Assessing the Future of the Bioeconomy in Greene County, Iowa

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Abstract

The bioeconomy is changing the landscape of some U.S. Corn Belt states. Not surprisingly, Iowans are experiencing significant effects from the developing ethanol industry, and many, including Greene County residents, are becoming more aware of bioeconomic trends. Knowing that positive and negative impacts arise as bioeconomic initiatives evolve in Iowa, this case study addresses the following central question: What should Greene County do to minimize the potentially negative impacts and maximize the positive prospects of the bioeconomy? The phases of the study were: (1) analyze current conditions with respect to feedstock potential and transportation; (2) determine residents' opinions about topics related to the bioeconomy, such as environment, water resources, and livestock; and (3) assess potential impacts and make recommendations. Geographic information systems (GIS) technology was used in part to address these phases. This study represents a replicable first step for analyzing growth of the bioeconomy in a rural Midwest county.

Key words: bioeconomy; ethanol production; geographic information systems; Iowa; web-based survey

1.0 Introduction

The bioeconomy is broadly defined as an economy based on renewable plant- or crop-based materials that are utilized as the basic inputs for industrial processes and energy production (Iowa State University Bioeconomy Institute, 2007). Bioeconomy is distinct from agroeconomy, which includes agricultural products produced for human and animal consumption. Growth of the bioeconomy is a relatively recent phenomenon in the United States, which merits study for both academic and practical reasons.

The U.S. Corn Belt states (primarily Illinois, Iowa, Minnesota, and Nebraska) are affected by expansion of the bioeconomy principally because of the construction and operation of ethanol biorefineries. Currently, corn is the primary raw material utilized in ethanol biorefineries. Therefore, it is not surprising that the ethanol industry is growing most rapidly in these four states, which are responsible for the majority of corn produced in the United States (United States Department of Agriculture [USDA], 2002). In fact, the number of ethanol biorefineries under construction or in operation in these states increased from 30 in 2003 to 97 in 2007. The ethanol industry in these states deserves attention because of the significant impacts it may have on the region and its communities.

Both positive and negative impacts are expected to result from the ethanol industry. Positive impacts could include creation of new jobs; collection of more taxes for public services; lower reliance on oil; increased farmer profits; added value to crop production; and improved quality of life in communities. Negative impacts could include increased property taxes due to tax abatement to attract ethanol plants; increased soil erosion from cultivated land; increased water pollution; loss of soil nutrients; decreased perennial cover; decreased biodiversity, and wildlife habitat; decreased economic diversity; increased competition between food and fuel production; damage to transportation infrastructure; creation of traffic congestion; and depletion of water resources.

Since the bioeconomy is a relatively new phenomenon in the United States, very little data exist on the potential impacts listed above. The planning and public policy sectors are poised to play decisive roles in intelligent development of the bioeconomy in rural areas. In particular, planners must assess the current conditions consequential for bioeconomic growth and consider the opinions and preferences of rural residents who would be affected by it. Such multifaceted investigations should seek to identify the potential impacts that could arise, so that community leaders may strive to maximize the positive and minimize the negative impacts identified.

This case study addresses the growth of the ethanol industry in Greene County, Iowa, which is located in the west-central part of the state (see Figure 1). Greene County covers 365,000 acres, and in 2006 had a total population of 9,809, equating to a population density of 17.1 persons per square mile (United States Bureau of the Census, 2006). The population of Greene County has been in decline in recent years, and the county is lagging in a number of socioeconomic measures when compared to the state average. Thus, Greene County can be considered a rural county in need of economic stimulus. Indeed, this project was initiated by an Iowa State University Extension industrial specialist who determined that residents were interested in exploring what impacts the bioeconomy could have in their county (personal communication J. Euken, January 24, 2007).

In 2002, Iowa was the top corn-producing state in the nation (USDA, 2002) and was the first ethanol-producing state to reach 1.42 billion gallons (American Coalition for Ethanol, 2007). Compared to Iowa averages, Greene County corn yields were 5% higher, area of corn planted was 25% higher, area of corn harvested was 27% higher, and corn production was 33% higher during the years 1992 to 2006 (USDA, 2002). Therefore, Greene County has the potential to produce corn ethanol at a level equal to or greater than the average county in Iowa. Given this, we believe that there is strong potential for Greene County to benefit from the bioeconomy, with strategic planning.

The central question we addressed in this case study was: What should Greene County do to minimize the potentially negative impacts and maximize the positive prospects of the bioeconomy? The phases of the study are described below and diagrammed in Figure 2. In Phase 1, the current conditions consequential to bioeconomic growth were assessed by performing basic spatial analyses of corn feedstock potential and transportation infrastructure using geographic information systems (GIS) technologies. In Phase 2, Greene County residents' opinions and perspectives about topics related to the bioeconomy were captured by conducting a web-based survey. In Phase 3, data acquired during the first two phases were used to gauge the potential impacts of growth of the bioeconomy in Greene County. Finally, recommendations were made to community leaders to aid strategic planning aimed at minimizing the negative and maximizing the positive impacts of bioeconomic development.

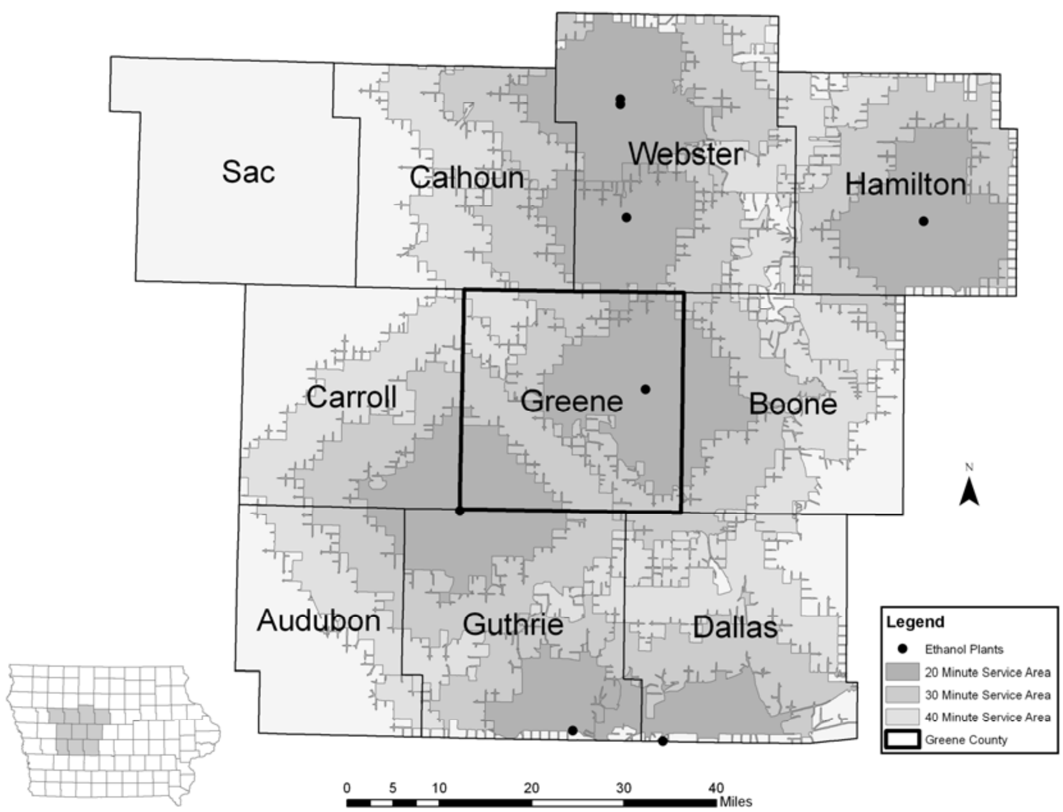


Figure 1. Service areas of the eight ethanol plants in the 10-county region.

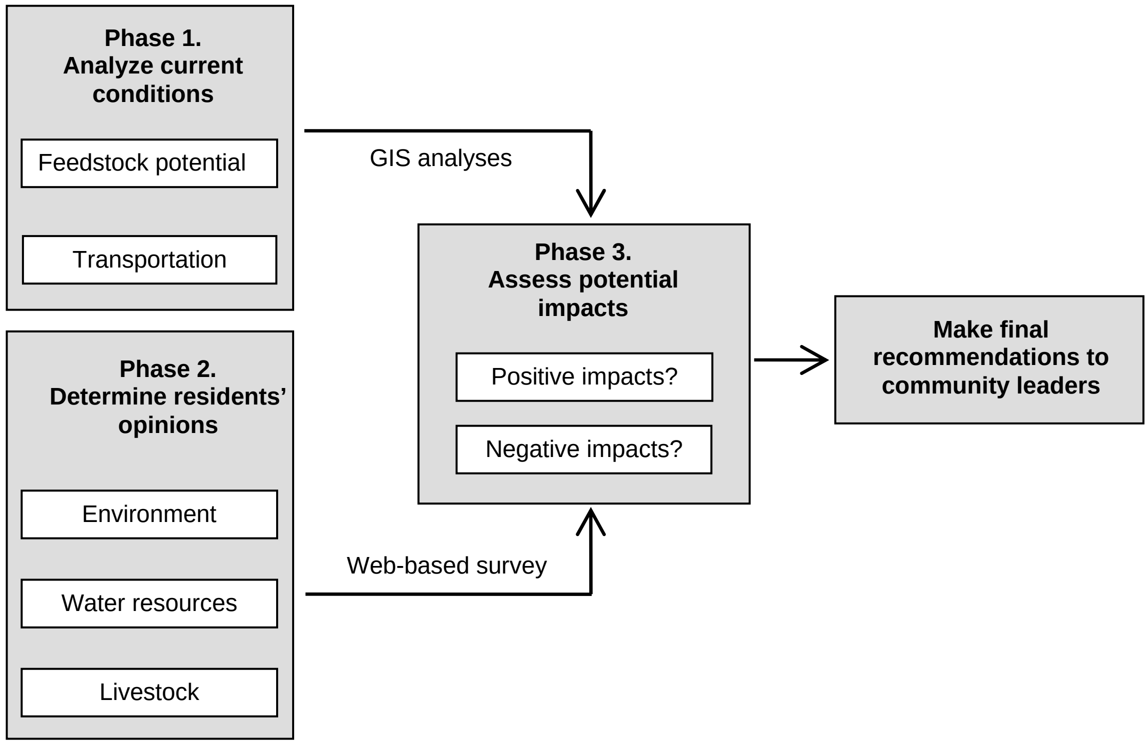


Figure 2. Framework for the Greene County bioeconomy case study.

2.0 Phase 1: Analyze Current Conditions Consequential for Bioeconomic Growth

Two critical aspects of ethanol biorefinery operation were analyzed to assess the current conditions in Greene County that are likely to affect growth of the bioeconomy. These are corn feedstock potential and transportation infrastructure. While not an exhaustive analysis of current conditions consequential for bioeconomic growth, these investigations represent some of the first basic steps necessary to answer this critical question and may serve as the basis for more in-depth investigations.

2.1 Corn Feedstock Potential

Feedstocks are the raw materials used in biorefineries to create bioenergy and other bioproducts. Since corn is the primary feedstock used in ethanol production today, we limited our analysis to corn feedstock potential. First, the specific locations of cornfields were identified in Greene County using the most recent land-cover data available from the Iowa Department of Natural Resources, created from aerial photographs and satellite images collected in 2002 and 2003. In 2002, the predominant land-cover classes in Greene County were corn (179,623 acres) and soybeans (118,765 acres).

After identifying cornfields in the land-cover data, the locations of these potential feedstocks were analyzed relative to locations of ethanol plants using GIS. Unlike some other agricultural industries, transportation of feedstock to a biorefinery is traditionally the responsibility of the producer. Therefore, it is in a farmer's best interest to haul his corn shorter distances to minimize cost. In fact, most producers prefer a maximum 40-minute drive time for hauling (Atchison & Hettenhaus, 2003).

Given that there were ethanol plants in neighboring counties that could realistically be markets for corn produced in Greene County (within a 40-minute drive), the study area was enlarged to include nine surrounding counties (see Figure 1). It is important to note that corn feedstocks grown in the surrounding counties were not included in the analyses. The 10-county study area had four ethanol plants in operation and four under construction that all utilized corn feedstock, only one of which was in Greene County (under construction).

Next, hypothetical "service areas" were created to delineate the regions within 20-, 30-, and 40-minute drive times from the ethanol plants. This was accomplished using the Environmental Systems Research Institute (ESRI) Network Analyst extension for ArcGIS 9.2 and the most recent transportation centerline data from the Iowa Department of Transportation (IDOT). Approximate travel times were calculated based on speed limits of the different road types; average travel speeds were assumed to be less than posted speed limits to account for time for turns, stops, or weather-related speed reductions. The following average travel speeds were used for this case study: 60 mph for interstate highways, 50 mph for U.S. highways, 45 mph for state highways, 40 mph for farm-to-market roads, and 25 mph for local streets and roads.

The areas and percentage of Greene County and the surrounding nine counties covered by the service areas are summarized in Table 1 and Figure 1. The 40-minute service areas encompassed 100% of Greene County and 70.5% of the surrounding nine counties. In contrast, the 20-minute service areas encompassed 51% of Greene County and 21.5% of the surrounding nine counties. Interestingly, the service areas were generally diamond shaped because of the east-west and north-south orientation of roads in Iowa (see Figure 1).

Table 1. *Proportion of Greene County and Surrounding Counties in the Service Areas*

Service areas	Greene County		Surrounding nine counties	
Minutes	Acres	%	Acres	%
20	186,317	51.0	716,739	21.5
30	330,869	90.5	1,582,895	47.4
40	365,440	100.0	2,353,397	70.5
(Total area):	365,440	100.0	3,338,229	100.0

Next, the acreage and percentage of corn in Greene County inside and outside the delineated service areas were determined using standard GIS procedures (see Table 2). The potential yields of corn inside and outside the service areas were calculated based on a mean yield of 180.9 bushels of corn per acre in Greene County during the growing seasons 2004–2006. Finally, the potential ethanol yields from the corn inside and outside the service areas were estimated based on a production ratio estimate of 2.75 gallons of ethanol per bushel of corn (USDA 1996, 2006, 2007). The primary purpose of these analyses was to estimate the amount of Greene County corn feedstocks not within the service areas of the eight existing and pending ethanol plants in order to determine if construction of a new ethanol plant was warranted.

Results from the analyses indicated that 52.8% of Greene County's corn crop was within the 20-minute service areas, while much larger percentages (92.2 and 100.0, respectively) were within the 30-minute and 40-minute service areas (see Table 2). Therefore, 47.2% of Greene County's corn crop was *outside* the 20-minute service area. This equates to over 15,000 bushels of corn and 41.9 million gallons per year (MMgy) of ethanol (see Table 2). In contrast, the corn crop outside the 30- and 40-minute service areas could produce only 6.9 MMgy and 0.0 MMgy, respectively. These volumes are all well below the annual production capacity of any of the eight existing ethanol plants (54 MMgy to 110 MMgy). This means that there would likely be enough corn supply in Greene County for only a very small ethanol plant (at most, 41.9 MMgy), in addition to the ones already under construction. In other words, there is not enough corn produced in Greene County outside service areas of existing ethanol plants to supply a new plant. This estimate is based on a comparison of the local corn supply (as indicated by USDA corn production statistics for the 2004 to 2006 growing seasons) and the local demand for corn in the eight local ethanol plants (as indicated by the annual production capacity of each plant, in MMgy).

Table 2. *Percentage of Cornfields Inside and Outside Service Areas and Potential Yields in Bushels of Corn and MMgy of Ethanol*

Service areas	Greene County corn *inside* service areas			Greene County corn *outside* service areas		
Minutes	%	Bushels	MMgy	%	Bushels	MMgy
20	52.8	17,079,325	46.9	47.2	15,252,815	41.9
30	92.2	29,826,342	82.0	7.8	2,505,798	6.9
40	100.0	32,332,140	88.9	0.0	0	0.0

This basic analysis of the availability of corn for ethanol production represents an essential first step for assessing the current conditions consequential for bioeconomic growth in Greene County. However, it is important to note that several assumptions were made in the analysis, which should be taken into account when considering the results. First, we assumed that none of the corn in the service areas is available for a new ethanol plant. In addition, because corn grown in adjacent counties is within the service areas of ethanol plants in adjacent counties, we assumed that this corn would not be available to a new ethanol plant in Greene County. Both of these assumptions were made because we lacked the data and economic model that would account for price competition, transportation costs, road and weather conditions, local markets, corn quality, and other factors that would influence day-to-day market decisions by corn producers.

2.2 Transportation Infrastructure

In addition to corn feedstocks, the current state of transportation infrastructure is an important condition that may well affect bioeconomic growth in Greene County. An adequate transportation system is important in rural areas (Denicoff, 2007; Kilkenny, 1998), in part because the agricultural and manufacturing sectors, including ethanol plants, rely heavily on such systems (Fox & Porca, 2001). In fact, increased traffic of semitrailers and other heavy vehicles resulting from the growing bioeconomy will likely accelerate deterioration of the transportation infrastructure, thereby increasing the maintenance expenses for state and local governments (Fox & Porca, 2001). Therefore, we sought to assess the current road conditions around ethanol biorefineries in operation and under construction in and around Greene County to determine where community leaders should invest to gain the greatest benefit from improved infrastructure.

Three biorefineries were considered in this analysis, one under construction in Greene County and two in operation in neighboring counties. These biorefineries were chosen for the analysis because they are closest to and thus most likely to utilize feedstocks from Greene County, and because transportation to and from the plants is affected by the road conditions in Greene County. Transporting corn biomass is expensive and a significant portion of this cost is due to truck transportation (Kumar, Cameron, & Flynn, 2005). Additionally, truck transportation is likely to only get more expensive with the rising price of diesel fuel (Energy Information Administration, 2008). Therefore, minimizing hauling distances is beneficial for both farmers and biorefineries (Mahmudi, Flynn, & Checkel, 2005). While biomass produced in Greene County is certainly utilized by plants other than the three considered here, this analysis represents the first step for understanding the current state of the transportation infrastructure and how it might affect bioeconomic growth.

First, three service areas were defined according to approximate road travel times (5, 10, and 15 minutes) from the three plants in a manner analogous to that described above in section 2.1. The service areas were assigned priority ratings based on the knowledge that the conditions of roads and bridges increase in importance the closer they are to a biorefinery (Smith, 2007). Therefore, the 5-minute service areas were designated Priority 1, the 10-minute service areas Priority 2, and the 15-minute service areas Priority 3.

To evaluate paved roads, condition classes were assigned based on their Surface Condition Score as suggested by the IDOT. The following road condition classes were considered important and included in further analyses: Very Poor (surface condition score 0–1) and Poor (surface condition score 2–4). Similarly, condition classes for bridges were assigned based on their Sufficiency Rating as suggested by the IDOT (Smith, 2007). The bridge condition classes deemed significant and therefore included in further analyses were Functionally Obsolete (sufficiency rating 0–50) and Requires Rehabilitation (sufficiency rating 51–80).

Next, the paved roads and bridges were spatially overlaid with the service areas and the condition classes within the priority regions were determined. In this case study we focused on the worst condition classes, Very Poor and Poor roads and Functionally Obsolete bridges, because we recognized that the public sector has scarce resources to rehabilitate transportation infrastructure. Only 0.47 miles of Very Poor roads and 0.85 miles of Poor roads were present in the Priority 1 regions. Within Priority 2, there were 0.79 miles of Very Poor roads and 2.87 miles of Poor roads. In Priority 3, there were 0.79 miles of Very Poor roads and 3.56 miles of Poor roads. There were four Functionally Obsolete bridges in Priority 1 regions, six in Priority 2 regions, and 12 in Priority 3 regions. Thus, there were a total of 12 Functionally Obsolete bridges in Greene County: four within 5 minutes, two within 10 minutes, and six within 15 minutes of a biorefinery. Greene County officials should direct their attention to the Very Poor and Poor paved roads and Functionally Obsolete bridges identified in the Priority 1 regions.

3.0 Phase 2: Determine Residents' Opinions

Public participation in the planning process is important for increasing "the accountability and transparency of the decision-making process" (Cullingworth & Nadin, 2002) and is a key element in a successful planning process (Conroy & Cowley, 2006). In rural regions, public participation is particularly important for learning what the public wants from agriculture and the countryside (Hall, McVittie, & Moran, 2004). Therefore, in Phase 2 of the study we sought to evaluate Greene County residents' opinions on the bioeconomy in terms of agriculture, the environment, water resources, and livestock.

3.1 Web-Based Survey Design and Implementation

Participation tools have inherent strengths and weaknesses, and planners must determine the most appropriate one for a specific situation. Web-based surveys are popular because they empower more people to be involved in planning (Al-Kodmany, 2000), have fewer restrictions in terms of when and where a survey is completed (Conroy & Cowley, 2006), and offer numerous advantageous features like interactive maps (Dillman, 2000; Wherrett, 1999). After considering these advantages and the fact that Greene County's population is dispersed over a large area, we opted to use a web-based survey.

Web-based surveys also have limitations (Al-Kodmany, 2001; Carter & Howe, 2006; Dillman, 2000; Wherrett, 1999). For this study the most pertinent of these is the potential lack of Internet access or computer knowledge among respondents, which could create sample bias. Rural populations are technologically disadvantaged (National Telecommunications and Information Administration, 2000), and the Midwest has low Internet penetration (Spooner, 2003). Therefore, we attempted to limit the graphic complexity of our survey in order to facilitate respondent access, and we also provided respondents with the option of completing a paper-based survey.

The survey was designed to assess residents' opinions about agriculture, the environment, water resources, and livestock expansion as they relate to the bioeconomy. The motivation and methods for addressing the environment and water resources are described below in sections 3.2 and 3.3, respectively. Livestock expansion was included in the survey because co-locating livestock facilities and biorefineries can make ethanol production more efficient and environmentally friendly and because it is possible that co-location in Greene County would require expansion of livestock facilities. Expanding livestock facilities can be problematic if planning is neglected because the ethanol and livestock producers may face environmental and economic consequences (Bailey, 1997; Fulhage, 1997).

The survey had two major parts, the first of which consisted of statements with an ordered sequence of response choices (strongly disagree, disagree, uncertain, agree, and strongly agree), also known as Likert items (Leedy & Ormrod, 2005). The second part consisted of a map series, which displayed alternate land-use scenarios that addressed the environment, farmland, and water resources. As described in detail below (sections 3.2 and 3.3), the respondents were asked to select which of the scenarios best matched their preference. Respondents had the option of using "dynamic" interactive maps or "static" maps that were not interactive.

The web-based survey was available online from July 18, 2007, to September 3, 2007. A total of 1,311 county residents, for whom we were able to obtain e-mail addresses through connections with the Greene County Extension Office, were contacted once by e-mail and twice by postal cards and invited to complete the survey. In addition, the survey was advertised in a local newspaper with countywide circulation and was promoted in each of seven weekly radio shows. These efforts attracted 203 respondents, approximately 16% of those contacted directly. Therefore, individuals that responded to the survey represented an "opportunistic sample of convenience" (Leedy & Ormrod, 2005).

3.2 Environment Alternate Scenarios

The web-based survey focused on two environmental aspects directly related to the bioeconomy: landscape conservation and farmland protection. Landscape conservation is important because agriculture has led to extensive ecosystem alteration in Iowa (Nassauer, Corry, & Cruse, 2002; Santelmann et al., 2004; Schulte, Liebman, Asbornsen, & Crow, 2006). One way to reduce the environmental impact of agriculture is to grow perennial crops that can be used for bioenergy production (Schulte et al., 2006). While this practice has proved effective, many factors keep farmers from implementing it (Smith, Peterson, & Leatherman, 2007), such as the spike in commodity prices of traditional row crops, which has resulted from the emerging bioeconomy (Smith et al., 2007). Additionally, farmers may bring fallow protected land back into production if crop prices continue to rise because of the high demand for renewable-energy crops (Secchi & Babcock, 2007).

Farmland protection is also a noteworthy issue in rural areas like Greene County (Diaz & Green, 2001; Hellerstein et al., 2002). Agriculturally, Iowa is the most productive state in the nation and Greene County has a Corn Suitability Rating (CSR) 13% higher than the state average (76.4 versus 63.5). The CSR index rates soils on a scale of 1 to 100 according to their potential for row-crop production. Thus, soils in Greene County have high production potential, validating the importance of farmland protection. Additionally, changes in agricultural land use may occur because of municipal growth. In the last decade, the populations of six of the seven county municipalities have increased, and the county seat has expanded its incorporated area three times in anticipation of growth. Finally, farmland protection is important in Iowa because of the inevitable loss of agricultural land in other regions of the country experiencing significant urban growth (Alig, Kline, & Lichtenstein, 2004).

We used GIS to create maps depicting three hypothetical scenarios of landscape conservation and farmland use in Greene County. The specific terms "environmentally sensitive land" and "land most suitable for crops" were used in the survey because we believed that they would be less ambiguous for the respondents.

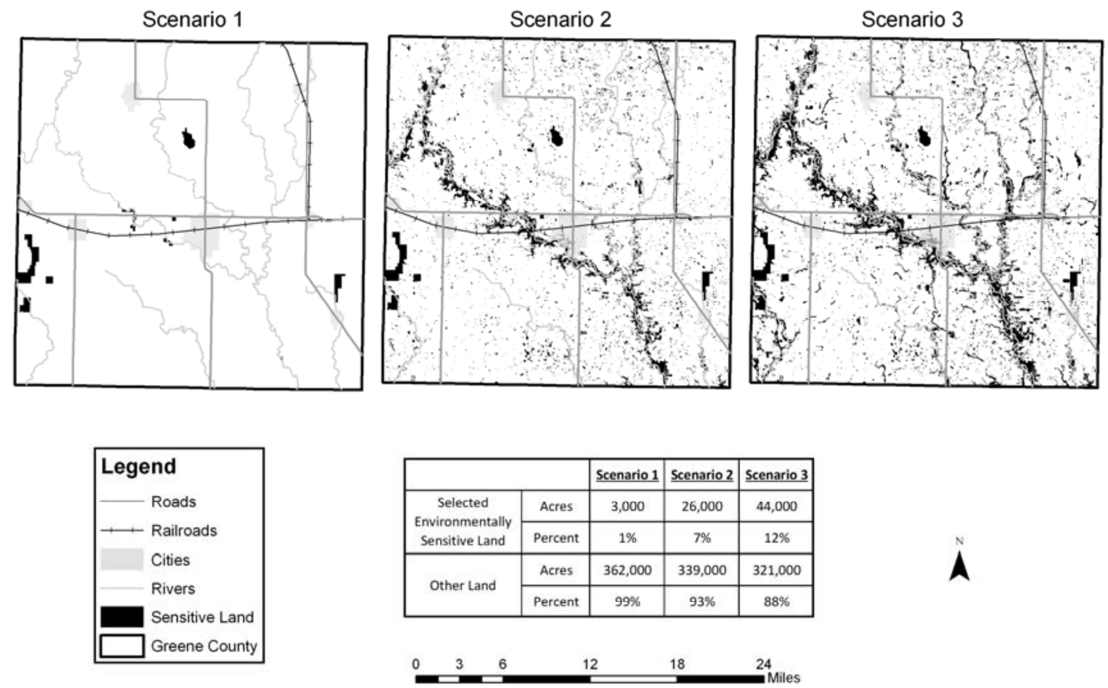
For the "environmentally sensitive land" scenarios, we used five GIS themes: (1) public stewardship lands owned by the Iowa Department of Natural Resources and other public conservation organizations; (2) existing permanent land cover (forest lands and Conservation Reserve Program grassland) from the *2002 Land Cover* data (Iowa Geological Survey, 2004); (3) wetlands from the *National Wetlands Inventory* (United States Fish and Wildlife Service, 2004); (4) floodplain and flood-prone areas from soils data; and (5) alfalfa and barren land from the *2002 Land Cover* data. Three scenarios were developed from these GIS themes and presented in the survey (see Figure 3). Scenario 1 represented a minimum area of environmentally sensitive land (theme 1 only), Scenario 2 represented the actual area (themes 1, 2 and 3), and Scenario 3 represented a maximum area (themes 1 through 5).

For the "land most suitable for crops" scenarios, we used CSR values from soils data. The CSR of Greene County soils ranges from 5 to 92 (area-weighted average of 76.4). CSR values were used to delineate areas of the county with highest productivity. Three scenarios were developed and presented in the survey: Scenario 1 had a small area of "land most suitable for crops" (CSR 88–91); Scenario 2 had a moderate area (CSR 84–91); and Scenario 3 had a large area (CSR 79–91). Scenarios 1, 2, and 3 represented 17%, 33%, and 45% of the county, respectively. Presentation of these maps in the survey was similar to that of the "environmentally sensitive land" maps shown in Figure 3.

3.4 Water-Quality Alternate Scenarios

Increases in corn production for ethanol will likely require increased application of agricultural chemicals and may lead to greater runoff of these chemicals into rivers and streams (Pimentel & Patzek, 2005). Indeed, the major source of the non–point-source pollutants nitrogen and phosphorus is cropland runoff (Dosskey, 2001). High concentrations of these chemicals in waterways promote the growth of vegetation, which ultimately dies and decomposes, thereby depleting oxygen and altering the aquatic ecosystem (Wortmann et al., 2006). However, runoff can be reduced by the presence of a riparian buffer (Food and Agricultural Policy Research Institute, 2007; Lowrance et al., 1997), a linear band of permanent vegetation adjacent to an aquatic ecosystem intended to maintain or improve water quality (Fischer & Fischenich, 2000).

We used GIS to create three scenarios aimed at gauging survey respondents' opinions about water in Greene County. Instead of presenting data about water pollution, we opted to present hypothetical riparian buffers in the maps. Scenario 1 represented a minimum buffer area (no riparian buffers in Greene County waterways), Scenario 2 represented the actual buffer area (digitized from 2006 aerial photographs), and Scenario 3 represented a maximum buffer area (actual riparian buffers extended 180 feet on each side). These three scenarios ensured both visual and quantitative contrast (see Figure 4).



		Scenario 1	Scenario 2	Scenario 3
Selected Environmentally Sensitive Land	Acres	3,000	26,000	44,000
	Percent	1%	7%	12%
Other Land	Acres	362,000	339,000	321,000
	Percent	99%	93%	88%

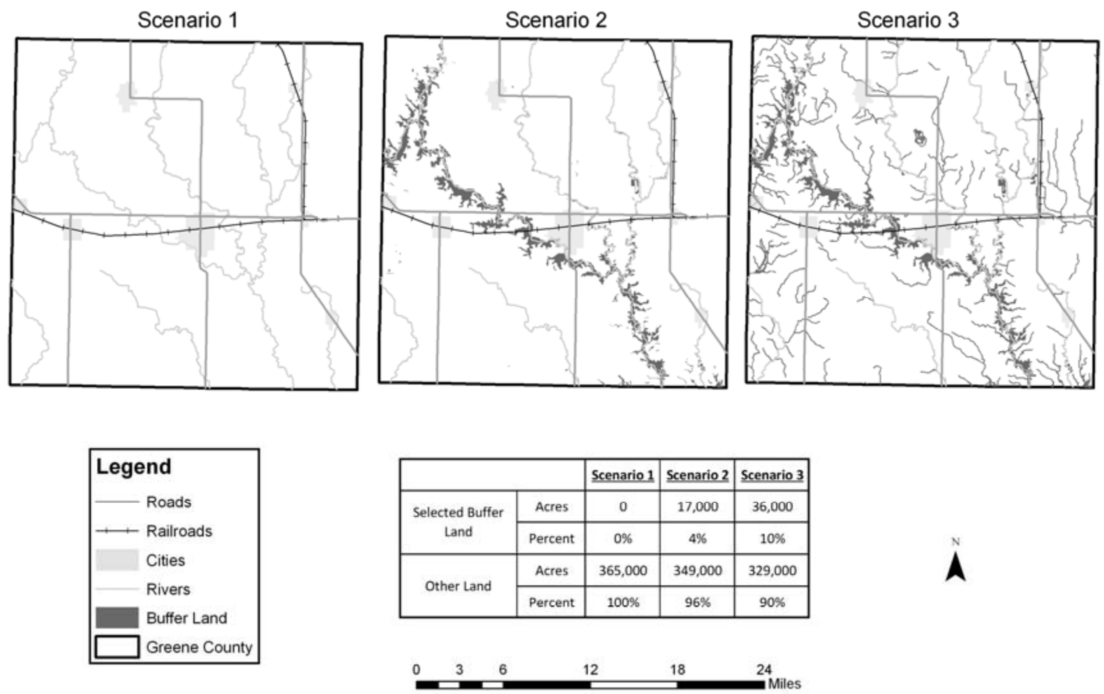
Figure 3. Environmentally sensitive land scenarios presented in the web-based survey.

3.5 Survey Results and Analysis

The results from the Likert item questions are summarized in Table 4 and results from the hypothetical scenario maps are summarized in Table 5. The numbers in Tables 4 and 5 represent the percent responses to each question, excluding surveys for which no response was given. Percentages for strongly disagree/disagree and strongly agree/agree were aggregated in Table 4 and the order of questions was arranged in descending order of percent agree/strongly agree. Statements that received the highest support related to biofuel-production facilities, biofuel crops, improving water quality, cattle production, and attracting dairy farms (see Table 4). The alternate scenario maps that received greatest support were Scenario 2 (retain existing area) for environmentally sensitive land and land most suitable for crops and Scenario 3 (maximize area) for riparian buffers (see Table 5).

Six main questions were posed prior to analyzing the survey responses in order to guide interpretation of the results. In the following paragraphs, the survey results are reviewed in terms of these six questions.

Question 1. Did a majority of respondents agree that increasing the bioeconomy would be good for Greene County? Nearly 73% of all respondents agreed or strongly agreed that "increasing the number of biofuel-manufacturing facilities in Greene County is good for its residents." There was little difference in the responses of "farmers" (individuals who own/operate farm/farmland) and nonfarmers (individuals who do not own/operate farm/farmland). These figures were 73% and 72%, respectively.



		Scenario 1	Scenario 2	Scenario 3
Selected Buffer Land	Acres	0	17,000	36,000
	Percent	0%	4%	10%
Other Land	Acres	365,000	349,000	329,000
	Percent	100%	96%	90%

Figure 4. Water-quality scenarios presented in the web-based survey.

Question 2. Did a majority of respondents indicate support for changing crops to meet bioeconomy needs? Over 67% of respondents agreed or strongly agreed that “changing the kinds of agricultural crops grown in Greene County to meet the future needs of the biofuels industry is good for its residents.” A higher percentage of farmers agreed with this than nonfarmers (~70% versus ~62 %).

Question 3. Which of the three map scenarios for environmentally sensitive land, land most suitable for crops, and riparian buffers did respondents favor? Among all respondents, Scenario 2, moderate area, was favored for both environmentally sensitive land (~56%) and land most suitable for crops (~55%). For both environmentally sensitive land and land most suitable for crops, Scenario 3, maximal area, was favored second, followed by Scenario 1, minimal area. In contrast, Scenario 3 was favored in regard to riparian buffers (~67%), followed by Scenario 2 and then Scenario 1 (see Table 5).

Question 4. Did a majority of the respondents disagree that the current quality of stream water in Greene County is acceptable? The percentage of respondents who disagreed that current stream water quality was acceptable (~36%) was similar to the percentage who agreed (~32%) and were uncertain (~33%). However, there was a large difference in the response of farmers (~18% disagreed) and nonfarmers (~46% disagreed). In other words, farmers agreed more than nonfarmers that the current quality of stream water was acceptable.

Table 4. *Results for the Likert-Item Questions in the Web-Based Survey*

Question	Disagree or strongly disagree (%)	Uncertain (%)	Agree or strongly agree (%)
Increasing the number of biofuel manufacturing facilities in Greene County is good for its residents	9.1	18.7	72.2
Changing the kinds of agricultural crops grown in Greene County to meet the future needs of the biofuels industry is good for its residents	5.6	27.0	67.3
Local program dollars should be used for improving water quality	6.2	28.8	65.0
Increasing cattle production in Greene County is good for its residents	7.6	29.4	62.9
Attracting dairy farms to Green County is good for its residents	9.2	31.6	59.2
Any land in Greene County that is most suitable for crops should be in crop production	25.0	15.9	59.1
Increasing sheep production in Greene County is good for its residents	10.7	40.1	49.2
Excluding crop production from environmentally sensitive land in Greene County is good for its residents	27.2	24.5	48.4
High-quality water is needed even if private landowners have to pay the cost of improving water quality	21.7	32.6	45.7
The current quality of underground water in Greene County is acceptable	20.6	34.9	44.6
Increasing hog production in Greene County is good for its residents	24.7	30.8	44.4
Increasing poultry production in Greene County is good for its residents	14.1	42.4	43.4
The current amount of underground water in Greene County is acceptable	14.1	45.8	40.1
The current quality of stream water in Greene County is acceptable	36.0	32.6	31.5

Question 5. Did a majority of respondents indicate preference for traditional row crops over more perennial crops for a future biofuel economy? Among all respondents, approximately 56% preferred “more perennial crops for a future biofuel economy” rather than “continue traditional row crop production.” Among farmers, a slight majority (53.6%) preferred to “continue traditional row crop production.” Among nonfarmers, a larger majority (68.5%) preferred “more perennial crops for a future biofuel economy.”

Question 6. Did a majority of respondents indicate preference for livestock production over other options? A large majority of respondents (~77%) preferred “continue current row crops and livestock mix” over “more intensive crops with less intensive livestock." Both farmers (~83%) and nonfarmers (~69%) indicated strong support for continuing the mix of row crop and livestock. Nearly 89% of respondents preferred "continue current row crops and livestock mix" over "more

Table 5. *Results for the Alternate Scenario Map Questions in the Web-Based Survey*

	Percentage of respondents indicating preference for the scenarios		
Scenario	Environmentally sensitive land	Land most suitable for crops	Riparian buffers (water quality)
1 – minimal area	11.9	8.3	2.3
2 – moderate area	**55.9**	**55.0**	30.5
3 – maximal area	32.2	36.7	**67.2**

intensive livestock with less intensive crops." There was little difference between the responses of farmers (~88%) and nonfarmers (~89%). Interestingly, a larger majority (~79%) of respondents preferred "more perennial crops for a future biofuel economy" over "more intensive livestock production." The response was similar for both farmers (~78%) and nonfarmers (~79%). Therefore, when choosing between the current row crops/livestock mix and a change in livestock, respondents overwhelmingly indicated preference for the status quo. When choosing between more perennial crops and more livestock, respondents overwhelmingly indicated preference for more perennial crops.

4.0 Phase 3: Assess Potential Impacts and Make Recommendations

In Phase 3 of this case study we sought to identify the potential positive and negative impacts of bioeconomic growth in Greene County. The ultimate question we sought to answer is: What should Greene County do to minimize the potentially negative impacts and maximize the positive prospects of the bioeconomy? We attempted to answer this question based on the analyses of our results from Phases 1 and 2, and we made recommendations to Greene County community leaders based on these.

In Phase 1 of the study we analyzed some aspects of the current conditions consequential to bioeconomic growth in Greene County. The corn feedstock-potential assessment results informed us that when the four plants under construction begin operation, there would likely be enough corn supply in Greene County for only a very small additional ethanol plant (at the most, 41.9 MMgy). Based on the transportation infrastructure spatial analysis, paved roads and bridges, in particular those around the existing and pending ethanol plants, appeared to be in good condition in Greene County. However, as pointed out in section 3, there were several locations that should be targeted for reconstruction and rehabilitation to accommodate the increased traffic likely to be generated by ethanol-production facilities.

In Phase 2 of the study we assessed the opinions of Greene County residents in regards to the growing bioeconomy. Results from our web-based survey of Greene County residents revealed that more than 72% of respondents supported increasing the number of biofuel-manufacturing facilities. The majority of respondents also supported growing more perennial crops for a future biofuel economy, and residents were overall concerned about water quality in the county. Interestingly, both farmers and nonfarmers preferred retaining the existing area of environmentally sensitive land and most respondents favored a scenario of a moderate land area of farmland. Additionally, almost half of respondents agreed that excluding crop production from environmentally sensitive land in Greene County is good for its residents. Approximately 63% of respondents also supported increasing cattle production, whereas support for increased hog (45%), poultry (43%), and sheep (49%) production was much lower. In contrast, almost 60% of respondents supported attracting dairy farms. As mentioned above, livestock operation is an important topic because co-locating ethanol plants and livestock operations can make ethanol production more efficient and environmentally friendly.

To aid strategic planning, recommendations based on the results of Phases 1 and 2 were proposed to community leaders as follows. First, to avoid future problems of corn supply for biorefineries, Greene County should require a current and detailed economic analysis of supply and demand before approving any other corn-ethanol biorefinery to be built within the county. This type of policy would minimize the negative impact—undersupply—and would promote a more stable market for Greene County farmers, which could lead to a positive impact (an increase in farmers' profit). Second, reconstruction and rehabilitation of specific locations in the transportation infrastructure should be addressed using a cost-benefit analysis to assure that Greene County has a transportation network in good condition. This recommendation would minimize the negative impact—damage to the transportation infrastructure. In doing so, leaders would also minimize the negative impact—creating traffic congestion—that could arise if many locations in the transportation infrastructure were in bad condition.

Third, given the survey responses, a countywide suitability analysis should be performed to explore the possibility of growing more perennial crops. Fourth, a campaign should be planned to further educate residents about the importance of landscape conservation. Fifth, because survey responses revealed significant uncertainty regarding water-quality issues, further investigations should be performed to explore future options and directions in this regard. Finally, given significant support in the survey, policies to support and encourage livestock expansion in Greene County should be considered and residents should continue to investigate the opportunities and limitations of such expansion.

5.0 Limitations and Future Directions

We believe that this study represented a respectable first step for analyzing growth of the bioeconomy in a rural Midwest county. However, we also acknowledge that the study had a number of significant limitations. First, the corn feedstock analysis was not exhaustive and was limited to analysis of past feedstocks. In such, we assumed that crop data were consistently defined, measured, and reported during the 15-year period analyzed. In addition, the land-cover data used in the analysis were 5 years old at the time of the analysis. More recent land-cover data, using field verification, would have resulted in estimates of amount and distribution with more certainty and comparability to USDA data.

Second, the transportation infrastructure analysis was also limited in that the road and bridge condition data were 2 years old at the time of the study. Also, the analysis only addressed the road conditions in three priority regions around ethanol plants, and did not consider overall county road conditions. Finally, recommendations about infrastructure to target for maintenance and rehabilitation was based only on proximity to a plant, without considering possible alternate routes that could be used to avoid the problem areas.

Finally, the web-based survey was limited in a number of ways. The survey was conducted in late summer, early fall to avoid planting and harvesting seasons. However, other activities may have prevented residents from participating, such as county fairs and summer vacations. Additionally, the survey respondents were an “opportunistic sample of convenience” rather than a random sample of Greene County residents. This means that the opinions expressed in the survey may not have been representative of the county as a whole. Moreover, participation in the survey may have been influenced by the fact that the survey was web-based. As described in section 3.1, access to Internet technology is relatively low in the Midwest. The web-based nature of the survey also meant that there was potential for individuals to complete the survey more than once, and potential for residents of other counties to complete the survey.

Given the results of the study and considering the limitations described above, we believe that further research is warranted. First, a follow-up survey would provide additional information about residents’ preferences regarding bioeconomy options, including their ethical implications. These include lignocellulosic feedstocks (especially corn stover), perennial crops (such as switchgrass), livestock options, dairy options, water-quality protection, and land most suitable for crops. Such a follow-up survey should be based on a random sample of the population, rather than a sample of convenience. Second, further research should address the potential supply of corn stover as a lignocellulosic feedstock. This would include spatial and statistical analysis of excess stover in Greene County. The actual amount of excess stover depends on tillage practices, crop rotations, soil type, and slope incline and length. These variables can be modeled using GIS technology to develop a refined estimate of the potential supply of excess stover as a biofuel feedstock. Third, more research is warranted to assess the potential to grow alternative crops for the bioeconomy. Suitability models, based on landscape characteristics such as soils, slopes, and drainage patterns, could be developed with GIS to assess the potential for growth of alternative crops. Fourth, because this research is limited to strategic planning for the bioeconomy, additional studies of economic feasibility (both supply side and demand side) need to be completed. Information from further investigations, together with the results of this three-phase case study, may further guide decisions about growth of the bioeconomy in Greene County.

6.0 Acknowledgments

The authors would like to thank Jill Euken for her insights to start the research project, and the financial support from the Greene County Development Corporation, the Iowa Energy Center, and the Leopold Center for Sustainable Agriculture. They would also like to thank Emily Brodersen, Kelly Delmonico, Basil Mahayni, and Bethany Wilcoxon for their research assistance.

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