM_{25}), Carbon monoxide (CO) and nitrogen oxide (NOX) are top pollutants. The pollution increases when we go from scenario one to scenario 9. It is important to remember that these values do not capture the complete life-cycle of production, since they only reflect pollution by industries present in each scenario region.

In order to better understand the magnitude of these pollution levels, they are compared to the estimated pollution currently produced in Oklahoma. These estimates are generated by taking total output by industry for Oklahoma in 2009 from IMPLAN and multiplying these values by the pollution coefficients in the CEDA 4.41 database. By comparing our estimated pollution levels with these benchmarks, one can discern the severity of the pollution gains. These are summarized in Table 35and Table 36.

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Table 33: Net GHG emission in ton CO_2 equiv. from switchgrass based ethanol production

Scenarios	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6
1	18,851	-4,667	12,366	69	0.05	102
2	38,623	-7,284	13,700	118	0.16	207
3	59,561	-11,540	32,965	171	0.37	331
4	91,482	-20,389	62,908	224	0.48	516
5	112,830	-24,145	64,999	274	0.58	638
6	141,914	-30,882	91,844	324	0.71	808
7	198,440	-37,530	95,457	500	0.76	1,126
8	260,303	-45,018	114,613	626	0.89	1,493
9	233,013	-58,059	154,485	495	1.10	1,258

Table 34: Net Criteria Pollutants and VOC emissions in ton CO_2 equiv. from switchgrass based ethanol production

Scenarios	CO	NOX	SO_2	PM10-PRI	PM25-PRI	VOC	AMMONIA
1	8,036	1,930	251	12,036	2,539	57	185
2	16,396	3,992	521	24,507	5,171	165	402
3	24,223	5,986	773	36,134	7,624	325	611
4	33,562	8,239	1,067	50,112	10,573	411	834
5	42,718	10,490	1,360	63,781	13,457	521	1,063
6	51,584	12,696	1,646	76,994	16,246	656	1,273
7	61,129	14,714	1,922	91,539	19,311	474	1,454
8	73,140	17,616	2,301	109,515	23,104	569	1,710
9	87,207	21,421	2,775	130,187	27,469	1,071	2,100

Table 35: Percentage of Net GHG emission in ton CO_2 equiv. from switchgrass based ethanol production to the total emission in Oklahoma in 2009

Scenarios	CO_2	CH_4	N_2O	HFCs	PFCs	SF6
Oklahoma	60,472,164	11,905,918	2,510,133	1,728,047	19,390	185,012
1	0.03%	-0.04%	0.49%	0.00%	0.00%	0.06%
2	0.06%	-0.06%	0.55%	0.01%	0.00%	0.11%
3	0.10%	-0.10%	1.31%	0.01%	0.00%	0.18%
4	0.15%	-0.17%	2.51%	0.01%	0.00%	0.28%
5	0.19%	-0.20%	2.59%	0.02%	0.00%	0.34%
6	0.23%	-0.26%	3.66%	0.02%	0.00%	0.44%
7	0.33%	-0.32%	3.80%	0.03%	0.00%	0.61%
8	0.43%	-0.38%	4.57%	0.04%	0.00%	0.81%
9	0.39%	-0.49%	6.15%	0.03%	0.01%	0.68%

Table 36: Percentage of Criteria Pollutants and VOC emissions in ton CO_2 equiv. from switchgrass based ethanol production to emission in Oklahoma in 2009

Scenarios	CO	NOX	SO_2	PM10-PRI	PM25-PRI	VOC	AMMONIA
Oklahoma	127,452	186,213	260,772	97,741.72	31,605.40	69,857	61,072
1	6.31%	1.04%	0.10%	12.31%	8.03%	0.08%	0.30%
2	12.86%	2.14%	0.20%	25.07%	16.36%	0.24%	0.66%
3	19.01%	3.21%	0.30%	36.97%	24.12%	0.47%	1.00%
4	26.33%	4.42%	0.41%	51.27%	33.45%	0.59%	1.37%
5	33.52%	5.63%	0.52%	65.25%	42.58%	0.75%	1.74%
6	40.47%	6.82%	0.63%	78.77%	51.40%	0.94%	2.08%
7	47.96%	7.90%	0.74%	93.65%	61.10%	0.68%	2.38%
8	57.39%	9.46%	0.88%	112.05%	73.10%	0.81%	2.80%
9	68.42%	11.50%	1.06%	133.19%	86.91%	1.53%	3.44%

CHAPTER IV

CONCLUSION

In this study, I have used IMPLAN 2009 economic data, CEDA 4.41 environmental data and other data sources to determine the economic and environmental impact associated with the production of switchgrass based ethanol production in Oklahoma. We have compared the previous land uses for crop and cattle production with projected increases in switchgrass and ethanol production to determine the net the economic and environmental impacts. We have laid a basis for local communities to appropriately assess the tradeoffs between economic and environmental impacts.

While this study delineated the pollution that is associated with switchgrass and ethanol production and compared the estimated pollution for the current and proposed land use patterns, this study did not determine ethanol's energy conversion efficiency. Such analysis would be necessary to evaluate the claim that biofuels will help meet the highly envisaged energy independence from imported fossil fuels as per the Energy Independence and Security Act of 2007; such analysis would be an interesting topic for future studies, once specific technologies are embraced for commercialization. In addition, the study did not consider the emission from construction of ethanol plants and also the emission from consumption of ethanol fuel. The results do suggest that production of ethanol increases GHG pollution, but whether these increases are offset by lower emissions during consumption (as compared to fossil fuels) is yet unknown. It is important to note that petroleum extraction and refinery cause emission which is accounted towards the fuel exporting country. On a wider perspective, the global warming that it causes might have additional economic and health impacts. Therefore, it is important to conduct more thorough cost-benefit analysis which considers all benefits, costs and externalities associated with cellulosic ethanol production. It will also be crucial to quantify the impact of the emissions I have determined for ethanol and switchgrass production on local economy in terms of output, employment and value-added.

The results suggest that the decision to pursue ethanol and switchgrass production highly depends on the priority of the local economy. For local policy makers who have an objective of improving labor income, decrease unemployment and enhance local GDP, my results show that switchgrass based ethanol production has a positive economic significance. On the other hand, for communities which consider environmental impact, bringing ethanol production by shifting land to produce switchgrass feedstock may not be desirable. The estimates presented earlier show that criteria pollutants, VOC's and most GHG's increase with ethanol production expansion with only exception of Methane which showed decreasing trend.

My results support the idea raised by Low and Isserman (2009) who found that local economic conditions affect the size of impact on local economies. The net total employment effect from switchgrass production was affected by the relative labor productivity between crop and cattle production and which supplying sectors were present in the production region.

Due to the scope of this study, availability of convenient data and the inherent nature of I-O model, many assumptions has been made regarding the nature, type and size of switchgrass and cellulosic ethanol production. In future studies, relaxing the assumptions made (e.g., alternate ethanol production technology, introducing a better estimate of feedstock transportation cost) will lead to better estimates of local impacts from both switchgrass and ethanol production. My models are based on 10% cropland and 10% pasture land conversion to switchgrass and all cropland acres were assumed to be taken from the major crop in the study area. However, in reality, farmers may not convert the required acres for production of switchgrass from other crops. For instance, a study on willingness to convert land to switchgrass among 684 farmers in Tennessee found that the mean acreage that would be converted is only 67.3, even if switchgrass production is profitable (Jensen et al., 2007). Farmers may also opt to shift marginal land, use CRP land, or convert the land of lower valued crops to switchgrass production instead. Thus, the actual economic and environmental impacts may be lower. In addition, the study did not take into account the effect of price changes or other government policies like subsidies and taxes that might affect the local impacts.

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APPENDICES

Table 37: Transportation cost computation

Description	Value
IMPLAN Sector 2 total output value- OK state	$658,857,910
Absorption coefficient (Abc) for IMPLAN sector 335	0.011684
Total expenditure in 'Transport by Truck' (TBT) industry by IMPLAN Sector 2	$ 7,698,096
Total wheat production in OK State in bushels	77,000,000
No. of trucks used by IMPLAN Sector 2	96,250
Cost per truck	$ 79.98

TBT=Total value of wheat production in OK * Abc for Transport by Truck sector

Legal Truck Capacity= 800 bushels/ truck for wheat

IMPLAN Sector 2= Grain Farming

IMPLAN Sector 335= Transport by Truck

$$\text{No. of trucks required to transport all wheat in 2009} = \frac{77{,}000{,}000}{800} = 96{,}250$$

$$\text{Average cost per truck} = \frac{7{,}698{,}096}{96{,}250} = \$79.98$$

Table 38: Expenditures of ethanol plants included in scenarios (in 000's of 2009 dollars)[8]

Industrial Sector (IMPLAN Sector Number)	Scenarios								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Electric power generation, transmission, and distribution (31)	4,721.6	9,443.2	14,164.8	18,886.4	23,608.0	28,329.6	33,051.2	37,772.8	42,494.4
Water, sewage and other treatment and delivery systems (33)	299.3	598.7	898.0	1,197.3	1,496.7	1,796.0	2,095.3	2,394.7	2,694.0
Construction of new nonresidential manufacturing structures (35)	36.6	73.2	109.8	146.4	183.0	219.6	256.2	292.8	329.4
Alkalies and chlorine manufacturing (123)	-	-	-	-	-	-	-	-	1,580.7
Other basic organic chemical manufacturing (126)	-	-	-	-	-	39,727.1	46,348.2	52,969.4	59,590.6
Fertilizer manufacturing (130)	-	309.7	464.6	619.4	774.3	929.1	1,084.0	1,238.8	1,393.7
All other chemical product and preparation manufacturing (141)	-	2.2	3.3	4.5	5.6	6.7	7.8	8.9	10.0
Lime and gypsum product manufacturing (164)	-	-	-	-	-	-	7,930.6	9,063.6	10,196.5
Power boiler and heat exchanger manufacturing (188)	-	-	2,292.8	3,057.0	3,821.3	4,585.5	5,349.8	6,114.1	6,878.3
Metal tank (heavy gauge) manufacturing (189)	-	-	1,951.3	2,601.7	3,252.1	3,902.5	4,552.9	5,203.4	5,853.8
Other fabricated metal manufacturing (202)	-	73.1	109.6	146.1	182.7	219.2	255.7	292.3	328.8
Farm machinery and equipment manufacturing (203)	122.6	245.2	367.7	490.3	612.9	735.5	858.0	980.6	1,103.2
Other industrial machinery manufacturing (207)	640.8	1,281.6	1,922.4	2,563.2	3,203.9	3,844.7	4,485.5	5,126.3	5,767.1
Air purification and ventilation equipment manufacturing (214)	-	-	-	4,147.3	5,184.2	6,221.0	7,257.8	8,294.7	9,331.5
Air conditioning, refrigeration, and warm air heating equipment manufacturing (216)	220.3	440.7	661.0	881.3	1,101.7	1,322.0	1,542.4	1,762.7	1,983.0

Table 38: Expenditures of ethanol plants included in scenarios (in 000's of 2009 dollars)[8] (cont'd.)

Industrial Sector (IMPLAN Sector Number)	Scenarios								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Turbine and turbine generator set units manufacturing (222)	-	-	-	-	-	-	-	6,636.5	7,466.1
Pump and pumping equipment manufacturing (226)	490.2	980.4	1,470.6	1,960.8	2,451.0	2,941.2	3,431.4	3,921.6	4,411.9
Material handling equipment manufacturing (228)	1,493.9	2,987.9	4,481.8	5,975.7	7,469.7	8,963.6	10,457.5	11,951.5	13,445.4
Other general purpose machinery manufacturing (230)	-	-	64.7	86.3	107.8	129.4	150.9	172.5	194.1
Industrial process variable instruments manufacturing (251)	-	-	-	-	-	257.1	300.0	342.8	385.7
Insurance carriers (357)	485.1	970.2	1,455.3	1,940.4	2,425.6	2,910.7	3,395.8	3,880.9	4,366.0
Accounting, tax preparation, bookkeeping, and payroll services (368)	484.5	969.0	1,453.5	1,938.0	2,422.5	2,907.0	3,391.5	3,876.0	4,360.5
Waste management and remediation services (390)	1,500.2	3,000.4	4,500.6	6,000.9	7,501.1	9,001.3	10,501.5	12,001.7	13,501.9
Commercial and industrial machinery and equipment repair and maintenance (417)	1,714.1	3,428.2	5,142.4	6,856.5	8,570.6	10,284.7	11,998.9	13,713.0	15,427.1
Total	**12,209**	**24,804**	**41,514**	**59,500**	**74,374**	**129,234**	**158,703**	**188,012**	**213,094**

Source: (De La Torre Ugarte et al., 2006)

[8] 50 MMG per year ethanol plant's expenditure is multiplied by the number of ethanol plants in each scenario.

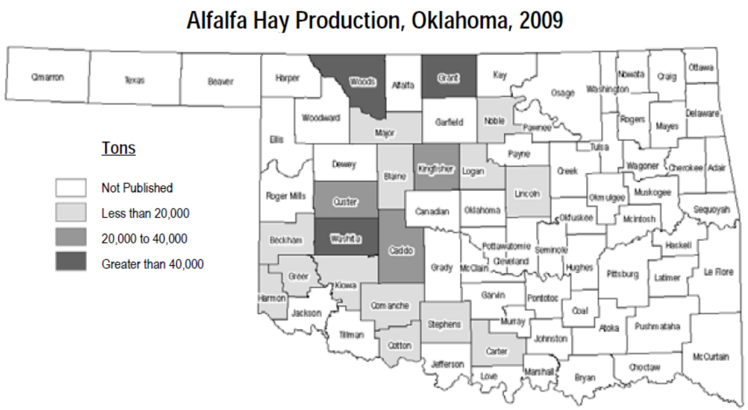
Table 39 : Expenditures of ethanol plants NOT included in the scenarios (in 000's of 2009 Dollars)[9]

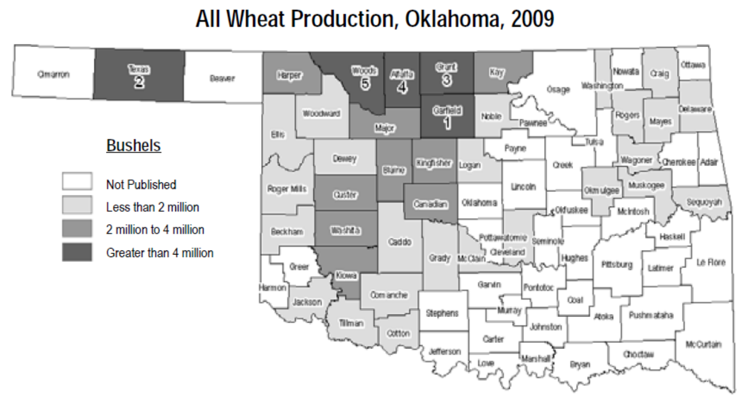
Industrial Sector (IMPLAN Sector Number)	Scenarios								
	1	2	3	4	5	6	7	8	9
Alkalies and chlorine manufacturing (123)	175.64	0.35	0.53	0.70	0.88	1.05	1.23	1.41	-
Carbon black manufacturing (124)	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other basic organic chemical manufacturing (126)	6,621.18	13.24	19.86	26.48	33.11	-	-	-	-
Lime and gypsum product manufacturing (164)	1,132.95	2.27	3.40	4.53	5.66	6.80	-	-	-
Power boiler and heat exchanger manufacturing (188)	764.26	1.53	-	-	-	-	-	-	-
Metal tank (heavy gauge) manufacturing (189)	650.42	1.30	-	-	-	-	-	-	-
Metal can, box, and other metal container (light gauge) manufacturing (190)	42.17	0.08	0.13	0.17	0.21	0.25	0.30	0.34	0.38
Other commercial and service industry machinery manufacturing (213)	107.27	0.21	0.32	0.43	0.54	0.64	0.75	0.86	0.97
Air purification and ventilation equipment manufacturing (214)	1,036.83	2.07	3.11	-	-	-	-	-	-
Heating equipment (except warm air furnaces) manufacturing (215)	73.31	0.15	0.22	0.29	0.37	0.44	0.51	0.59	0.66
Turbine and turbine generator set units manufacturing (222)	829.57	1.66	2.49	3.32	4.15	4.98	5.81	-	-
Air and gas compressor manufacturing (227)	80.20	0.16	0.24	0.32	0.40	0.48	0.56	0.64	0.72
Other general purpose machinery manufacturing (230)	21.56	0.04	-	-	-	-	-	-	-
Industrial process variable instruments manufacturing (251)	42.85	0.09	0.13	0.17	0.21	-	-	-	-
Total	**11,578.41**	**23.16**	**30.43**	**36.42**	**45.53**	**14.65**	**9.16**	**3.83**	**2.73**

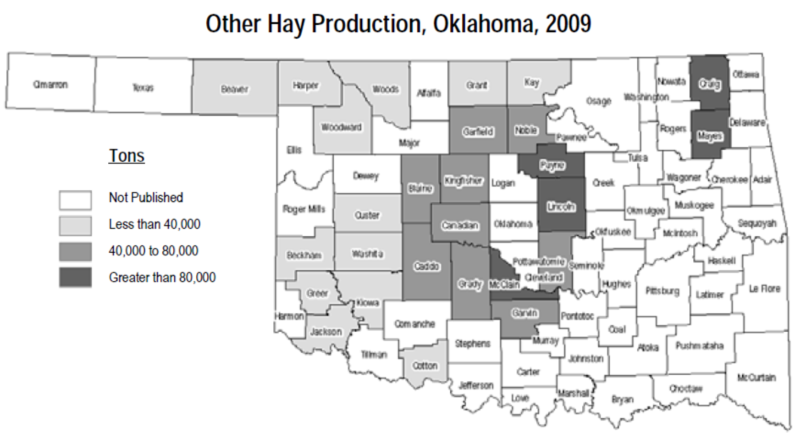
Source: (De La Torre Ugarte et al., 2006)

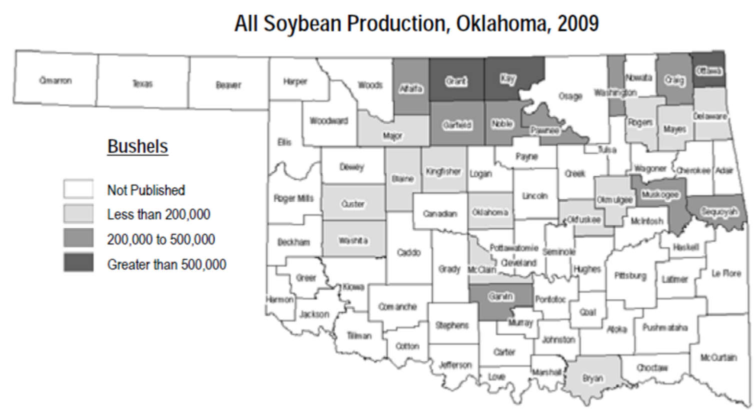
[9] This table represents the expenditure of ethanol plant that is included in each scenario because the appropriate sectors do not exist in the study area data. Thus, it will be a leakage from my models in terms of imported input levels.

Figure 2: Crops production distribution in Oklahoma in 2009









VITA

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Scope and Method of Study: In this study IMPLAN 2009 economic data, CEDA 4.41 environmental data and other data sources are used to determine the economic and environmental impact associated with switchgrass based ethanol production in Oklahoma. The previous land uses for crop and cattle production have been compared with projected increases in switchgrass and ethanol production to determine the net economic and environmental impacts to provide a basis for local communities to appropriately assess the tradeoffs.

Findings and Conclusion: Given the model's assumptions, the results suggest that cellulosic ethanol production using Oklahoma grown switchgrass would result in more than 3,000 jobs, almost $250 million in value-added, and over $430 million in output to the state's economy if nine plants, each producing 50 million gallons of ethanol per year, were operational. However, switchgrass based ethanol production would increase most of the greenhouse gas emissions in the state except methane (CH_4). Criteria pollutant and VOC emissions will also increase with cellulosic ethanol production. Carbon dioxide, carbon monoxide (CO), nitrogen oxide (NOX), nitrous oxide and particulate matter (PM_{10} and PM_{25}) are found to be the major pollutants. This implies that switchgrass and ethanol production contribute to environmental degradation. Thus, the decision to pursue switchgrass and ethanol production depends on a local community's priority of economic gains or environmental quality.

ADVISER'S APPROVAL: Dr. Dave Shideler