The Global Warming and Land Use Impact of Corn Ethanol Produced at the Illinois River Energy Center

Prepared By:
Steffen Mueller, University of Illinois at Chicago,
Energy Resources Center
muellers@uic.edu
(Principal Investigator)

Ken Copenhaver, Institute for Technology Development
Michelle Wander, University of Illinois at Urbana-Champaign

Modeling support provided by:
Life Cycle Associates LLC

Prepared For:
Illinois Corn Marketing Board
David Loos
and
Illinois River Energy
Martha Schlicher

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Executive Summary

This study assessed the global warming impact (GWI) of ethanol produced at the Illinois River Energy ethanol plant (IRE) on a life cycle basis. IRE is located 80 miles west of Chicago. The plant currently produces 58 million gallon per year of ethanol with an expansion underway to double capacity.

The life cycle assessment includes the GWI contributions from corn agriculture, corn to ethanol conversion at the IRE biorefinery, distribution to the terminal, and combustion.
The analysis was performed using Argonne National Laboratory's GREET model with customizations based on different data sets:

1. We collected detailed data on agricultural practices within the corn draw area around IRE. A survey was conducted with 29 corn growers supplying 2,528,850 bushels of corn to IRE or 12% of all delivered bushels (representative of about 6.9 million gallon of ethanol production). The survey assessed key agricultural variables including fertilizer application rates, tractor fuel use and other on-farm fuel consumption, and yields.

2. Using the USDA NASS Cropland Data Layer (developed from satellite imagery) combined with the National Land Cover Dataset we determined the crop rotations and land use changes (including land conversions from non agricultural uses) within the IRE corn draw area.

3. From a literature survey we determined different methodologies that account for the nitrogen and carbon adjustments from land use changes. Based on these methodologies we determined nitrogen emissions and carbon sequestration rates for the IRE corn draw area.

The three data sets were used to parameterize GREET. The results show that IRE produced corn ethanol has a substantially lower GWI of 54.8 g CO_2e/MJ than the current GREET default value for corn ethanol of 69.1 g CO_2e/MJ (a 21% reduction). This reduction is primarily due to higher corn yields, reduced on-farm energy consumption, and reduced energy consumption at the biorefinery. Compared to gasoline, the GWI of IRE corn ethanol is 40% lower (54.8 g CO_2e/MJ vs. 92.1 g CO_2e/MJ for gasoline). These results exclude the impact from indirect and international land use changes. Including the current GREET default factor for land use change would increase the GWI of IRE ethanol by 0.7 g CO_2e/MJ to 55.5 g CO_2e/MJ.

IRE is currently exploring advanced technologies that may further reduce the GWI of its ethanol product including corn fractionation and a digester to offset natural gas consumption with biogas. The results also indicate that if advanced agricultural management practices such as no-till and winter crops were promoted, the GWI of IRE corn ethanol could drop to as low as 41.4 g CO_2e/MJ or a 55% reduction from gasoline.

Finally, the study finds a much lower on-farm energy consumption of 7,855 Btu per bushel for IRE supplied corn than the current GREET default value of 22,500 Btu per bushel (representing US national average). The large difference should prompt a reassessment of GREET's agricultural energy default value.

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Introduction

This study assessed the global warming impact (GWI) of ethanol produced at the Illinois River Energy ethanol plant (IRE) on a life cycle basis. The life cycle assessment includes the GWI contributions from corn agriculture, corn to ethanol conversion at the IRE biorefinery, distribution to the terminal, and combustion. The analysis was performed using Argonne National Laboratory's GREET model. The GREET model was customized using data collected from a survey on agricultural practices around the IRE plant, an assessment of crop rotations using satellite imagery, and an assessment of N_2O emissions and carbon sequestration processes based on published literature. The individual data sets and the GREET modeling approach are detailed in this report.

1. Survey Data

1.1 Survey Variables

The survey instrument (see Appendix A) was designed to explore agricultural practice variables included in global warming impact (GWI) assessments. The survey instrument was designed by IRE plant personnel and reviewed by representatives from the Illinois Corn Growers Association and the University of Illinois at Chicago.

The survey asked each respondent a total of 12 questions, grouped into three types in the following order on the survey instrument.

Type A: Agricultural Productivity Variables
These types of variables explore the acreages planted, the crop rotations, and the current and historical yields. For the purpose of a GWI assessment these variables are particularly relevant in an assessment of the direct and indirect emissions from land use change.

Type B: Corn Cultivation Practices
These types of variables assess the tillage practices and agricultural chemical use (fertilizer pesticide, fungicide) as well as the type of corn traits planted. The GWI varies with agricultural practices since, for example, conservation tillage allows for more carbon sequestration in the soil. The types and amount of agricultural chemicals are important since the different chemical compounds applied to the land not only require significant amounts of energy during their production process (a contributor to GWI) but these chemicals may also be greenhouse gases themselves or transform into a greenhouse gas. For example, nitrogen in the fertilizer is transformed into the powerful greenhouse gas nitrous oxide.

Type C: Farm Energy Use
These types of variables explore the fossil fuel consumed by each grower for corn planting, harvesting and transportation to IRE as well as that used for corn drying. The fossil energy used for these purposes is a direct contributor to the GWI of biofuels.

1.2 Survey Sample Frame

IRE has a database of all growers delivering to the ethanol plant. To assure that growers from each county would be selected a stratified random sampling process by county was employed.

A pre-test of the survey instrument was performed during a growers meeting at the IRE plant on March 26, 2008. About 20 growers attended the meeting. The feedback obtained on the survey instrument at the growers meeting was incorporated into the actual survey instrument.

1.3 Survey Response Characteristics

During the time frame of March 2007 through February 2008 a total of 272 growers delivered directly to IRE. Grower direct delivered corn accounts for about 75% of IRE's total corn feedstock of 20,450,000 bushels. The remainder is sourced from grain elevators. Tracing the agricultural practices of corn from grain elevators is difficult due to the mixing of corn from many farmers at these facilities. Therefore, only the agricultural practices of corn directly delivered to the facility by growers was assessed.

The survey was sent out by mail to a total of 100 growers. The following "response facilitators" were incorporated into the survey to increase response rates: a) the survey was sent out with a personalized cover letter, b) a return postage envelope was provided, and c) a prior request to fill out the mailed survey was made by email and/or a telephone call. In addition, about 25% of the surveys were completed during follow up telephone calls and direct visits with the individual growers. Out of the 100 mailed surveys 31 surveys were returned resulting in a response rate of 31%. Two of the returned surveys had to be excluded: one was missing basic classification information (in this case the total amount of delivered bushels), the other respondent did not deliver corn to IRE during the time frame.

The 29 returned survey respondents delivered 2,528,850 bushels to IRE or 12% of all delivered bushels (representative of about 6.9 million gallon of ethanol production). Individual survey respondents delivered between 8,000 to 355,000 bushels. The respondent with the largest delivery (355,000 bushels) accounts for 14% of the surveyed quantity of corn. This relatively low number assures that no individual survey can introduce a significant bias to the survey results based on size of bushels delivered.

One survey question asked the respondents in which county/counties they grow corn. Figure 1 below shows the results. As can be seen growers from all surrounding counties responded to the survey, as would be expected from a stratified random sampling procedure.

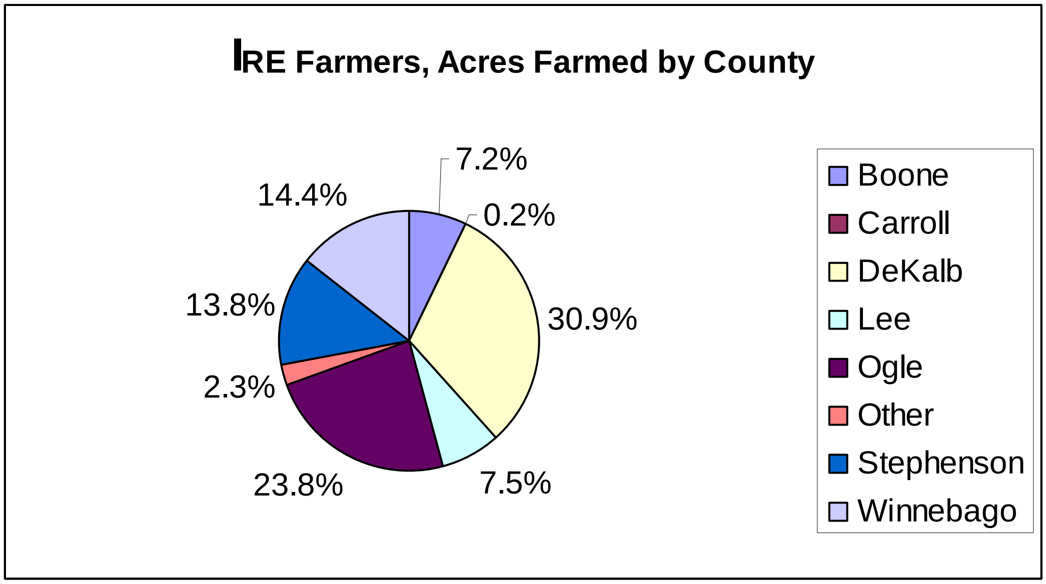

Figure 1: Survey Responses by County

2 Survey Data Analysis

The data obtained from the survey instrument is analyzed below.

2.1 Yield

The survey respondents report steady average yield increases between the 2005, 2006, and 2007 growing seasons. Table 1 and Figure 2 below summarize the results. Yields in 2007 at 196.1 bushels per acre are on average 17% higher than those in 2005. The consistent standard deviations indicate that no single farmer introduced a significant bias in any one year.

Table 1: Surveyed Yields

	2005 Bu/acre	2006 Bu/acre	2007 Bu/acre
Yield	167.4	183.1	196.1
STD	23.3	23.3	19.5
N=28			

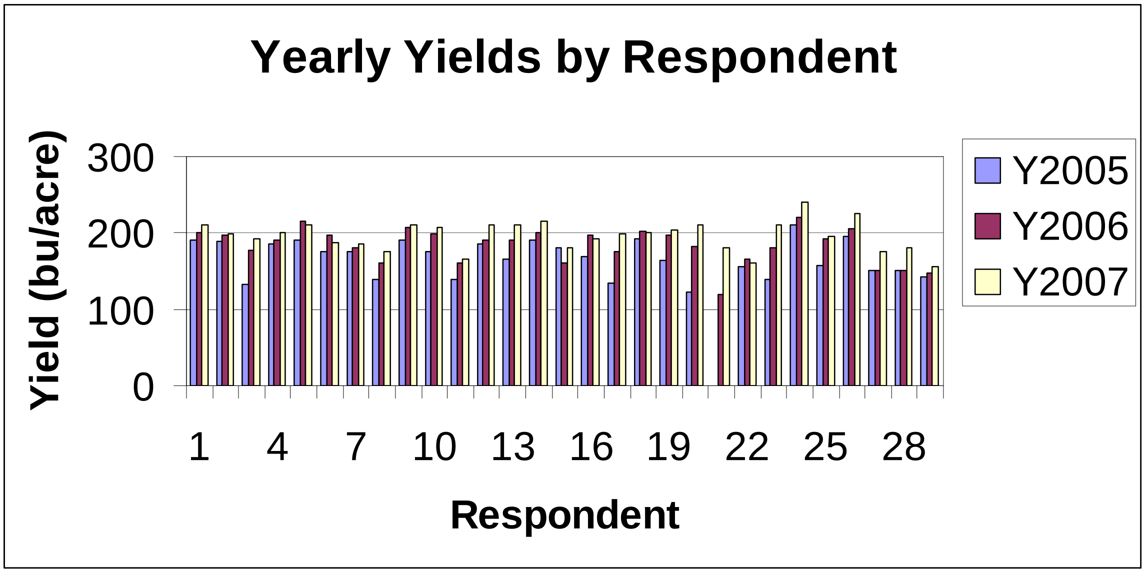

Figure 2: Yields by Respondent

2.2 Tillage Practices

The respondents were asked whether they employ a) conventional tillage, b) minimum tillage, c) no till, or d) strip till. The tillage methods differ by the amount of biomass left above ground: Conventional tillage leaves less than 10% of biomass above ground, minimum till leaves 30% above ground, strip till about 70-80%, and with no till about 90% of the biomass remains on top. Applying the surveyed percentages of practiced tilling to the amount of corn delivered to IRE results in a conservation tillage rate (generally defined as no-till plus strip till) of 13%. The results are shown in Figure 3. The analysis assumes that farmers apply the same tillage practices to all of their farm land including land used for IRE production.

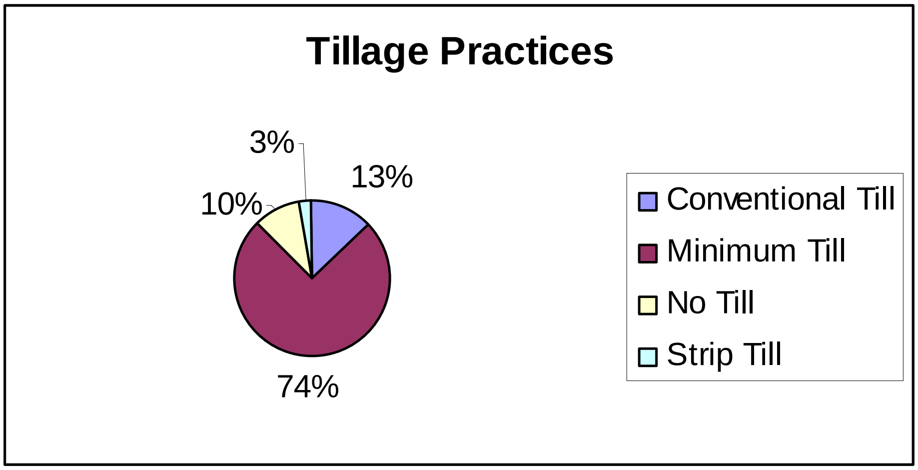

Figure 3: Tillage Practices around IRE

Note: Graph is based on 2,478,850 delivered bushels. One farm did not report tillage practices

The survey also asked respondents about the number of tractor trips made each year across the field. Table 2 below indicates that the till practices correlate with the reported tractor trips across the fields.

The respondents that utilize majority no till reported on average fewer tractor trips (4.7) than those employing conventional till (6.1 tractor trips). Note that these values are based on relatively few respondents.

Table 2: Tractor Trips and Tillage Practices

	Conventional Till Tractor Trips	No-Till Tractor Trips
Mean	6.1	4.7
STD	1.9	1.2
N=	8	19

2.3 Corn Transportation to IRE

On average corn is transported 29.5 miles one-way by truck to the plant. While the survey instrument asked for the one-way hauling distance to IRE we suspect that some respondents may have answered this question on a per trip- or round trip-basis. For example, one grower reported a 90 mile one-way transportation distance that is likely a round trip distance based on the indicated farmed counties. The stated fuel economy is also very low at 3.4 miles/gallon. While surveyed transportation distances are high and the fuel consumption is likely low, no adjustments to the data was made as a conservative measure.

Table 3: Corn Transportation

	Transportation Distance to IRE	Corn Transportation Fuel Consumption
Mean	29.5	3.4
STD	21.6	1.5
N=	29	9

2.4 Fertilizer Program

The survey asked respondents what type of fertilizer products they use. Table 4 shows the results.

Table 4: Type of Fertilizer Product Used

	Nitrogen as NH_3	Nitrogen as 28%	Nitrogen as 32%	N-P-K as 18-46-0	N-P-K as 0-46-0	N-P-K as 0-0-60	Ammonium Sulfite	Ag-Lime
Number of Growers	17	5	13	14	6	21	1	8
N=27								

All surveyed growers apply nitrogen fertilizer to the crop. The most common form of nitrogen fertilizer used is in anhydrous form as NH_3 (ammonia). Some growers use 32% liquid N fertilizer and 28% liquid N fertilizer, often in combination with NH_3.
On average 368 g/bu of nitrogen are applied. Where growers apply nitrogen via a combination of NH_3, 28%, 32%, or 18-46-0 the total amount of N is calculated based on the mass fraction of N.[1]

Table 5: Nitrogen Application

	lb/acre	g/bu
Mean	159	368
STD	40	90
N=27		

Most growers also apply phosphorus and potash nutrients to the crop using 18-46-0 and 0-0-60 fertilizer and respectively. Some growers also use 0-46-0 for phosphorus applications. Table 6 below shows the application rates for phosphorus. Rates are consistent with the U of I Agronomy Guide.

Table 6: Phosphorus Application

	lb/acre	g/bu
Mean	64	147
STD	51	109
N=26		

Note: 5 respondents do not apply P

Table 7 below shows the potash application rates.

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[1] The correlation coefficient between N applied and yield was calculated. At -0.12 the correlation coefficient is weak. The negative sign may indicate that further N application may not increase yield. However, the study design and collected data is likely insufficient to perform a yield response analysis.

Table 7: Potash Application

	lb/acre	g/bu
Mean	118	278
STD	72	164
N=26		

Note: 3 respondents do not apply K

Only 8 growers reported the application of lime on an “as needed” basis. Based on the assumption that farmers apply lime one in five years, we divided the value by 5 and assume that this amount is used for all acres within the area of concern. The reported lime application rates are likely of low reliability.

Table 8: Agricultural Lime Application

	lb/acre	g/bu
Mean	449	1,095
STD	1297	3268
N=27		

Note: 21 respondents do not apply lime

2.5 Corn Trait Selection

Another survey section assessed the growers’ corn trait selection. Respondents indicated that the vast majority of delivered bushels have genetically enhanced organisms (GEO) traits (89%) and the vast majority of GEO corn is triple stack type. Figure 4 below indicates the make up of the corn trait by bushel.

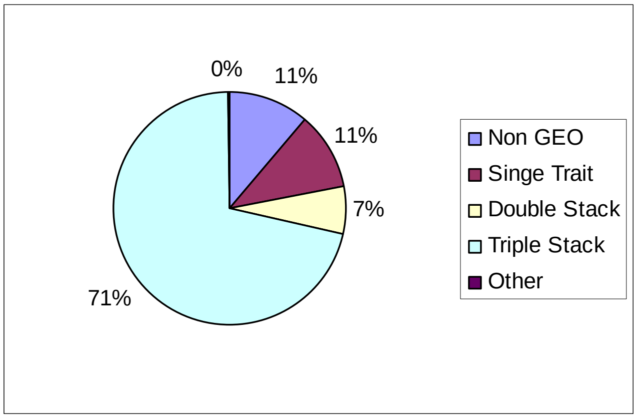

Figure 4: Corn Trait Selection of Farmers Supplying to IRE
Note: N=27

2.6 Insecticide and Herbicide Programs:

This section of the survey asked about the insecticide and herbicide program employed by growers. Aztec (tebupirimphos and cyfluthrin) and Roundup (glyphosate) are the most commonly used insecticides and herbicides, respectively. The application rate for insecticides ranges from 4 to 8.5 lbs per acre. The rate for herbicides ranges between 2-4 quarts. These values were not statistically evaluated.

2.7 Corn Drying

The majority of respondents (26 out of 29) indicated some form of propane or natural gas drying. However, the dataset was difficult to evaluate since some stated the propane/natural gas cost and some stated the total use in gallons. For the purpose of this study the respondents that stated the use in gallons were evaluated and the mean gal/bu was calculated. The results are shown in Table 9 below. The derived number was supported by an additional, in person, interview with an IRE corn grower. The calculation assumes that corn delivered to IRE is treated the same as corn handled for other markets. In a separate personal conversation with a corn grower delivering to IRE it was pointed out that IRE may have a slightly stricter standard for accepting partially dried corn than other markets. The average gallons of fuel for drying are shown in Table 9 below.

Table 9: Fuel Consumption for Corn Drying

	gal/bu
Mean	0.029
STD	0.012
N=6	

Electricity is also used during the drying process primarily to run fans and pumps. Table 10 below lists the average use of electricity reported by the respondents. Note that electricity use was surveyed on a cost basis and converted to kWh based on an assumed rate of $0.1/kWh.

Table 10: Electricity Consumption for Corn Drying

	kWh/bu
Mean	0.31
STD	0.29
N=8	

2.8 Growing Cycle Fuel Use

Growing cycle fuel use falls into three categories: fuel used by the grower in tractor trips across the field, fuel used by contractors (referred to as custom machine hire) and for hauling corn back to the farm. Table 11 below shows the fuel used by the grower.

Table 11: Grower Fuel Use

	gal/acre	gal/bu
Mean	5.5	0.028
STD	2.2	0.011
N=18		

In a second analysis of grower fuel use the correlation coefficient between surveyed fuel consumption and the surveyed number of trips was calculated. While the coefficient is weak at 0.35 it is positively correlated meaning that, as expected, fuel consumption increases with increasing number of trips.

Custom machine hire varies by task. Table 12 below shows the percent of acres that farmers hire out by task. Fertilizer and pesticide applications are contracted out the most.

Table 12: Custom Machine Hire by Task

	Fertilizer Application	Pesticide Application	Combining of Crop	Crop Hauling
Mean	55.8%	28.0%	14.3%	16.9%
STD	48.0%	53.6%	33.1%	37.2%
N=24				

The fuel consumption for custom machine hire is calculated by first calculating the value of fuel consumption per custom machine hire trip. This value is derived by dividing the total fuel consumption per bushel in Table 11 above by the number of trips across the field. Then, the ratio of custom farmed acres to total farmed acres for each farm is calculated and multiplied by the gal/bu/trip to derive the gal/bu of custom machine hire for each type of machine hired. This value assumes that the acres dedicated to IRE corn farming are treated the same as the rest of the farm acres. The results are shown in Table 13 below.

Table 13: Fuel Consumption for Custom Machine Hire

	Fertilizer Application (gal/bu)	Pesticide Application (gal/bu)	Combining of Crop (gal/bu)	Crop Hauling (gal/bu)	Total Custom Machine Hire (gal/bu)	Total Custom Machine Hire (Btu/bu)
Mean	0.0026	0.0024	0.0012	0.0011	0.0073	933
STD	0.003381	0.005616	0.002957	0.002878		
N=14						

The fuel share of grower fuel and custom machine hire is about 95% diesel and 5% gasoline.[2] Based on these fuel shares and the respective heating values for diesel and gasoline Table 13 also shows combined custom machine hire fuel consumption in Btu/bu.

Corn transportation from the field to the farm (input hauling) was not assessed in the survey. Based on a personal interview with a farmer delivering to IRE on average hauling will include a 5 mile trip (10 miles roundtrip) by truck.[3] Utilizing the above surveyed fuel economy of 3.4 miles/gallon and 950 bu/trip results in an adder of 0.003 gallons/bu or 384 Btu/bu (converted based on fuel shares and respective heating values, see above). This number can be considered conservative since it is a) based on a very conservative (high) truck fuel economy b) some farmers may deliver corn directly to IRE rather than first hauling it back to the farm.

2.9 Irrigation Energy Use

The respondents were asked about irrigation practices. None of the respondents indicated using any form of irrigation.

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[2] Personal conversation with Paul Taylor, Rochelle, IL

[3] Personal conversation with Paul Taylor, Rochelle, IL

3. Ethanol Plant Production and Logistic Data

The IRE ethanol plant started operation in December 2006. The plant utilizes a natural gas fired boiler for steam generation and natural gas fired rotary drum dryers. Table 14 below lists the plant production and logistics data for the first 12 months of operation at full capacity (March 2007 through February 2008).

The majority of whole stillage is converted and sold as DDGS, a small fraction of WDG is also sold. All of the DDGS is sold to Asia. The DDGS is sold via backhaul arrangements (if the containers were not loaded with DDGS they would likely go back empty). All corn is shipped to the ethanol plant by truck. Likewise, the majority of ethanol is shipped to the terminal by truck, a smaller fraction by rail. In March, IRE started selling E85 ethanol directly to a retail gas station approximately 10 miles away. The fraction of retail sales and associated logistics are not considered in this study.

Table 14: Ethanol Plant Production and Logistic Data

	Unit	Value
Plant Performance:		
Annual total anhydrous ethanol production	gallon per year	55,820,804
Annual total denatured ethanol production	gallon per year	57,812,280
Description of denaturant used (type)	Debutinized Natural Gasoline	
Average ethanol yield per bushel (anhydrous)	gal/bu	2.73
Plant Energy Systems:		
Annual total natural gas consumption HHV	Btu	1,671,765,900,000
Annaul total electricity consumption	kWh	39,898,320
Natural Gas (HHV) per unit Anhydrous Ethanol Production	Btu/gal	29,949
Natural Gas (HHV) per unit Denatured Ethanol Production	Btu/gal	28,917
Natural Gas (LHV) per unit Anhydrous Ethanol Production		26,981
Natural Gas (LHV) per unit Denatured Ethanol Production		26,051
Electricity per unit Anhydrous Ethanol Production	kWh/gal	0.71
Electricity per unit Denatured Ethanol Production	kWh/gal	0.69
By-Products:		
Annual total DDGS production	tons	153,213
Annual avg DDGS moisture	%	11
Annual total WDG(S) production	tons	13,488
Annual avg WDG(S) moisture	%	30

Annual total S production - as product sold	tons	5,036
Annual avg S moisture	%	60
Transportation Logistics:		
Corn by truck	%	100
Corn by rail	%	0
DDGS shipments by truck	%	Backhaul Shipment
DDGS shipments by rail	%	Backhaul Shipment
DDGS shipments by ship	%	Backhaul Shipment
WDGS shipments by truck	%	100
Ethanol shipments by truck	%	98
Ethanol shipments by rail	%	2
Ethanol shipments by barge	%	0
Avg ethanol distance transported by truck (per trip - one way)	mi	80
Avg ethanol distance transported by rail (per trip - one way)	mi	1,000
Avg ethanol distance transport from terminal to retail outlet (per trip one way)	mi	10

4. Global Warming Impact Modeling of IRE Corn Ethanol Using the GREET Model

The agriculture on-farm energy assumptions in the current GREET 1.8b version are based on USDA data collected in 1996 (Shapouri, Duffield et al. 2002). Although more recent data has been collected by the same group and summarized based on 2001 USDA surveys GREET has not been updated to reflect the newer data (Shapouri, Duffield et al. 2004). Instead, it appears that adjustment factors to the 1996 data set were applied to derive the current GREET on-farm energy value of 22,500 Btu/bu. Yield and fertilizer inputs are updated frequently: GREET 1.8b yield and fertilizer data is based on 2006 USDA statistics.

For this analysis, the agricultural energy input tables for both USDA data sets (1996 and 2001) were recreated to allow substitution with surveyed IRE corn agriculture values. The results are shown in Table 15. The fist and third columns show the average corn farming values for the state of Illinois and the United States from the 1996 USDA data set, respectively. Substituted IRE surveyed data are shown in bold in the second column. As can be seen a much higher yield of 196.1 bu/acre was substituted for the 126 bu/acre published in the IL-1996 data set and the 125 bu/acre in the US average-1996 data while nitrogen application rates per acre are similar for IRE compared to Illinois average (159 vs 160 lbs/acre). Also, diesel and gasoline consumption at 5.5 gal/acre for IRE corn agriculture are lower than the Illinois average of 10 gal/acre. The default values for LPG, electricity, and natural gas from the USDA Illinois average were used since the survey results for these data points are less reliable.[4] This is also the case for agricultural lime application (not shown). In summary the overall IRE corn agriculture energy consumption is much lower at 7,855 Btu/bu than Illinois average 18,230 Btu/bu and US average 23,075 Btu/bu for US average.

The fourth column shows the updated farming energy assumptions (USDA 2001 data) resulting in already substantially lower energy assumptions (16,176 Btu/bu) than currently used in GREET (22,500 Btu/bu). Substituting IRE surveyed values into this template results in IRE agricultural energy consumption of 7,192 Btu/bu.

Table 15: IRE and USDA Agriculture Parameters

Corn Farming Energy Inputs		**IL Avg**	**IRE Avg**	**US Avg**	**US Avg**	**IRE Avg**	**GREET 2010**
Data Source:		**1996 USDA**	**1996 USDA**	**1996 USDA**	**2001 USDA**	**2001 USDA**	**1996 USDA Mod**
Yield	bu/acre	126.0	**196.1**	125.0	139.3	**196.1**	158
Seed	kernels/acre	25384.0	*25384.0*	25495.0	28739.0	28739.0	
Fertilizer:							
Nitrogen	lb/acre	160.0	**159.0**	129.4	133.5	**159.0**	146
Potash	lb/acre	102.0	**118.0**	59.3	88.2	**118.0**	51
Phosphate	lb/acre	71.0	**64.0**	48.2	56.8	**64.0**	62
Energy:							
Diesel	gal/acre	7.0	**5.2**	8.6	6.9	**5.2**	
Gasoline	gal/acre	3.0	**0.3**	3.1	3.4	**0.3**	
LPG	gal/acre	5.0	*5.0*	6.4	3.4	3.4	
Electricity	kWh/acre	15.0	15.0	77.1	33.6	33.6	
Natural gas	cu ft/acre	150.0	150.0	200.0	246.0	246.0	
Custom work	Btu/bu	3146.0	**933.0**	3366.0	1581.0	**933.0**	
Input hauling	Btu/bu	920.0	**384.0**	663.0	202.0	**384.0**	
Conversions to Btu/bu (LHV)							
Diesel	Btu/bu	7,136	3,422	8,837			
Gasoline	Btu/bu	2,764	163	2,870			
LPG	Btu/bu	3,371	2,166	4,322			
Electricity	Btu/bu	406	261	2,105			
Natural Gas	Btu/bu	1,170	752	1,573			
Custom work	Btu/bu	2,662	789	2,848			
Input hauling	Btu/bu	721	301	520			
Total Ag Energy (LHV)	Btu/bu	18,230	7,855	23,075	16,176	7,192	22,500

The agricultural on-farm energy consumption values were combined with the plant energy consumption at IRE and the ethanol yield. The IRE plant energy consumption totals 26,989 Btu/gal (LHV) from natural gas and 2,423 Btu/gal from electricity (0.71 kWh/gal) for a total of 29,404 Btu/gal. The GREET default value is 35,889 Btu/gal. The ethanol yield at IRE is 2.73 gal/bu compared to the 2.72 gal/bu GREET default value.

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[4] Electricity and natural gas use for corn drying reported in the IRE survey is based on low respondent number.

The corn transportation distance was set to 30 miles (50 miles default value) and the surveyed IRE transportation distance from the plant to the bulk terminal at 80 miles was identical to the GREET default value.

The different agricultural energy input values as well as IRE plant energy consumption values were used to parameterize GREET. Modeling was performed with support from Life Cycle Associates using a macro tool that allows to substitute selected values in GREET and collect the GREET results into a separate spreadsheet. The advantage of this approach is that all parameters are replaced at once eliminating the error potential from forgetting to set/reset certain GREET values manually. The modeled cases are shown below. Figure 5 and Table 16 below show the results. For each case the individual GWI components from nitrogen fertilizer application, the GWI contribution from the ethanol plant energy consumption, and the remaining GWI contributions (remaining agricultural energy consumption, distribution, denaturant) are shown. The modeled cases do not include the relatively small GREET default factor for GWI emissions from land use change associated with corn ethanol production. This factor in GREET is less than 1 g/MJ. Land use change issues are discussed separately in this report.

IRE Case #1: This case represents the agricultural energy consumption detailed in Column 2, Table 15. In essence, this can be viewed as substituting current GREET derived agricultural input assumptions with IRE surveyed data including IRE plant energy consumption data. Total GWI for this case is 54.8 g CO_2e/MJ.

IRE Case #2: This case represents agricultural energy consumption detailed in Column 5 (IRE surveyed data substituted into the USDA 2001 template). As can be seen, the results are very close to Case #1 indicating that IRE surveyed data displaces a significant part of the original agricultural data sets. The GWI for this case is 54.5 g CO_2e/MJ.

IRE Case #3: This is a sensitivity case to Case 1 substituting the default Illinois SERC electricity region for the Exelon Generation dominated northern Illinois electricity grid to which IRE connects.[5] As can be seen the nuclear dominated northern Illinois grid results in a lower GWI of 46.7 g CO_2e/MJ.

GREET Agriculture Default with IRE Plant Energy Consumption: This case models the current GREET agriculture default values with the IRE plant energy consumption. The total GWI of this case is 60.8 g CO_2e/MJ.

GREET Agriculture Default with GREET Plant Energy Consumption: This models the current GREET agriculture default values (22,500 Btu/bu) with the current GREET natural gas fired default ethanol plant (33,330 Btu/gal from natural gas and 2559 Btu/gal

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[5] Electricity Mix

Fuel	Oil	Natural Gas	Coal	Nuclear	Biomass	Total
IL SERC	1.8%	10.0%	57.3%	25.2%	1.9%	96.2%
Exelon (IL)	2.4%	5.5%	2.8%	88.2%	0.0%	98.9%

Source: eGrid

from electricity for a total of 35,889 Btu/gal). According to GREET, these values are considered representative of current US corn ethanol production from dry mill plants.

<u>Gasoline:</u> For comparison purposes the GWI of CA reformulated gasoline is listed. In summary the GWI for IRE produced corn ethanol is lower than the GREET default value of 92 g CO_2e/MJ.

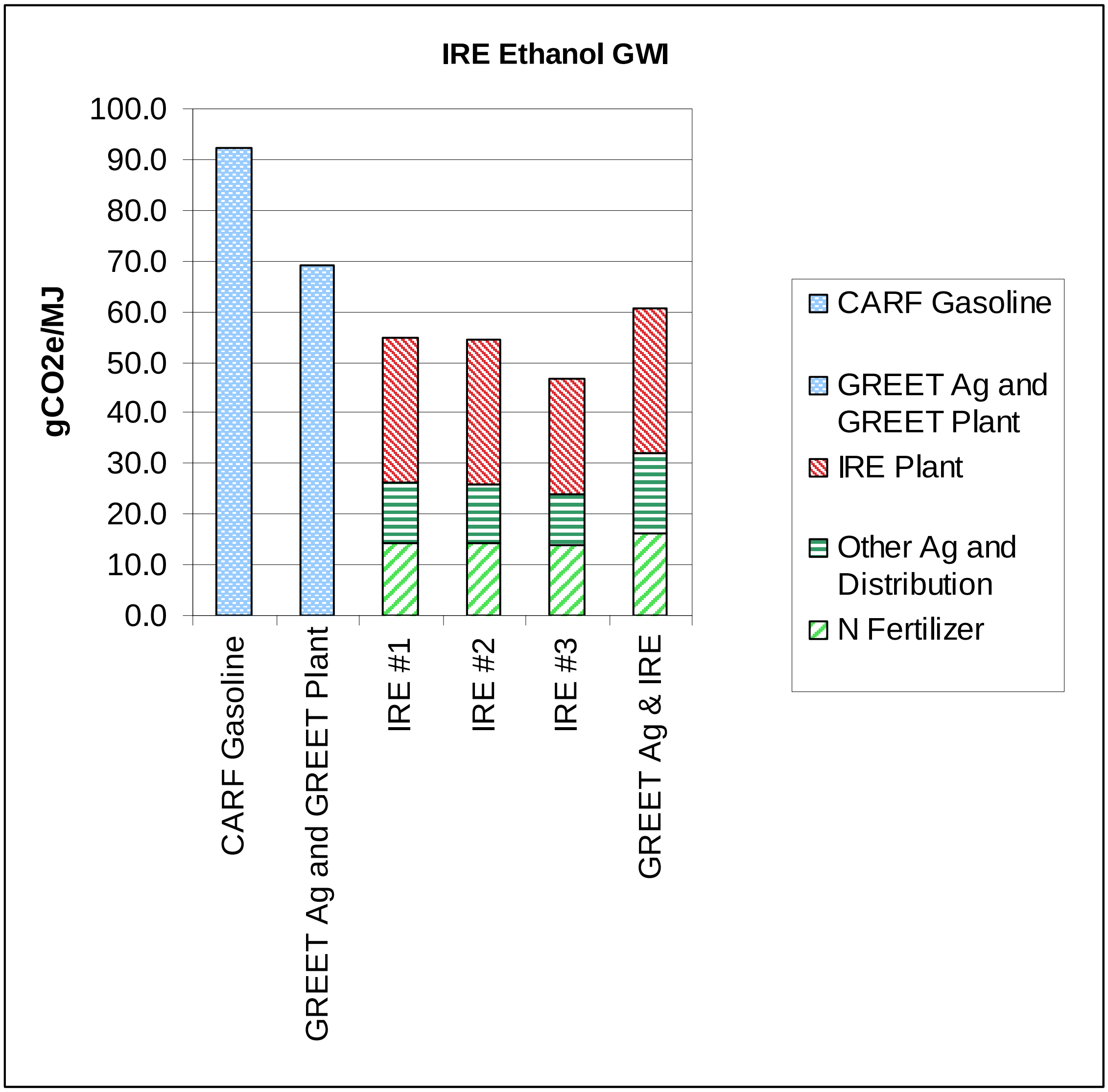


Figure 5: IRE Ethanol GWI

Cases

- Gasoline
- GREET Agriculture Default with GREET Default Plant Energy Consumption
- GREET Agriculture Default with IRE Plant Energy Consumption
- IRE Case #1: Substituting GREET derived ag. inputs (USDA-1996 template) with IRE Survey
- IRE Case #2: Substituting USDA-2001 template with IRE Survey
- IRE Case #3: Sensitivity to Case 1. Substituting Illinois SERC grid for northern Illinois grid

Table 16: IRE Ethanol GWI

	CARF Gasoline	GREET Ag and GREET Plant	IRE #1	IRE #2	IRE #3	GREET Ag & IRE
			GWI (g/MJ)			
N Fertilizer			14.2	14.2	13.9	16.3
Other Ag and Distribution			11.9	11.6	9.9	15.8
IRE Plant			28.7	28.7	22.9	28.7
GREET Ag and GREET Plant		69.1				
CARF Gasoline	92.1					
Total GWI:	92.1	69.1	54.8	54.5	46.7	60.8
Red. GREET Default:			-20.7%	-21.2%	-32.4%	-12.0%

In summary IRE ethanol offers significantly reduced life cycle global warming emissions compared to the current GREET default values for current US average corn ethanol. Depending on the assumptions GWI reductions range between 21% to 32%.
The key components contributing to the GWI reduction are high prevailing yields resulting in reduced nitrogen application rates (368 vs 420 gN/bu), reduced agricultural energy consumption in IRE’s corn draw area (5.5 gal/acre vs. >10 gal/acre), lower custom work and input hauling energy consumption, and lower ethanol plant energy consumption (29,404 Btu/gal vs. 35,889 Btu/gal, LHV inclusive of electricity).

5. Land Use Emissions and Carbon Sequestration

The GWI results from ethanol life cycle analyses depend on system boundaries, input parameters, modeling scope, and other factors. Recent ethanol life cycle studies have expanded the boundaries and have included the impact of international land use as well as the impact of secondary agricultural sector GWI impacts from increased ethanol production such as changes in livestock emissions due to changes in agricultural commodity prices (Searchinger, Heimlich et al. 2008), (Fargione, Hill et al. 2008). These studies incorporate one or a combination of several models including the U.S. Forest and Agricultural Sector Optimization Model (FASOM), the Food and Agricultural Policy Research Institute (FAPRI) modeling system, or the Global Trade Analysis Project (GTAP) model. The accuracy of GWI analyses that rely on these models is only as good as the statistical summary data going into these models.

The present ethanol GWI study does not take international land use data or agricultural commodity prices into account but instead correlates very localized data sets that include in-ground measurements, a survey with growers, and local remote sensing data. More specifically, the present study looks at the GWI contributions to corn ethanol produced at the IRE ethanol plant from N_2O emissions and soil carbon sequestration.

N_2O emission and soil carbon sequestration rates depend largely on land management practice and geographic region. We have compiled a very detailed data set to account for the influence of these variables:

- We used USDA satellite data to determine the crop and land use practices in the vicinity of the ethanol plant.
- From the survey of growers delivering corn to IRE we have data on actual applied nitrogen fertilizer rates and derived yields.
- From the survey we have also land management data and, in particular, the practiced type and share of conservation tillage.
- We have actually measured carbon sequestration rates for soils within the IRE corn draw area.

5.1 Land Use Rotations Within the IRE Corn Draw Area

N_2O emissions and carbon sequestration of soil depend on the current and historic land use. This section assesses the land use within the IRE corn draw area. The derived land use pattern is representative of the acres used for IRE corn supply.

The land use change for a particular parcel of land can be determined by either using remote sensing (via satellite data) or by conducting a census. The Farm Services Agency does indeed conduct a census and assesses the land use for each field. However, this data is not publicly available. Therefore, this study used remote sensing.

The first step in the process was to create a draw area boundary for the Rochelle ethanol plant. This was performed in ArcGIS. Using the address for the ethanol plant as the center point, a circle with a 40 mile radius was developed as a geographic information system (GIS) polygon file (see Figure 6). This circle represented the approximate draw area for corn required for the production of ethanol by the plant for one year.

The second step of the analysis combined USDA NASS Cropland Data Layer with the polygon file. The USDA NASS Cropland Data Layer is a spatial crop type map developed from satellite imagery. Classification of all land other than crop was performed using the national land cover dataset which was developed in 2001 also using remote sensing via satellite. (Homer 2007).

In the third step of the analysis the crop types were extracted for the ethanol plant draw area using the 2005, 2006, and 2007 Cropland Data Layers. The analysis was performed to calculate the acres in corn in 2005, 2006, and the acres in corn in 2007. Next a model routine was created to determine the crop rotations (of each 30 square meter location). In contrast to the above analysis, the model allows a location specific correlation: what was the specific land use of one particular acre in 2005 and 2006 (as opposed to how did the land use change within a masked area analyzed above). The results showed that the total area in corn within the corn draw circle in 2007 totaled 1,487,560 acres. The crop rotations by percent acreage are shown in Figure 7. All land use changes aside from corn and soy are summarized into the “diversified” category. As can be seen, the crop rotations are dominated by corn-soy-corn (33%) followed by corn-corn-corn (24%).

The study found that the “diversified” area (land use changes from non-crop land such as pasture land, woodland, etc. to crop land) must be viewed with great caution. While the USDA Cropland Data Layer has been shown to have accurate methods of around 95% for the delineation of corn and soybeans (Johnson 2007) and that dataset is updated every year, the national land cover data set dates back to 2001 and introduces much higher uncertainties.

An analysis was performed to demonstrate this finding. As can be seen in Figure 8, according to USDA NASS approximately 30,000 acres would have gone from corn (in 2005) to “diversified” (in 2006) and back to corn (in 2007), an unlikely scenario. A more likely scenario in this case suggests that the land was consistently used for crop production. Therefore, the “diversified” data point must be viewed with caution and likely overestimates the conversion from non-cropland to cropland. This finding prompted the requisition of a separate study that specifically addresses the uncertainties associated with assessments of land use change given the currently available statistical data sets. The study will be released shortly. For the purpose of the present study, the derived acreage for the “diversified” category will be viewed as a conservative (overestimation) of non-cropland to cropland conversion. It follows that the carbon sequestration values based on this data and assessed in the next sections are therefore conservative and likely low.

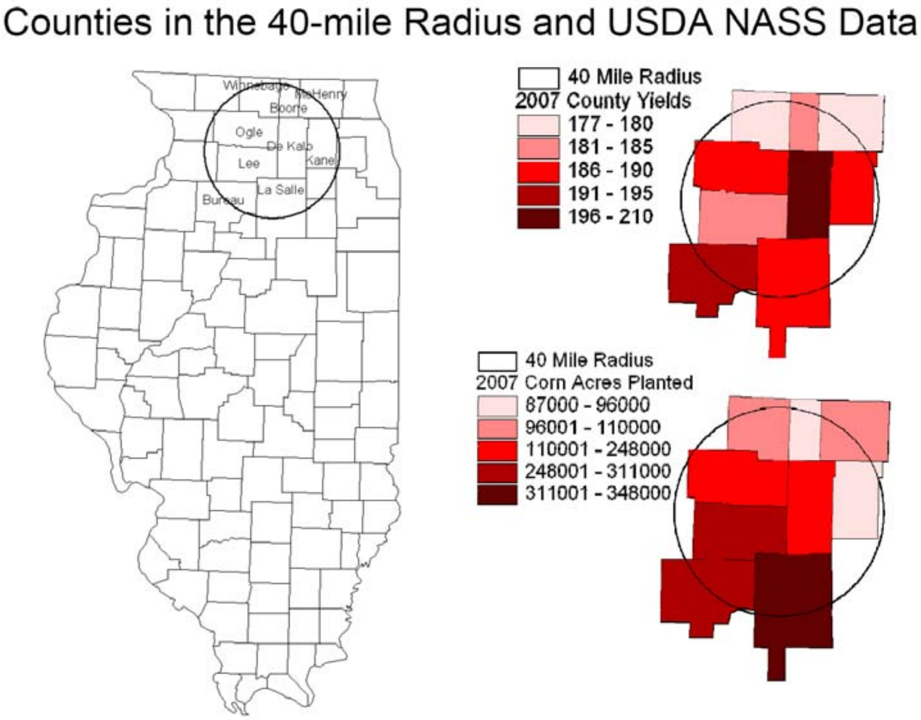


Figure 6: GIS Corn Draw Area

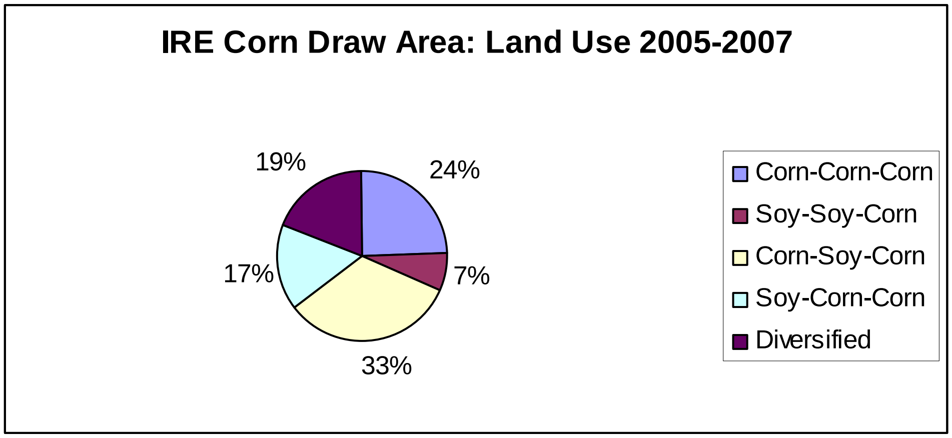
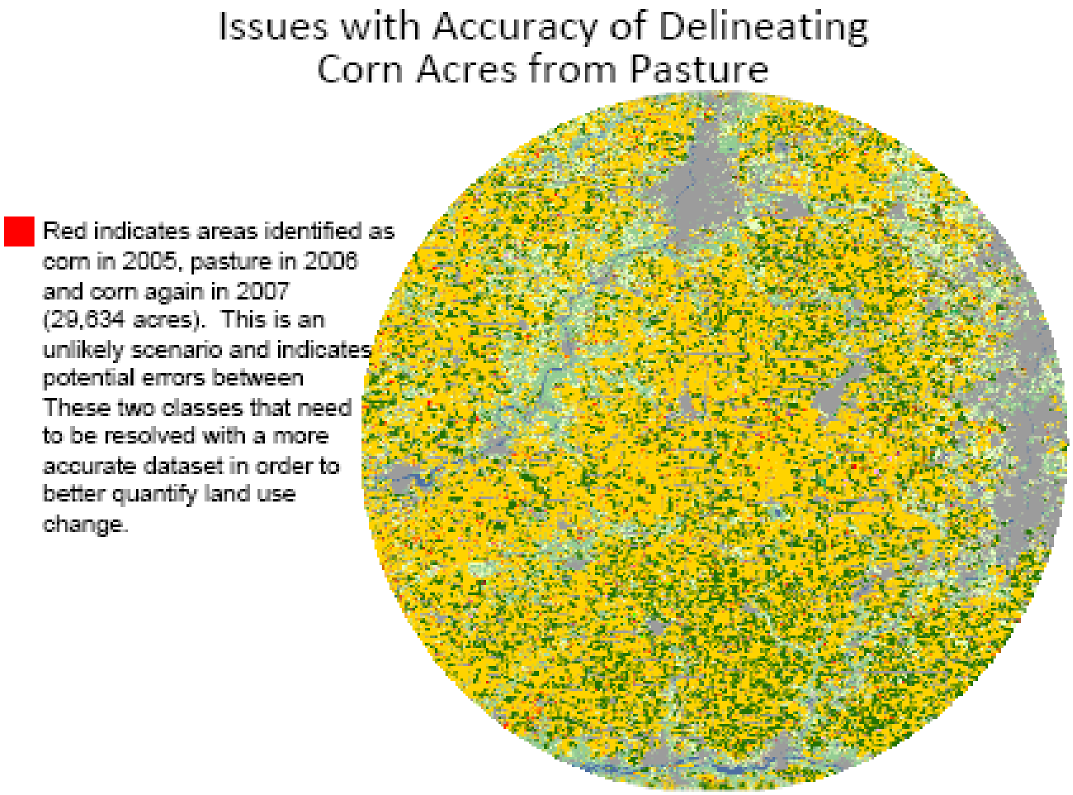


Figure 7: Crop Rotations by Percent of Acreage



Issues with Accuracy of Delineating Corn Acres from Pasture

🟥 Red indicates areas identified as corn in 2005, pasture in 2006 and corn again in 2007 (29,634 acres). This is an unlikely scenario and indicates potential errors between These two classes that need to be resolved with a more accurate dataset in order to better quantify land use change.

Figure 8: Accuracy of Delineating Corn Acres from Pasture

5.2 N_2O Emissions

The earth's atmosphere contains about 78% dinitrogen (N_2) (Mc Isaac et al, 2007). N fixation is the transformation of dinitrogen to biologically useful forms for organisms such as NH_3 (Hofstra and Bouwman 2005). Denitrification removes fixed N through microbial respiration when oxygen is limiting whereby N_2O production is a major by-product. The proportion of N denitrified as N_2O varies. Emphasis is placed on N_2O because it is a gas contributing to GWI where N_2 is not.

Denitrification is often difficult to measure in the field since one of the main end products, N_2, constitutes such a high percentage of the atmosphere and thus small changes in N_2 concentrations are hard if not impossible to detect (McIsaac 2007). Sampling is generally conducted with measurement chambers placed over the soil surface for a period of time or by taking a soil core sample back to the lab for evaluation of denitrification potential. Another method to assess denitrification is the N-balance approach. In the N-balance approach the inputs and outputs for a given area can be measured and denitrification is the unaccounted part of the equation (Hofstra and Bouwman 2005). The difficulty with the N-balance approach is that it is very complex to determine all sources and sinks thus introducing uncertainties. The denitrification amounts determined with these methods provide the data behind different models.

The IPCC (1997) Good Practice Amendment provides an emissions factor based model. In this model the calculation of N_2O emissions from crop production assumes that 1.25% +/- 1% of N inputs are lost from soil as direct N_2O emissions and 30% of applied N is leached or runs off into ground and/or surface waters contributing to indirect emissions (Del Grosso, Mosier et al. 2005). This modeling approach does not take into account detailed variations in agricultural system, crop types, climates, soil types and management practices. The GREET model is also based on an emissions factor approach.

In contrast, process based models such as DAYCENT attempt to account for these variables (Del Grosso, Mosier et al. 2005). Mummey et al using process-based modeling provides N_2O emission rates by crop rotation and management practices (till vs. no-till) (Mummey, Smith et al. 1998). Oftentimes, indirect effects are not included in process based models and must be added for comparison purposes with emissions factor based modeling results.

Using the land use management practices surveyed for the IRE corn draw area, we compare the sensitivity of these practices under two modeling approaches and actual measured N_2O emissions rates for Illinois soils.

5.2.1 GREET N_2O Emissions Calculations

As discussed above, GREET employs an emissions factor model based on IPCC. The current GREET Version 1.8b uses the following equation for N_2O emissions estimates from fertilizer application.

N_2O from nitrogen fertilizer, and above and below ground biomass =
(420 g/bu of N + 141.6 g/bu of N) * 0.01325 *44/28 = 11.7 g/bu

Where:

420 g/bu of N is the default value for N applied in fertilizer

141.6 g/bu of N is N content of above and below ground biomass (ie corn stover left on the field).

0.01325 is a factor for N in N_2O as fraction of N in N fertilizer and biomass. GREET assumes that 1.3% (including 0.2% from leaching) of the available N is converted to N in N_2O.

44/28 is the mass fraction of N_2O and N_2 in the molecule

Substituting the GREET default value of 420 g/bu of N applied in the above equation for the actual N application rate of the IRE corn draw area of 368 g/bu from the survey, we calculate N_2O emissions of 10.6 g/bu. This is a 10% reduction from the GREET default value of 11.7 g/bu.

GREET implicitly assumes that the N_2O conversion rate is relatively constant among different nitrogen sources (eg fertilizer, soil material, etc.). Process models such as the one used by Mummey et al attempt to control for these additional variables.

5.2.2 N_2O Emissions According to Mummey et. al

The amount of N_2O released from agriculture depends on different factors including tillage practices and crop rotations. Mummey et al used a process based modeling approach to control for these variables. Mummey points out that in most soil types N_2O emissions may actually increase with low tillage practices primarily due to the higher moisture levels. Mummey's emissions factors are reproduced in Table 17 (Mummey, Smith et al. 1998).

Table 17: N_2O Emission Factors by Mummey et al

	CSC and SSC kg N_2O-N/ha per y	SCC and CCC kg N_2O-N/ha per y	Diversified kg N_2O-N/ha per y
Conv.Till	3.7	2.9	4.8
No Till	4.2	3.6	4.6

The N emissions factors listed in Table 17 were applied to the surveyed tillage practices to derive a blended N emissions factor by crop rotation for the IRE corn draw area. Then, the N emissions factors by crop rotation were applied to the number of acres in that particular crop rotation that supply corn to IRE to derive N emitted per year.
The results indicate that based on the crop rotations and other land use changes (pasture land to corn), the acres that deliver corn IRE may emit approximately 154 metric tons of N_2O-N per year and based on the surveyed yield or 7.5 g/bu N_2O-N (direct and indirect emissions).

The Mummey et al factors only take direct dinitrification effects into account. Applying an additional 30% indirect denitrification factor results in total N_2O emissions of 15.4 g/bu. These emissions are substantially higher than the GREET derived emissions. However, one must be careful. While these factors take IRE corn draw area rotation and tillage practices into account, these factors do not account for other IRE conditions (including the actual soil type and fertilizer application rates). The results do indicate however the range of possible N_2O emissions estimates under different assumptions.

Table 18: N_2O Emissions of IRE Corn Acres According to Mummey Factors

		CSC/SSC	SCC/CCC	Diversified
N-Emissions Factors		kg N_2O-N/ha per year	kg N_2O -N/ha per year	kg N_2O-N/ha per year
Conventional Till		3.7	2.9	4.8
No Till		4.2	3.6	4.6
Surveyed Tillage Practice				
Conventional Till (%)	0.87			
No Till, Strip Till (%)	0.13			
Blended Emissions Factor (kg N_2O -N/ha per y)		3.765	2.991	4.774
Blended Emissions Factor (kg N_2O -N/acre per y)		1.524	1.210	1.932
Bushels Delivered to IRE	20,450,000			
Average Yield	196			0
Corn Acres Needed for IRE Supply	104,337			
Surveyed Crop Rotation (%)		40%	41%	19%
IRE Acres in Crop Rotation (acres)		41,496	42,909	19,931
Emitted N_2O -N (kg/y)		63,228	51,939	38,508
Total Emitted N_2O -N on IRE Acres (kg/y)	153,676			
Total Emitted N_2O -N of IRE Del. Corn (g/bu)	7.51			
Total Emitted N_2O of IRE Del. Corn (g/bu)	11.81			
Indirect Emissions Factor	30%			
Total direct and indirect emissions (g/bu)	15.35			

5.2.3 N_2O Emissions according to Measurements

A third assessment of N_2O emissions was made based on actual measurements on Illinois soil. These measurements were conducted in a conventionally managed field during corn and soybean phases at the University of Illinois at Urbana Champaign. Gas samples were collected using chambers sampled intermittently during the growing season with N_2O then quantified by gas chromatography. The measured values range from 4 to 6 micro gram per m^2 per hour. Converting these measurements to a g N_2O /bu basis based on the surveyed yield and adding indirect effects results in emissions of 1.41 g N_2O /bu on the high end. The results are summarized in Table 19. The low values observed by direct-in field measurement reflect the reality of the denitrification process, which is highly variable in space and time, with long periods of low–efflux being punctuated by brief episodes of high denitification. Weather conditions that promote high denitrification rates frequently do not accommodate the measurement process. This weakness in direct measurement techniques explains the need to rely on models and/or interest in extrapolating measured “real” values with data on climate and agricultural practices.

Table 19: N_2O Emissions of IRE Corn Acres According to Illinois Measurements

	Range	
Measured micro gram N_2O per m^2 per h	4	6
Measured gram N_2O per m^2 per h	0.000004	0.000006
Measured gram N_2O per m^2 per y	0.0350	0.0526
Measured gram N_2O per ha per y	350.40	525.60
Measured gram N_2O per acre per y	141.80	212.70
Converted to gram N_2O /bu at IRE Yield	0.72	1.08
Including Indirect effects (gN_2O/bu)	0.94	1.41

An attempt was made to customize some of the available N_2O emissions assessment approaches with data surveyed at IRE. While this customization provides likely a better estimate than the default values used in these models a wide range of values is possible.

5.3 Soil Carbon Sequestration

5.3.1 GREET Soil Carbon Sequestration

GREET includes a land use change factor of 195 gCO_2e/bu of net emissions additions. It is not documented what fractions of this number represent direct and indirect land use changes or N_2O emissions and CO_2 sequestration.

5.3.2 Carbon Sequestration with Data from University of Illinois at Urbana Champaign

The amount of carbon stored in soil depends on soil type, climate, vegetation, and historical land use and land management. Eve et. al take U.S. national carbon inventory factors developed by the Intergovernmental Panel on Climate Change and adjust these factors to account for various management options of cropland as well as climate and soil types (Eve, Sperow et al. 2002). Eve et al. report weighted average soil carbon accumulation resulting from a reduction in tillage intensity from conventional till to no-till of 0.43 metric tonnes of carbon per hectare per year (0.17 MT C per acre per year). Eve et al. also report that their finding is identical to values measured by Wander for Illinois locations (Wander, Bidart et al. 1998). Coincidentally, one of these locations happened to be in DeKalb within the corn draw area of IRE.

Since these measurements were performed for various crop rotations and management practices of soil in Illinois including DeKalb, we asked Wander to provide a summary of first order sequestration factors for the present study. The factors are informed by Eve et al. and are listed in Table 20. The diversified category represents net carbon emissions from conversion of pasture land and small grains to corn/soy crop land. It should be noted that carbon gains generally occur in surface depth (0-30 cm). At deeper depths gains disappear which means that conversions away from carbon storing management practices may have a reversible effect. Furthermore, these are so-called linear rates that are applicable for about 10 years of a particular land use practice.

Table 20: CO_2 Sequestration Factors by Eve et al

	CSC and SSC MT C/acre per year	SCC and CCC MT C/acre per year	Diversified MT C/acre per year
Conventional Till	0.01	0.05	-0.15
No Till	0.02	0.2	-0.1

The sequestration factors listed in Table 20 were applied to the surveyed tillage practices to derive a blended sequestration factor by crop rotation for the IRE corn draw area. Then, the sequestration factors by crop rotation were applied to the number of acres in that particular crop rotation that supply corn to IRE to derive carbon sequestered per year. The results indicate that based on the crop rotations and other land use changes (pasture land to corn), the acres that deliver corn to IRE may sequester approximately 2,167 tonnes of CO_2 per year. Based on the surveyed yield for these acres, this amounts to 106 gCO_2/bu. Note that a relative large amount of net emissions (2,860 tonnes) are released from converting diversified land to corn agriculture. As demonstrated above high uncertainties exist in the data accuracy of diversified land conversions to corn. Therefore, the net emissions shown from the conversion of diversified land are likely too high.

There is further room for improvement. Going to 100% no-till (as opposed to the currently practiced 13%) would increase CO_2 sequestration to 27,200 tonnes on IRE supply acres or 1,330 g/bu (but it would in turn increase N_2O emissions from 15.35 to 17 g/bu in the Mummey model). Eve et al and direct measures show that adding winter cover crops could additionally double the carbon sequestration rates.

Table 21: Carbon Sequestration of IRE Acres According to Eve et al Factors

		CSC MT C/acre per year	SCC MT C/acre per year	Diversified MT C/acre per year
CO_2 Sequestration Factors				
Conventional Till		0.01	0.05	-0.15
No Till		0.02	0.2	-0.1
Surveyed Tillage Practice				
Conventional Till (%)	0.87			
No Till, Strip Till, Minimum Till (%)	0.13			
Blended Sequestration Factor		0.011	0.070	-0.144
Bushels Delivered to IRE	20,450,000			
Average Yield	196			0
Corn Acres Needed for IRE Supply	104,337			
Surveyed Crop Rotation (%)		40%	41%	19%
IRE Acres in Crop Rotation (acres)		41,496	42,909	19,931
Sequestered Carbon (MT/y)		469	2,982	-2,860
Total Sequestered Carbon on IRE Acres (MT C/y)	591			
Total Sequestered Carbon on IRE Acres (MT CO_2/y)	2,167			
Total Sequestered Carbon on IRE Acres (MT CO_2/acre)	0.02			
Total Sequestered Carbon of IRE Del. Corn (g CO_2/bu)	106			

5.3.3 Chicago Climate Exchange Soil Carbon Management Offsets

The Chicago Climate Exchange offers soil carbon management offsets for agricultural land treated with conservation tillage practices (CCX 2007). The basic specifications for Soil Carbon Management Offset as stated by CCX are listed below. Information regarding registering offsets with CCX is listed in Appendix B.

- Minimum five year contractual commitment to continuous no-till or striptill (conservation tillage) on enrolled acres.
- Tillage practice must leave at least two-thirds of the soil surface undisturbed and at least two-thirds of the residue remaining on the field surface.
- CCX contracts are issued for conservation tillage at a rate between 0.2 and 0.6 metric tons CO_2 per acre per year. Figure 9 indicates Illinois belongs to Zone A where 0.6 metric tons CO_2 per acre per year are issued for conservation tillage.
- Carbon sequestration projects must be enrolled through a CCX registered Offset Aggregator.

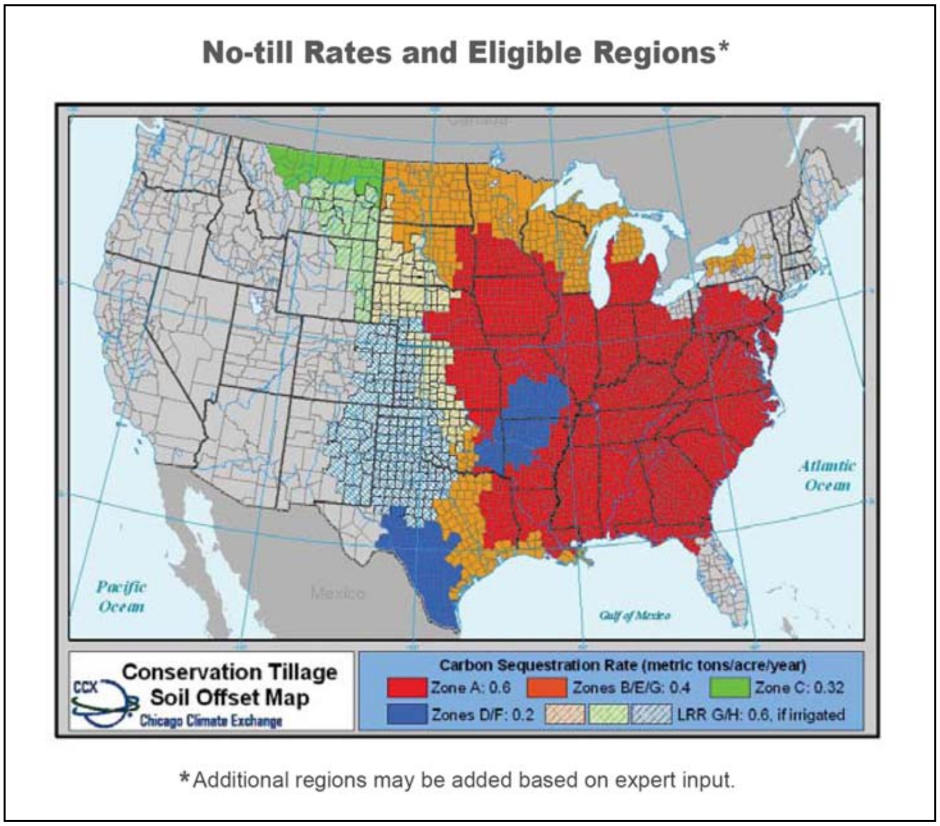


Figure 9: CCX Carbon Sequestration Factors

The survey results indicate that 10% of delivered bushels are no-till and 3% of bushels are strip till, which means about 2,658,500 bushels (13% of 20,450,000 bushels) would be produced by conservation tillage practices. Since farmers did not report yields per acre and the corresponding tillage practices for that acre (instead they reported the different tillage practices applied as a percentage to their total acres) we cannot say whether conservation tillage resulted in lower yields. However, anecdotally, one farmer (delivering 34,000 bu to IRE) reported 100% no till and a yield of 199 bu/acre, which is close to the average surveyed yield of 196.1 bu/acre. With that we use the average yield and convert 2,658,500 bushels to 13,557 acres farmed for IRE supply with conservation tillage practices. At a CCX rate of 0.6 metric tonnes per acre per year this would result in soil carbon management offsets of 8,134 tonnes per year.

If we include minimum tillage practices reported in the survey as a form of conservation tillage (minimum till may meet the 2/3 of residues left on field CCX specification in many cases) then 87% of bushels are farmed under CCX conservation tillage or 90,727 acres resulting in carbon management offsets of 54,436 tonnes per year. If we assume 100% no till on all IRE supply acres we calculate 62,570 metric tons of carbon management offsets. It is widely recognized that actual carbon sequestration rates in the field may be lower than what is theoretically possible or what is awarded in contracts by carbon trading organizations (Eve et al.).

5.4 GWI Accounting for Carbon Sequestration

Table 22 and Figure 10 below summarize the derived N_2O emissions and carbon sequestration values in tonnes of CO_2e per year for the corn acres supplying to IRE. Carbon sequestration values are shown as negative numbers. N_2O emissions and carbon sequestration from IRE corn supply contribute to the GWI of the 57.8 mgpy of corn ethanol produced at IRE. The contribution of N_2O emissions and carbon sequestration per MJ of ethanol produced are also shown in the table and the figure below. Depending on the employed assessment methodology and agricultural practice N_2O emissions can contribute between 1.5 g CO_2e/MJ to 20 g CO_2e/MJ to the GWI of IRE ethanol, whereas carbon sequestration can reduce the GWI by between 1.7 g CO_2e/MJ to 13.4 g CO_2e/MJ.

Table 22: Summary of N_2O Emissions and Carbon Sequestration Rates

Metric Tons Sequestered on IRE Acres	**CO_2e (tonnes/y)**	**IRE Ethanol GWI Contribution (g/MJ LHV)***
N_2O: Mummey Factors	92,917	20.0
N_2O: GREET Default	70,822	15.2
N_2O: GREET Customized	64,164	13.9 - 14.2
N_2O IL Measured	7,113	1.5
Sequestr.: UIUC Factors, 13% no till	-2,160	-0.5
Sequestr.: CCX CMO, 13% no till	-8,134	-1.7
Sequestr.: UIUC Factors, 100% no till	-27,200	-5.8
Sequestr.: UIUC Factors, 100% no till, Winter Cover	-54,400	-11.7
Sequestr.: CCX CMO, 100% no till	-62,570	-13.4

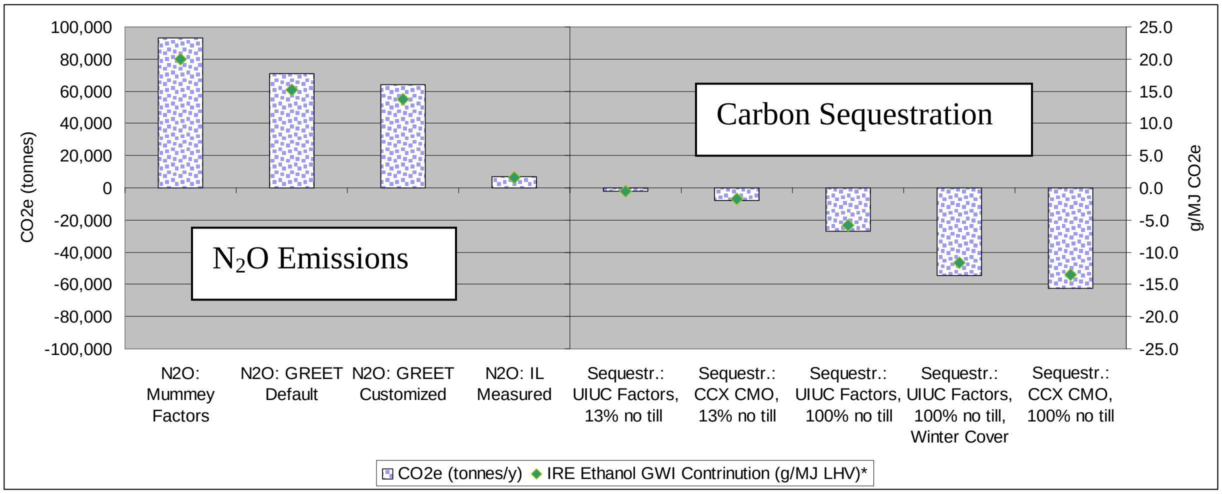


Figure 10: N_2O Emissions and Carbon Sequestration Rates of IRE Supplied Corn

GREET does take N_2O Emissions into account but does not account for carbon sequestration. Therefore, we subtracted the carbon sequestration potential assessed with satellite imagery within the IRE corn draw area from the previously determine GWI for IRE ethanol. Since we determined the GWI for IRE ethanol under different scenarios (IRE Case #1 reflected SERC electricity grid, IRE Case #3 reflected Exelon Generation grid) we subtracted the carbon sequestration potential from these different cases.

Figure 11 and Table 23 show the GWI of IRE Case#1 accounting for carbon sequestration assessed a) with UIUC supplied sequestration factors for no-till and winter cover and b) CCX sequestration factors for no-till. The results indicate that, if farmers were enticed to practice no till and/or winter cover, the GWI of IRE ethanol would drop by between 11.7 to 13.4 g CO_2e/MJ and in the IRE Case#1 a reduction down to 41.4 g CO_2e/MJ to 43.1 g CO_2e/MJ would be incurred.

Table 23: GWI Accounting for Carbon Sequestration (IRE Case #1)

	IRE #1	IRE #1 UIUC 100% no-till & winter cover	IRE #1 CCX 100% no-till
		g CO_2e/MJ	
N Fertilizer	14.2	14.2	14.2
Other Ag and Distribution	11.9	11.9	11.9
IRE Plant	28.7	28.7	28.7
C-Sequestration	0	-11.7	-13.4
Net GWI		43.1	41.4

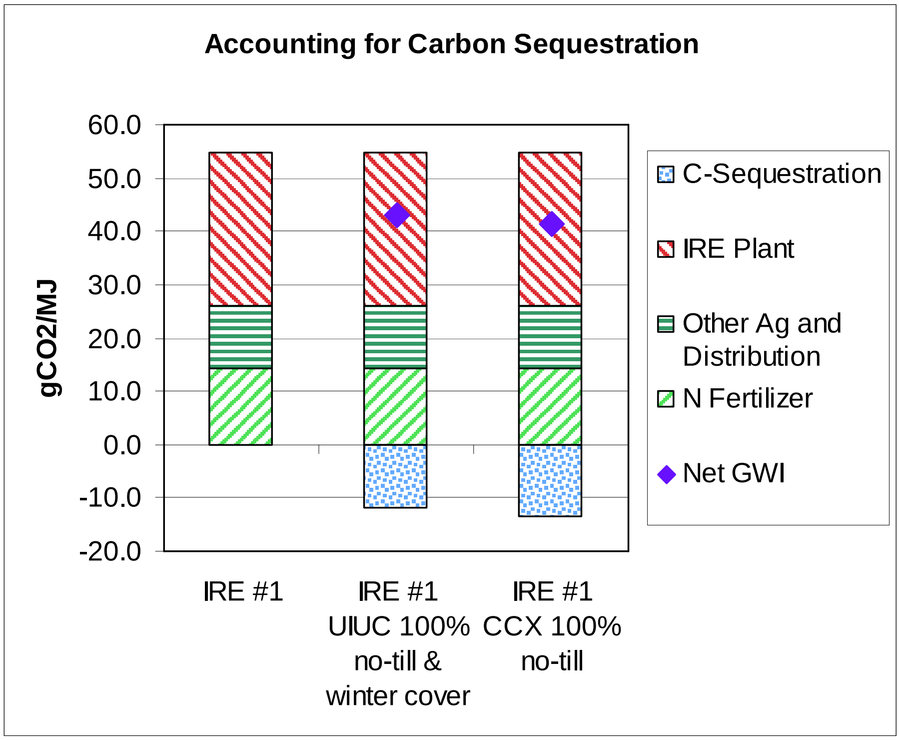


Figure 11: GWI Accounting for Carbon Sequestration (IRE Case #1)

Figure 12 and Table 24 show the GWI of IRE Case#3 accounting for carbon sequestration assessed a) with UIUC supplied sequestration factors for no-till and winter cover and b) CCX sequestration factors for no-till. The results indicate that, if farmers were enticed to practice no till and/or winter cover, the GWI of IRE ethanol would drop by between 11.7 to 13.4 g CO_2e/MJ and in the IRE Case#3 a reduction down to 33.3 g CO_2e/MJ to 35.0 g CO_2e/MJ would be incurred.

Table 24: GWI Accounting for Carbon Sequestration (IRE Case #3)

	IRE #3	IRE #3 UIUC 100% no-till & winter cover	IRE #3 CCX 100% no-till
		g CO_2e/MJ	
N Fertilizer	13.9	13.9	13.9
Other Ag and Distribution	9.9	9.9	9.9
IRE Plant	22.9	22.9	22.9
C-Sequestration	0.0	-11.7	-13.4
Net GWI		35.0	33.3

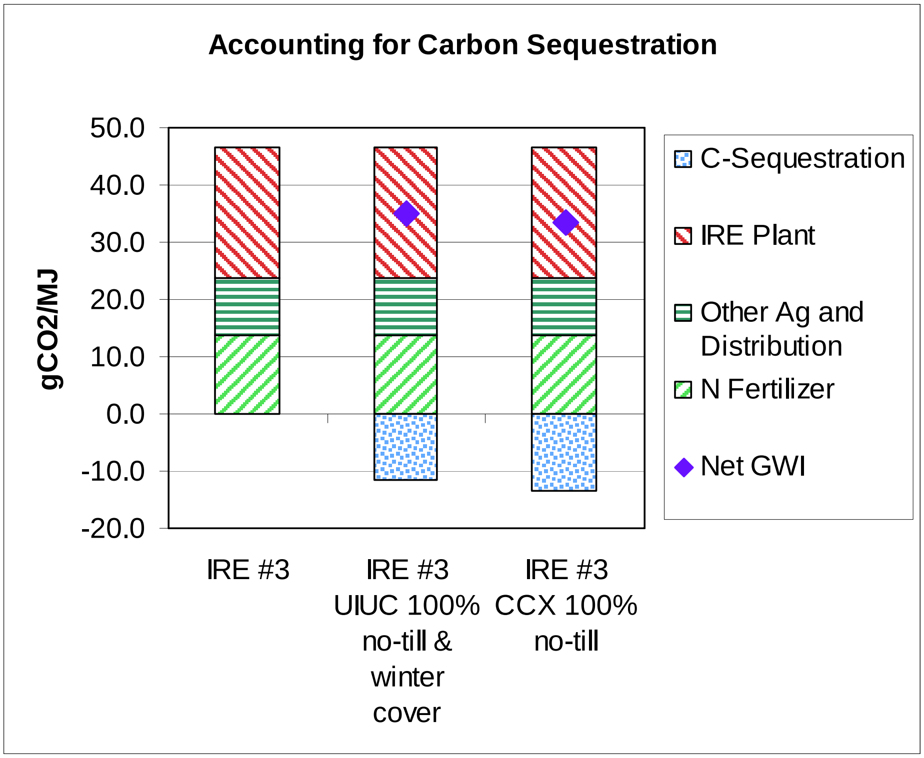


Figure 12: GWI Accounting for Carbon Sequestration (IRE Case#3)

In summary, the following conclusions can be made:

- The calculated N_2O emissions and sequestration values differ widely by the employed method.
- High uncertainties exist when determining land use conversions from non crop lands to crop lands (including pasture land) based on USDA statistics. The current statistical approach may result in over-estimating pasture to agricultural land conversions and therefore under-estimate carbon sequestration and over-estimate net emissions additions.
- Carbon sequestration effects could be of the same magnitude as N_2O emissions.
- Winter crops and no-till can significantly improve the overall GWI from land use change.
- However, the gain in carbon sequestration from no-till may be partially offset since N_2O emissions are expected to increase slightly with no-till in Illinois.
- The widely differing results for N_2O emissions and carbon sequestration based on different assessment methods combined with the uncertainties in determining land use change do not allow the conclusion that increased corn agriculture in the surrounding area of the IRE ethanol plant increases the global warming impact of ethanol produced at that facility from direct land use change.
- However, best management practices such as no-till and winter crops have a positive effect on the GWI of corn ethanol produced at IRE.
- IRE should promote no-till and winter crops practices among its corn suppliers.

- Models that assess the impact of corn ethanol production on an international level need to detail their assumptions for US domestic corn ethanol production as well as the geographic resolution of their data sets since the demonstrated high uncertainties with local data and methods may influence their results derived for international assessments.

Appendix A: Survey Instrument

1 Number of Bushels of corn delivered to Ethanol Plant in the past year

2 Surrounding Counties in which you grow crops
Acres per County

	Name	Acres/County		Name	Acres/County
County Name 1			County Name 5		
County Name 2			County Name 6		
County Name 3			County Name 7		
County Name 4			County Name 8		

3 Typical Crop Rotation for Corn Acres

(eg. 200A corn on corn; 50A corn/bean rotation)

Corn on Corn
Corn/Beans
Other (describe)

4 Average corn yield over the past three years (bu/A)

2005	2006	2007

5 Corn Acre Tillage Practices

	% 0f Corn Acres	% of Soy Acres
Conventional		
Minimum Till		
No Till		
Strip Till		

6 Irrigated Corn Acres (%)

7 Typical Fertilizer Program

7a Application Timing: Please state Amounts/Acre

	Fall	Spring	POST
N Lbs./A			
P Lbs./A			
K Lbs./A			
Ag lime Lbs./A			
MicroNutrients Lbs/A			
Manure: gal/A			
Other:			

7b What Products do you use: Please mark all that apply with an "x"

NH3	
28%	
32%	
18-46-0	
0-46-0	
0-0-60	
Others:	

8 Corn Hybrid Selection

		# of Acres
Non Biotech		
Biotech	Herbicide control	
	Insect control	
	Herb & insect	

9 Pesticide Program

			Application timing: amounts/acres			
	Name/type	**Acres Treated**	**Fall**	**PPI/PRE**	**POST**	**Other**
Example:	*Aztec*	*200*	*6.1#*			
Insecticide 1						
Insecticide 2						
Herbicide 1						
Herbicide 2						
Herbicide 3						
Additional						

10 Number of Trips Over Each Field

11 Annual Fuel Self Use (gal) per Acre

12 Annual Custom Machine Hire

	# of ACRES	Fuel Estimate (gal)
Fertilizer Application		
Pesticide Application		
Combining of Crop		
Crop Hauling		
Miles / Bushel		

13 Hauling Energy to Ethanol Plant (1 way)

Miles
bu transported/trip
gal/mile

14 Corn Drying

	Cost Per Bushel
Propane	
Electricity	
or Volume of Propane Used	

Appendix B: Chicago Climate Exchange Offset Registration

The following is reproduced from the CCX website. The contents can be found at: http://www.chicagoclimatex.com/content.jsf?id=104

Offset Project Registration, Verification & Crediting Procedure

While the various project types have different eligibility and quantification requirements, all CCX offset projects go through the same standardized registration, verification and crediting process. Members of the CCX staff are available to assist project owners in assessing the eligibility of their project(s), as well as provide technical support throughout the crediting process.

Steps:
1. Submit project proposal and/or project questionnaire to CCX: CCX staff will provide project questionnaires and/or guidance on the proposal specifications. This proposal will be submitted to the CCX Committee on Offsets for review and preliminary approval and may be further referred to scientific technical advisory committees.

2. Obtain independent project verification: Upon project approval by the Committee on Offsets, a project owner or aggregator must obtain independent verification by a CCX-approved verifier. Verifiers use information provided by the project owner or aggregator, combined with possible site visits, to accurately assess a project's actual, annual greenhouse gas (GHG) sequestration or destruction. Verification reports are reviewed by CCX staff as well as the CCX provider of regulatory services, FINRA, for completeness and accuracy.

3. Register as a CCX Offset Provider or Offset Aggregator: Join CCX as an Offset Provider, or enroll the project through an existing Offset Aggregator. Project owners or aggregators may enroll an unlimited number of eligible projects for offset credit. Each distinct project within the portfolio must be registered independently; aggregated projects are registered on a combined basis.

4. Receive Carbon Financial Instrument® (CFI®) contracts for project offsets: Upon approval by the Committee on Offsets, CCX issues the Offset Provider or Aggregator CFI contracts in a quantity equal to the project's GHG sequestration or destruction (net CFI contracts withheld for a reserve pool if applicable). Offset Projects are issued CFI contracts on an annual basis, with the CFI Vintage applying to the program year in which GHG mitigation took place. For example, a methane capture and destruction offset project for methane destruction that occurred during calendar year 2005 would earn a given quantity of 2005 Vintage CFI contracts.

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