The Journal of
Regional
Analysis
& Policy

JRAP 41(1): 22-32.

Ethanol Production in the Southern High Plains of Texas: Impacts on the Economy and Scarce Water Resources

Bridget Guerrero*, Jeff Johnson#, Steve Amosson*, Phil Johnson#, Eduardo Segarra#, and James Surles#

Texas AgriLife Extension Service, Texas Tech University# - USA*

Abstract. The establishment of new biorefineries in an effort to increase energy security in the United States has generated positive impacts by creating jobs and generating economic output. However, communities and local and state leaders are concerned about whether ethanol production is an effective use of limited water resources. Input-output analysis is used to determine if locating ethanol plants in the Southern High Plains of Texas is an effective use of water resources relative to current irrigated crop production in terms of socioeconomic impacts. Results indicate ethanol production generates impacts above and beyond that of crop production utilizing an equivalent amount of water.

1. Introduction

The effort to replace foreign oil imports with domestically produced ethanol in the United States has had many significant impacts, especially on local rural economies. The construction and operation of new biorefineries has generated positive economic effects throughout the country by creating jobs, generating economic output, and increasing demand in other sectors such as transportation. Numerous studies have estimated the economic impacts of ethanol production to a particular region (Flanders et al., 2007; Low and Isserman, 2009; Parcell and Westhoff, 2006; Pierce et al., 2007; Swenson and Eathington, 2006; Urbanchuk, 2007). However, building biorefineries in semi-arid regions has added complexity to the discussion as many communities are concerned about the use of scarce water resources to produce ethanol. This study examines both of these topics for an ethanol plant located in the Southern High Plains of Texas.

The Ogallala Aquifer has long been the primary source of water for the Texas High Plains. The discovery of this aquifer resulted in the growth in irrigated crop production starting in the 1930s. The excellent growing conditions, central location, sparse population, and availability of feed and water attracted the fed-cattle industry, starting in the 1960s and steadily expanding over the years, accelerating the development of irrigation. Irrigated acreage in the region peaked in the mid-1970s at almost six million acres. Water use in the region has exceeded the minimal recharge leading to increased depletion of the aquifer and decreased irrigated acreage of approximately 3.3 million acres (Amosson et al., 2010).

The depletion of the Ogallala Aquifer is creating concern among residents and local and state leaders about the future economic viability of the region and the appropriate use of its scarce water resource. This concern has been heightened in recent years with the development and expansion of dairy operations and now ethanol production in the region. Since 2007, a capacity of 240 million gallons of ethanol production has been built in the area with another 100 million gallon facility under construction (Amosson et al., 2010).

This study focuses on evaluating the impacts on the regional economy and water use from recent expansion of ethanol production in the Southern High Plains of Texas. Data collected from the 40 million gallon Levelland Hockley County Ethanol plant, which began operation in 2008, is utilized in the analysis. This plant is particularly unique as it was built in a cotton producing region with the goal of using only grain sorghum as a feedstock and municipal wastewater for the majority of its water requirement in the production of ethanol. The data collected serve as input into a socioeconomic input-output model (IMPLAN) to estimate the county and regional socioeconomic impacts of the ethanol plant. Similar analysis is then performed on the major irrigated crops which currently constitute approximately 96 percent of water use in the region (Llano Estacado Regional Water Planning Group, 2010). Finally, a comparison of the results of these two analyses is made to determine in terms of socioeconomic impacts if locating ethanol plants within the region is an effective use of scarce water resources relative to current irrigated crop production.

2. Ethanol industry overview

The United States is highly dependent on oil, which accounts for 37.5 percent of total energy consumption. Imports from other countries satisfy 56.9 percent of consumer demand. The industrialization of some developing countries such as India and China has escalated demand, creating more competition for oil resources (Energy Information Administration, 2009). The result has been higher and more volatile prices for oil and gasoline. Expanding production of biofuels such as ethanol has been a main focus of the nation in an attempt to reduce demand for foreign oil and increase energy security.

The main driver of the rapid ethanol industry expansion has been the enactment of legislation in which mandates were established for future domestic ethanol production. The Energy Policy Act of 2005 established a national Renewable Fuel Standard (RFS), which was amended by the Energy Independence and Security Act of 2007, with a phase-in for renewable fuel volumes beginning with nine billion gallons in 2008 and increasing to 36 billion gallons by the year 2022 (Renewable Fuels Association, 2008). As a result, ethanol production in the United States has increased more than 550 percent since 2000 (Figure 1).

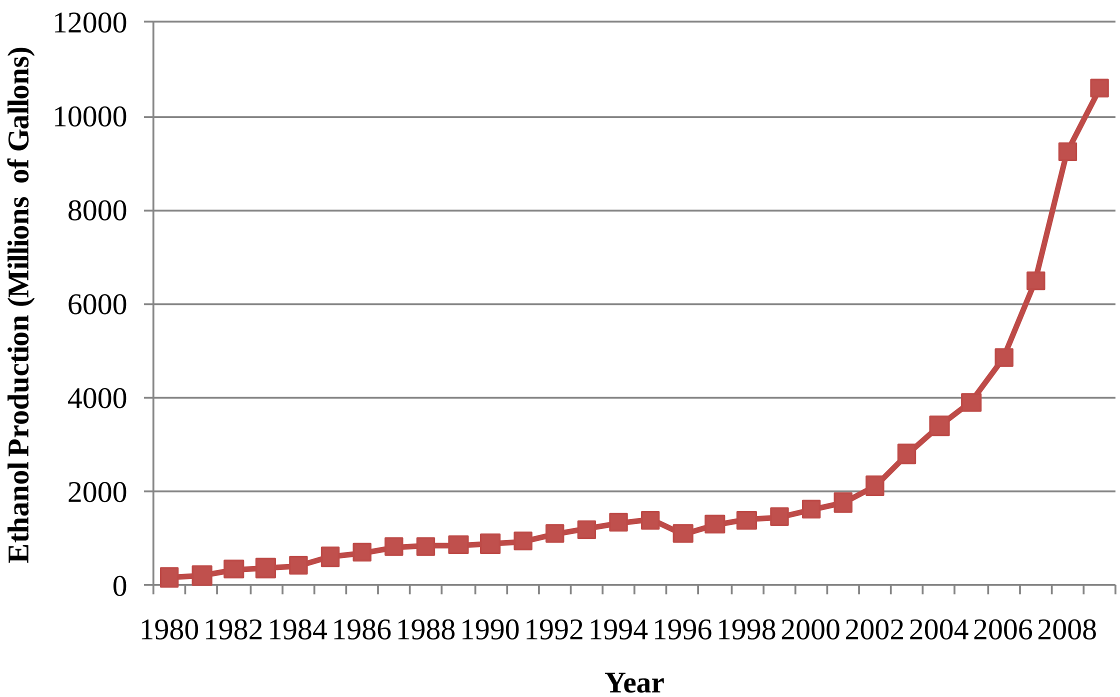

Figure 1. U.S. ethanol production, 1980-2009. (Source: Renewable Fuels Association 2010)

Production of ethanol reached an all-time high of over 10.6 billion gallons in 2009 despite tough times with high feedstock prices and relatively low oil prices (Renewable Fuels Association, 2010a). The 2010 RFS requires 12.95 billion gallons of renewable fuel of which 12 billion gallons is conventional biofuel. The targeted level for conventional biofuel reaches a maximum in 2015 at 15 billion gallons (Renewable Fuels Association, 2010a). The blending rate of ethanol in gasoline for non flex-fuel vehicles has been ten percent (E10), resulting in a maximum market potential of 12.5 to 13.5 billion gallons and creating a "blending wall" (Renewable Fuels Association, 2010b). Recently, the Environmental Protection Agency allowed for an increase of the blending rate of ethanol in gasoline from ten percent to 15 percent (E15). The E15 blend has been approved for model year 2001 and newer light-duty motor vehicles; however, additional testing and regulatory issues must be addressed for practical widespread use of E15 (United States Environmental Protection Agency, 2011). The increase in blending rates will allow for some expansion of grain-based ethanol once these matters are resolved.

3. Literature review

There are numerous popular press articles addressing the debate over ethanol production and subsidization. Currently, the Volumetric Ethanol Excise Tax Credit (VEETC) provides eligible ethanol blenders with a tax incentive of 45 cents per gallon of ethanol blended with gasoline. In addition, small ethanol producers, with less than 60 million gallons of production, can benefit from an incentive of 10 cents per gallon for the first 15 million gallons of ethanol produced annually (Renewable Fuels Association, 2011). Supporters stress the many benefits of ethanol production including increased energy security, reduced emissions, support of the agricultural sector, and the creation of jobs (United States Department of Energy, 2011).

Opponents argue that ethanol production should not be mandated or subsidized due to its contribution to food price increases (Runge, 2010) and lack of evidence for environmental benefits (Bolch and Lyons, 1995). Bolch and Lyons (1995) report several reasons why oxygenated-fuels may not be environmentally beneficial. First, volatile organic compounds found in ethanol which react with nitrogen oxides and sunlight can cause smog. Second, although ethanol use is often portrayed as a way to help reduce carbon-monoxide, the article suggests that the reduction in carbon-monoxide should instead be attributed to the introduction of cleaner-burning engines and that "ambient carbon monoxide levels had begun to fall well before the use of oxygenated fuels" (Bolch and Lyons, 1995, p. 35). In addition, several studies found conflicting results about the environmental effects and net energy value of ethanol relative to gasoline when considering its entire life-cycle (Hsu et al., 2010; Searchinger et al., 2008; Taylor et al., 2010).

These studies bring about relevant research concerns. However, they are limited in their application to this specific study of the regional socioeconomic impacts of a particular ethanol plant in the Southern High Plains of Texas. The reality is that with current ethanol mandates and subsidies in place, ethanol production will continue to grow, having a positive effect on rural economies and promoting local development of other industry sectors. There is a substantial literature related to the regional economic impacts of ethanol plants (Flanders et al., 2007; Low and Isserman, 2009; Parcell and Westhoff, 2006; Pierce et al., 2007; Swenson and Eathington, 2006; Urbanchuk, 2007). These studies utilize an economic input-output model and concentrate on how the construction and operation of ethanol plants affect different aspects of regional economies including employment and industry output.

English et al. (2000) estimated the potential regional economic impacts of converting corn stover to ethanol using the IMPLAN (Impact Analysis for PLANning) input-output model. This study analyzed the economic impacts from plant construction and the three stages of ethanol production including harvesting of the residue, transporting stover to the ethanol plant, and converting corn stover to ethanol. Ten states (Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, South Dakota, and Wisconsin) were included in the study area. Economic information for the ethanol production process was obtained from the National Renewable Energy Lab (NREL). POLYSYS (Policy Analysis System) was used to estimate corn stover residues, and ORIBAS (Oak Ridge Integrated Bioenergy Analysis System) was used for estimates of feedstock and transportation costs. The study estimated an economic impact to the ten-state region of $11 billion in total industry output.

A recent study projected the economic impacts of increasing ethanol and biodiesel production beyond the levels established in the Renewable Fuel Standard through the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007

(De La Torre Ugarte et al., 2007). The study analyzed ethanol production in the U.S. at 10, 30, and 60 billion gallons annually by 2010, 2020, and 2030, respectively. The study utilized an interface program to integrate the POLYSYS model with the IMPLAN model. POLYSYS projections of acreage, price, change in government programs, and cost output were automatically incorporated into IMPLAN, adding a renewable energy sector to the model. The scenario assumed that cellulose-to-ethanol technology would be commercially available by 2012 and that corn grain would be available for the production capacity of plants. The estimated economic impact totaled $368 billion per year creating an estimated 2.4 million jobs. In addition, the study estimated that the cumulative displacement of oil could be as high as 10.48 billion barrels by 2030, decreasing imports by $629 billion.

While these studies have focused on different regions in the United States, no literature has yet quantified the impacts of ethanol production from the Southern High Plains of Texas ethanol plant analyzed in this study. In addition, a comparison of alternative uses for water resources in the region is made in this study to determine in terms of socioeconomic impacts if ethanol production is an effective use of water.

4. Conceptual framework

Regional economics served as the framework for this ethanol study. In particular, input-output analysis was the method employed to quantify economic impacts of construction and operation of the ethanol plant. This type of analysis portrays the economy in terms of a circular flow of income between producers and consumers. Identification of these economic flows and interdependence allowed assessment of the effects of the ethanol industry on the economy. The interested reader is directed to Richardson (1972) for technical information on input-output analysis and regional economics.

5. Methods and procedures

Production data from an ethanol plant in the study region were gathered and are the basis for this study. The socioeconomic input-output model, IMPLAN (Minnesota IMPLAN Group, 1999), was used to estimate the changes in the region's economy due to the increase in demand for inputs used in the construction of the plant and the production of ethanol. These changes were then used to compare the socioeconomic impacts generated for ethanol production and irrigated crop production using equivalent amounts of water. Following is a discussion of the study area, collection of data, IMPLAN input-output model, and comparison of socioeconomic impacts for alternative uses of water.

5.1. Study area

The ethanol plant evaluated in this study was the Levelland Hockley County Ethanol plant located in the Southern High Plains of Texas outside the city of Levelland. Construction began in January 2007, and the plant started operating in March 2008. In 2008, the plant produced 40 million gallons of ethanol using 100 percent sorghum feedstock. The plant processes 15 million bushels of grain sorghum per year into ethanol. Thus, approximately 2.67 gallons of ethanol are produced with every bushel of grain sorghum. Economic impacts of the ethanol plant were examined for Hockley County. In addition, impacts were estimated on a regional basis due to widespread effects beyond county lines. Specifically, the region analyzed included the 24 counties overlying the Ogallala Aquifer in the area from the southern border of Parmer, Castro, Swisher, and Briscoe counties in Texas westward into the state of New Mexico to the southern border of Midland and Glasscock counties of Texas as shown in Figure 2.

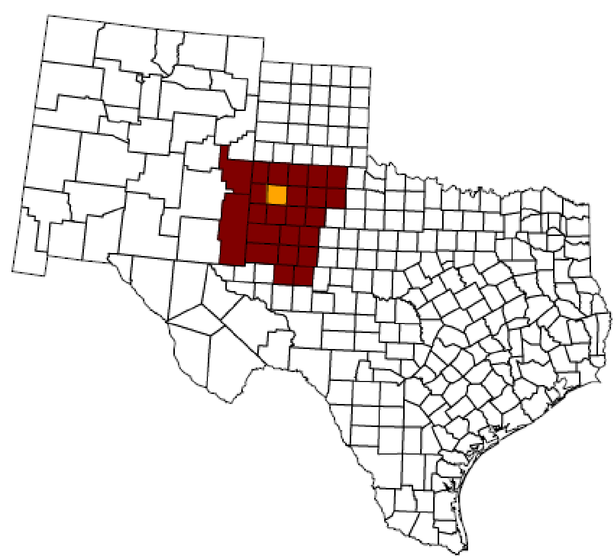

Figure 2. Levelland Hockley County Ethanol Study Region.

5.2. Data

Cost information pertaining to construction and operation of the ethanol plant was collected directly from the plant. Construction costs included the capital investment for plant erection and the labor and management expenses incurred during the building phase. Many of the materials used to build the ethanol plant were purchased outside the study region. Therefore, the construction company was surveyed to determine which inputs were purchased in the county and region versus outside of the area. Operating costs for the plant were from 2008 and included variable costs for the inputs required for ethanol production. The primary inputs to production included feedstock, water, and energy. Other inputs necessary for the process included enzymes, yeasts, chemicals, denaturants, waste management, maintenance, and transportation. In addition, the costs of labor and management were obtained. Income information was also obtained for the sale of ethanol, dried/wet distillers grains, and syrup.

5.3. IMPLAN

Many studies that have quantified the economic impacts of an ethanol plant on a region have utilized the IMPLAN input-output model building system. This computer-based system was originally developed by the United States Department of Agriculture's Forest Service to assist in land and resource management planning. IMPLAN was developed by the Minnesota IMPLAN Group (1999) and provides access to comprehensive and detailed data coverage of the entire U.S. by county. IMPLAN datasets are compiled from a wide variety of sources including the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor, and the U.S. Census Bureau. One advantage of the IMPLAN model is that it allows the incorporation of user-supplied data throughout the model building process. This aspect makes the model flexible and enhances the accuracy of impact results (Minnesota IMPLAN Group, 2004). The IMPLAN model was the primary tool used in this study to measure the regional economic impacts of the ethanol plant.

The data collected from the ethanol plant served as the input for the socioeconomic model to estimate the effects on overall economic activity in the study area. This model captures the "spillover effects" of the establishment and operation of the ethanol plant on other economic sectors linked directly and indirectly to ethanol production. Input-output modeling is a method used to understand the linkages between sectors of an economy and estimate the impacts of changes in the economy. These impacts are referred to as direct, indirect, and induced effects. Direct effects represent the impacts for ethanol plant construction expenditures and ethanol production values specified as direct final demand changes. Indirect effects represent the impacts caused by industries buying from other industries to supply additional inputs for ethanol production. Induced effects represent the response of all local industries caused by the change in household income / spending generated by the direct and indirect effects of final demand changes (Minnesota IMPLAN Group, 2004).

The model produces multipliers that estimate the total economic impact of expenditures within an economy. Three measures of economic activity that can be estimated through IMPLAN are industry output, value added, and employment. Industry output is the value of total production of an economy or the total economic activity that occurs in a region. Value added is the income or wealth portion of industry output that includes employee compensation, proprietary income, other property income, and indirect business taxes. Finally, employment is simply the number of jobs in an economy (Minnesota IMPLAN Group, 2004). These are the measures reported in this study.

5.4. IMPLAN model modifications

The IMPLAN model was adjusted to incorporate a new industry sector for ethanol production by modifying the wet corn milling industry with actual output and employment data obtained from the ethanol plant. These factors were also used to adjust the value added components of the study area data for the industry. The production function for the wet corn milling sector was subsequently adjusted to represent the actual input costs of the ethanol plant and the byproducts modified to include wet and dried distillers grains as well as syrup.

The manufacturing and industrial building sector was also modified to more closely resemble the construction sector for the ethanol plant using actual costs and employment data from the construction company. Finally, because no increase in crop production for feedstock was expected in the study area, the regional purchase coefficient for the grain farming sector was set to zero so that impacts would not be overestimated. All modifications were made for both the county and regional IMPLAN models used.

5.5. Socioeconomic impacts for alternative uses for a scarce water resource

The regional socioeconomic impacts resulting from the operation of the Levelland Hockley County Ethanol plant were compared to regional socioeconomic impacts from irrigated crop production. Four major irrigated crops – corn, cotton, sorghum, and wheat – are produced in the region. Water use estimates were obtained by crop (Texas AgriLife Extension Service, 2009) to determine the amount of acreage of each crop that would require the same amount of water as the ethanol plant.

Gross receipts were calculated for the irrigated crop acreage with equivalent water use to estimate the socioeconomic impacts by crop. To calculate gross receipts, a three year average price (Texas AgriLife Extension Service, 2010) was multiplied by the three year average production per acre by crop for the region (United States Department of Agriculture – National Agricultural Statistics Service (USDA-NASS), 2010). This value was then multiplied by the determined equivalent water use acreage by crop to estimate total gross receipts. Total gross receipts were then input into the IMPLAN model (Amosson et al., 2009b) to determine the socioeconomic impacts by crop. A comparison was made between socioeconomic impacts for ethanol production versus irrigated crop production requiring equivalent amounts of water.

6. Results

The ethanol plant in this study has impacted the regional economy through construction expenses and operational input costs, which created jobs and additional industry output. The location of ethanol plants in local rural communities has had a positive effect on those economies. Many small communities have struggled to survive as more people move into urban areas for employment (McGranahan and Beale, 2002). Ethanol plants have brought jobs and additional economic activity to some of these areas which, in turn, have created impacts well beyond the walls of the plant. The construction and operational impacts on both Hockley County and the Southern High Plains of Texas region from the ethanol plant are estimated in this study.

6.1. Levelland Hockley County Ethanol Plant

The Levelland Hockley County Ethanol plant was a $65 million construction project. The resultant economic impact to Hockley County and the region totaled $0.6 million and $4.8 million, respectively. Employment impacts were minimal with only five jobs created in Hockley County and 35 jobs generated in the region. Most construction inputs for the ethanol plant were purchased outside the region analyzed and, thus, the construction impact was relatively small. In addition, the construction impacts of the plant are a one-time occurrence.

Sales from the Hockley County ethanol plant, including ethanol and byproducts (wet/dried distillers grains and syrup), were approximately $128.6 million in 2008. This resulted in a total economic impact from plant operation to Hockley County of $132.8 million, with value added accounting for $10.1 million. The ethanol plant directly employed 35 people in full time positions for the operation of the plant. An additional 27 jobs were created through indirect and induced effects in Hockley County for a total of 62 jobs (Table 1).

Table 1. Economic impacts of the operation of the Levelland Hockley County Ethanol Plant in 2008.

Hockley County				
	Direct	**Indirect**	**Induced**	**Total**
Industry Output	$128,596,000	$3,509,224	$698,108	$132,803,332
Value Added	$7,690,107	$1,966,418	$431,692	$10,088,217
Employment	35	18	9	62
Region				
	Direct	**Indirect**	**Induced**	**Total**
Industry Output	$128,596,000	$22,570,113	$4,438,324	$155,604,437
Value Added	$7,690,107	$11,320,659	$2,708,341	$21,719,107
Employment	35	86	48	169

Regional impacts were much larger, capturing the leakages and additional input demand satisfied outside of Hockley County. The total economic impacts to the region were $155.6 million, with value added accounting for $21.7 million. Employment created within the region including direct, indirect, and induced effects totaled 169 jobs. These impacts are expected to occur annually as long as the plant is in operation.

6.2. Comparison of socioeconomic impacts for alternative uses for a scarce water resource

The Levelland Hockley County Ethanol plant used an estimated 2.7 gallons of water for every gallon of ethanol produced in 2008. (By comparison, it takes approximately 2.0 to 2.5 gallons of water to produce one gallon of gasoline (Aden, 2007)). Water is used primarily for cooling and to create mash by mixing milled sorghum and water in the ethanol production process. Total water use for the plant running at capacity amounted to approximately 108 million gallons of water per year. One of the unique aspects of this plant is that recycled waste water from the city of Levelland is used in the production process. The reverse osmosis water is used in the boilers, to provide steam to the plant, and in the cooling tower. Reverse osmosis water accounts for 90 percent of water used in the production process while groundwater accounts for the remaining 10 percent. In addition to using reverse osmosis water, 63 percent of the total water requirement was reused in the production process.

The Southern High Plains of Texas is dependent on the Ogallala Aquifer for irrigated crop production due to the semi-arid nature of the region and low levels of precipitation. Irrigated crop production accounts for approximately 96 percent of total water use in the region (Llano Estacado Regional Water Planning Group, 2010). The primary irrigated crops grown in the region are corn, cotton, sorghum, and wheat. Irrigation requirements for the four major crops were estimated using irrigated acreage and water use estimates by crop and are shown in Figure 3 (Amosson et al., 2009a; National Agricultural Statistics Service, 2011).

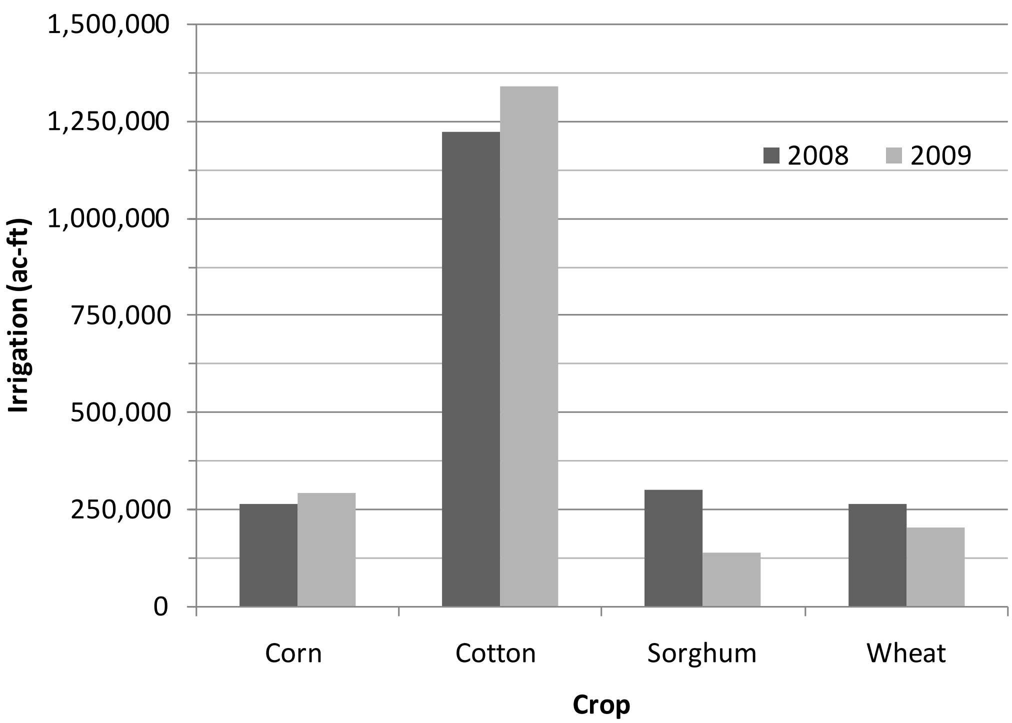

Figure 3. Estimated Irrigation Requirements by Crop for the Levelland Hockley County Ethanol Study Region, 2008 and 2009.

In 2008, cotton accounted for the majority of irrigation water required in the region, followed by sorghum, corn, and wheat. The crop mix changed slightly in 2009 with cotton the leading irrigation use followed by corn, wheat, and sorghum. However, irrigation for sorghum actually decreased by 54 percent, which does not represent an expected response to the introduction of the ethanol plant in the region. Grains produced in this region are typically exported for further use or processing. Thus, the introduction of the ethanol plant did not change crop mix, but instead affected the percentage of sorghum that is used locally. According to water use estimates obtained from the Texas AgriLife Extension Service (2009), the acreage of the major irrigated crops requiring an amount of water from the aquifer equivalent to that used in the annual ethanol production process (108 million gallons) was determined to be 199 acres of corn, 331 acres of cotton, 284 acres of sorghum, or 265 acres of wheat.

The regional socioeconomic impacts from production of ethanol and irrigated crops requiring a similar amount of water are shown in Table 2. Results indicate that the total impacts from ethanol production are significantly higher than the total impacts from irrigated crop production requiring equivalent water. Ethanol production in the Southern High Plains of Texas created a total of 169 jobs for the region. On the other hand, irrigated corn production has a total employment impact of only eight jobs, irrigated cotton production has total employment impact of six jobs, and irrigated sorghum or wheat have total employment impact of four jobs each. In terms of total industry output, ethanol production generates $155,604,437 in economic activity, whereas the economic activity generated from irrigated crop production is $345,603, $425,549, $177,587, and $151,479, for corn, cotton, sorghum, and wheat, respectively. Value added, or the income portion of industry output, was $21,719,107 for ethanol, with much lower values of $172,405 for corn, $171,504 for cotton, $87,153 for sorghum, and $77,762 for wheat.

Table 2. Comparative Regional Socioeconomic Impacts of Ethanol versus Irrigated Crop production with Equivalent Water Requirements.*

Alternative Use	Industry Output	Value Added	Employment
Ethanol (40 mill gallons)	$155,604,437	$21,719,107	169
Corn (199 acres)	$345,603	$172,405	8
Cotton (331 acres)	$425,549	$171,504	6
Sorghum (284 acres)	$177,587	$87,153	4
Wheat (265 acres)	$151,479	$77,762	4

* Estimated impacts include direct, indirect, and induced effects.

7. Summary and Conclusions

The debate over ethanol production and subsidization in the United States will persist as the industry evolves. Ethanol production has been publicized as a way to increase energy security, reduce greenhouse gas emissions, and stimulate rural development. However, analysts have questioned the environmental benefits of ethanol when considering possible negative externalities (Bolch and Lyons, 1995). Some studies have concluded that ethanol production offers improvement over gasoline with respect to greenhouse gas emissions and net energy value (Hsu et al., 2010), while other studies report that biofuels may actually be detrimental to the environment (Searchinger et al., 2008). The ethanol industry has also been targeted for causing increased food prices (Runge, 2010) and, in effect, elevated world hunger, although it is difficult to establish a direct correlation (Anderson et al., 2008). These studies emphasize several relevant environmental concerns. However, they are limited in their applicability to this particular study, which focuses on the regional economic effects of a local ethanol plant. Ethanol production will continue to grow in the United States given the current mandates and subsidies in place. One aspect about the growth of ethanol that most analysts can agree on is that it has a positive effect on rural economies and promotes rural development of other industry sectors tied directly and indirectly to ethanol production.

Results of this study indicate that the contribution of the Levelland Hockley County ethanol plant to the economy of the Southern High Plains of Texas is substantial. While construction expenditures are a one-time occurrence, the region will continue to benefit from operational impacts as long as the ethanol plant is running. The ethanol plant in this study is located in a rural region where irrigated agricultural crop production dominates. Water resources in this area come from the Ogallala Aquifer, which is being depleted. Residents of the area have expressed concern over the use of limited water to produce ethanol. However, the comparison of the socioeconomic benefits of using water resources for the production of ethanol versus irrigated crop production indicates that ethanol production generates economic impacts above and beyond that of crop production utilizing an equivalent amount of water. For example, the employment generated by the ethanol plant is 21 to 42 times the employment generated by irrigated crop production using the same amount of water. Thus, the addition of biorefineries within the region should be encouraged and may be a potential strategy to offset inevitable economic losses that will occur with decreases in irrigated crop production as water availability from the aquifer declines.

The regional economy experiences some additional benefits from ethanol production. First, due to a higher demand for feedstock used for the production of ethanol across the country, agricultural producers have benefitted from higher commodity prices. Second, higher corn prices initially had a negative impact on confined livestock operations located in the region but the byproducts of ethanol production, including dried and wet distillers grains and syrup, have provided relatively inexpensive feed substitutes for these businesses. Finally, the transportation industry, including locally owned trucking businesses and the railway, have expanded due to additional demand for feedstock at the ethanol plant as well as the transportation of ethanol and byproducts to their final destinations.

There are limitations to this study that should be mentioned. The future profitability of ethanol plants is uncertain, which could result in the loss of benefits to the local economy. In addition, indirect water use of ethanol plants through the growth of feedstock was not considered in this study. However, this plant is unique relative to other plants in the region in that the source of feedstock is sorghum (both irrigated and dryland), which requires less water in production relative to corn. In addition, sorghum was typically exported outside of the region before the establishment of the plant, and, thus, there has been little to no change in crop mix in the region, but rather a change in local use of the feedstock. Finally, the IMPLAN model captures only economic linkages from the farm-gate backward and any forward linkages to local elevators or processing sectors tied to irrigated crop production are not captured. Accounting for these impacts, the difference in economic impacts between ethanol production and irrigated crop production would not be as great, since most irrigated crops are processed further within the region, but ethanol is a finished product with a portion being exported. Further research is needed in order to make forward-linked economic impact estimates for crop sectors in the region.

Acknowledgements

Research supported in part by the Ogallala Aquifer Program, a consortium between USDA-Agricultural Research Service, Kansas State University, Texas AgriLife Research, Texas AgriLife Extension Service, Texas Tech University, and West Texas A&M University.

References

Aden, A. 2007. Water Usage for Current and Future Ethanol Production. *Southwest Hydrology* 6(5): 22,23. www.swhydro.arizona.edu/archive/V6_N5/SWHVol6Issue5.pdf. Accessed February 8, 2009.

Amosson, S., L. Almas, F. Bretz, D. Jones, P. Warminski, and J. Planchon. 2009a. Texas Crop and Livestock Enterprise Budgets, Texas High Plains, Projected for 2010. Texas AgriLife Extension Service, Texas A&M University System. College Station, Texas.

Amosson, S., L. Almas, B. Golden, B. Guerrero, J. Johnson, R. Taylor, and E. Wheeler-Cook. 2009b. Economic Impacts of Selected Water Conservation Policies in the Ogallala Aquifer. Ogallala Aquifer Project.

Amosson, S., B. Guerrero, J. Smith, J. Johnson, P. Johnson, J. Weinheimer, L. Almas, and J. Roberts. 2010. Water Use by Confined Livestock Operations and Ethanol Plants in the Texas High Plains. Texas AgriLife Extension Service, Texas Tech University, and West Texas A&M University. August 2010.

Anderson, D. P., J. L. Outlaw, H. L. Bryant, J. W. Richardson, D. P. Ernstes, J. M. Raulston, J. M. Welch, G. M. Knapek, B. K. Herbst, and M. S. Allison. 2008. The Effects of Ethanol on Texas Food and Feed. Agricultural and Food Policy Center; Texas AgriLife Research and Extension. April 10, 2008. College Station, TX.

Bolch, B. W., and H. Lyons. Alcohol Haze. *National Review* May 29, 1995: 34-35.

De La Torre Ugarte, D. G., B. C. English, and K. Jensen. 2007. Sixty Billion Gallons by 2030: Economic and Agricultural Impacts of Ethanol and Biodiesel Expansion. *American Journal of Agricultural Economics* 89(5): 1290-1295.

Energy Information Administration. 2009. Annual Energy Review 2008. DOE/EIA-0384(2008). June 2009. www.eia.doe.gov/aer. Accessed August 21, 2009.

English, B., J. Menard, D. G. De La Torre Ugarte, and M. Walsh. 2000. Using Corn Stover for Ethanol Production: A Look at the Regional Economic Impacts for Selected Midwestern States. University of Tennessee, Department of Agricultural Economics. Knoxville, Tennessee. www.brdisolutions.com/pdfs/bcota/abstracts/1/69.pdf. Accessed March 24, 2008.

Flanders, A., A. Luke-Morgan, G. Shumaker, and J. McKissick. 2007. Economic Impacts of Ethanol Production in Georgia. *Southern Agricultural Economics Association Annual Meeting*, Mobile, Alabama, February 4-6, 2007.

Hsu, D. D., D. Inman, G. A. Heath, E. J. Wolfum, M. K. Mann, and A. Aden. 2010. Life Cycle Environmental Impacts of Selected U.S. Ethanol Production and Use Pathways in 2022. *Environmental Science and Technology* 44(13): 5289-5297.

Llano Estacado Regional Water Planning Group. 2010. Llano Estacado Regional Water Planning Area Initially Prepared Regional Water Plan. Prepared for the Texas Water Development Board with administration by the High Plains Underground Water Conservation District No. 1 with technical assistance by HDR Engineering, Inc. www.twdb.state.tx.us/wrpi/rwp/3rdRound/2010_IPP/RegionO/. Accessed March 2010.

Low, S., and A. Isserman. 2009. Ethanol and the Local Economy: Industry Trends, Location Factors, Economic Impacts, and Risks. *Economic Development Quarterly* 23(1): 71-88.

McGranahan, D. and C. Beale. 2002. Understanding Rural Population Loss. *Rural America* 17(4): 2-11.

Minnesota IMPLAN Group. 1999. *IMPLAN*. Stillwater, Minnesota.

---. 2004. *IMPLAN Professional Version 2.0; User's Guide; Analysis Guide; Data Guide*. 3rd ed: MIG, Inc.

National Agricultural Statistics Service. 2011. Planted Irrigated Crop Acreages by County, 2008 and 2009. United States Department of Agriculture. www.nass.usda.gov/. Accessed February 2011.

Parcell, J., and P. Westhoff. 2006. Economic Effects of Biofuel Production on States and Rural Communities. *Journal of Agricultural and Applied Economics* 38(2): 377-387.

Pierce, V., J. Horner, and R. Milhollin. 2007. Employment and Economic Benefits of Ethanol Production in Missouri. Missouri Corn Growers Association, Prepared by the Commercial Agriculture Program, University of Missouri. February 2007.

Renewable Fuels Association. 2008. Renewable Fuels Standard. www.ethanolrfa.org/pages/renewable-fuels-standard. Accessed February 8, 2008.

---. 2010a. 2010 Ethanol Industry Outlook: Climate of Opportunity. www.ethanolrfa.org/page/-/objects/pdf/outlook/RFAoutlook2010_fin.pdf?nocdn=1. Accessed May 2010.

---. 2010b. The Paradox of Rising U.S. Ethanol Exports: Increased Market Opportunities at the Expense of Enhanced National Energy Security? http://ethanolrfa.3cdn.net/650a769ab9c9a94c36_r9m6iviy6.pdf. Accessed May 2010.

---. 2011. Tax Incentives. www.ethanolrfa.org/pages/tax-incentives. Accessed February 2011.

Richardson, H. W. 1972. *Input-output and regional economics*. New York: Wiley.

Runge, C. F. 2010. The Case Against Biofuels: Probing Ethanol's Hidden Costs. Yale Environment 360. http://e360.yale.edu/feature/the_case_against_biofuels_probing_ethanols_hidden_costs_/2251/. Accessed February 2011.

Searchinger, T., R. Heimlich, R. A. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, and T.-H. Yu. 2008. Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change. *Science* 319(5867): 1238-1240.

Swenson, D. and L. Eathington. 2006. Determining the Regional Economic Values of Ethanol Production in Iowa Considering Different Levels of Local Investment. Department of Economics, College of Agriculture, Iowa State University. July 2006.

Taylor, C. R., R. D. Lacewell, and E. Seawright. 2010. Economic Cost of Biodiesel and Corn Ethanol per Net BTU of Energy Produced. BioEnergy Policy Brief - Auburn College of Agriculture; Texas A&M AgriLife. April 2010. https://sites.auburn.edu/academic/ag/group/bioenergy/_layouts/viewlsts.aspx?BaseType=1.

Texas AgriLife Extension Service. 2009. 2010 Texas Crop and Livestock Enterprise Budgets. District 2 - South Plains. Extension Agricultural Economics. http://agecoext.tamu.edu/resources/crop-livestock-budgets/by-district/district-2.html. Accessed March 2010.

---. 2010. 2007-2009 Average Cash Prices for Corn, Cotton, Sorghum, and Wheat. Extension Agricultural Economics. http://agecoext.tamu.edu/resources/basis-data.html. Accessed March 2010.

United States Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). 2010. 2007-2009 Harvested Irrigated Crop Acreages and Production by County for Corn, Cotton, Sorghum, and Wheat. www.nass.usda.gov/. Accessed March 2010.

United States Department of Energy. 2011. Ethanol Benefits. www.afdc.energy.gov/afdc/ethanol/benefits.html. Accessed February 2011.

United States Environmental Protection Agency. 2011. E15 (a blend of gasoline and ethanol). www.epa.gov/otaq/regs/fuels/additive/e15/#wn. Accessed February 10, 2011.

Urbanchuk, J. M. 2007. Economic Impacts on the Farm Community of Cooperative Ownership of Ethanol Production. *U.S. Department of Agriculture - Agricultural Outlook Forum*, March 1-2, 2007.