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California Environmental Protection Agency
Air Resources Board
Byron Sher Auditorium, Second Floor
1001 I Street
Sacramento, California 95814

Subject: Comments on Corn Ethanol Land Use Change Analysis in the Proposed Regulation to Adopt the Low Carbon Fuel Standard

Dear Air Resources Board:

Page IV-19 of the "Proposed Regulation to Implement the Low Carbon Fuel Standard" states:

> *"A sufficiently large increase in biofuels demand in the U.S. will cause non-agricultural land to be converted to crop land both in the U.S. and in countries with agricultural trade relations with the U.S. Models used to estimate land use change impacts must, therefore, be international in scope"*

We disagree with the above statement and believe that a thorough regional analysis of direct and indirect land use change is superior to the employment of models that are international in scope. These international models require a host of input variables (some of which are shown in Table C5-1) with unknown probability distribution functions. A localized, or bottom-up modeling approach detailed below is superior and consistent with the look up tables provided in Table IV-20. The bottom up approach demonstrates that there is no reason why the "Land Use or Other Effect" values in the look up table cannot vary by pathway similar to "Direct Emissions."

In most cases, ethanol plants source corn from localized, geographically distinct areas surrounding the plants. Our study at the Illinois River Energy Center (IRE) ethanol plant in Illinois which includes a survey of 30 growers delivering corn to this 58 mgpy plant shows that farmers deliver corn within a 40 mile radius "corn draw area" or "CDA" (see Mueller, October 2008). ProExporter Network, a grains flow consulting firm also regularly establishes CDA's based on local transport conditions and grain commodity prices. Since an ethanol plant's effect on corn supply starts with an easy to establish, geographically limited area we argue that any land use analysis of corn ethanol must start with an analysis of the yields, crop rotations, and land use conversions in that CDA.

As a modeling example we assess land use for IRE's CDA using high resolution satellite imagery with additional vetting routines (see Mueller, December 2008). We find that a) no significant conversion of non agricultural land to corn occurs, b) yield increases surveyed for the CDA are sufficient to meet the ethanol plant's corn demand, and c) changes in crop rotations are not explained by the ethanol plant's corn demand. The study concludes that the operation of the Rochelle Illinois ethanol plant does not contribute to land use change. Therefore, greenhouse gas emissions from IRE related land use change are insignificant. The life cycle global warming analysis for IRE produced corn ethanol (including farming, conversion, distribution, denaturing) totals 54.8 gCO2e/MJ as established by parameterizing GREET for the surveyed agricultural practices in the CDA and IRE's corn processing technologies (N-inputs, yields, plant fuel and electric use, etc.). IRE started operation in December 2006 and the plant technology is representative of approximately 3 billion gallons of corn ethanol produced today.

We realize that this is a case study of one particular plant. And, we do agree that a different ethanol plant built in a less productive agricultural area and different commodity flows may contribute to land use change. It follows that the share of land use effect from each ethanol plant differs from plant to plant but that these different shares cannot be captured by international trade models. High resolution satellite imagery is available to assess the land use effect for each plant from the bottom up. In contrast, high resolution satellite imagery is not available to model international land use change prompted by biofuels production (see Mueller, March 2009). Therefore, it is scientifically unsound to assign one land use effect value (30 gCO2e/MJ) to all corn ethanol produced, a value that is derived with an international trade model with input variables of unknown probability distributions.

We are currently expanding our bottom-up modeling approach to include more ethanol plants. We urge CARB to provide a mechanism to allow individual ethanol producers to demonstrate their plant's impact on land use change.

Best Regards,

Steffen Mueller, PhD
Principal Economist

Ken Copenhaver
Senior Engineer

Attached References:

Mueller, S. and K. Copehaver, M. Wander. "The Global Warming Impact and Land Use Impact of Corn Ethanol Produced at the Illinois River Energy Center"; October 20, 2008.

Mueller, S. and K. Copenhaver. "A Bottom-Up Assessment of Land Use Related to Corn Ethanol Production"; December 11, 2008

Mueller, S. and K. Copenhaver. "Use of Remote Sensing to Measure Land Use Change from Biofuels Production"; March 26, 2009.

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

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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.

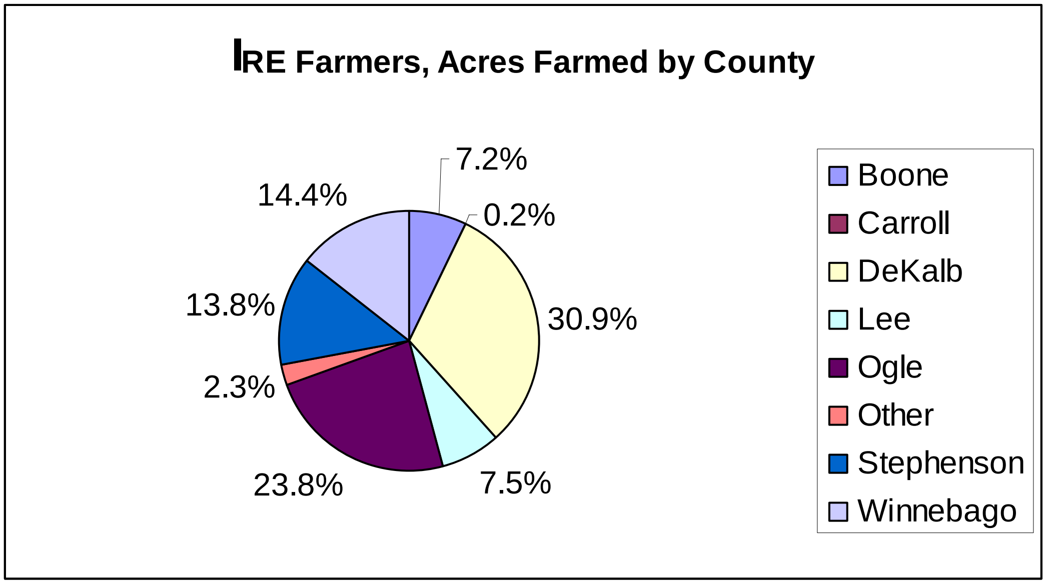

Figure 1: Survey Responses by County

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			

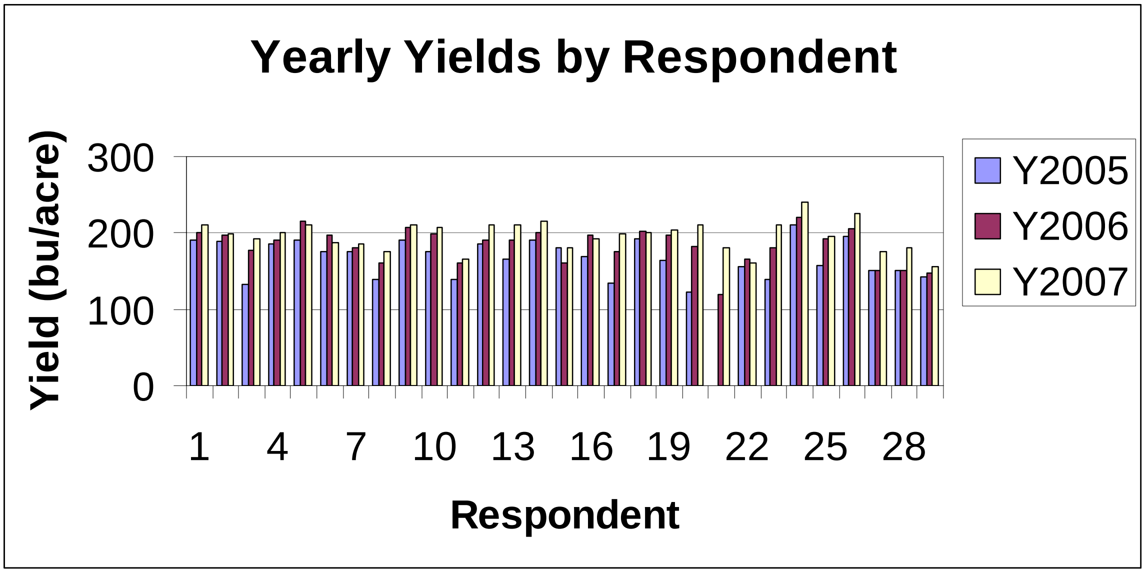

Figure 2: Yields by Respondent

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%-60% 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.

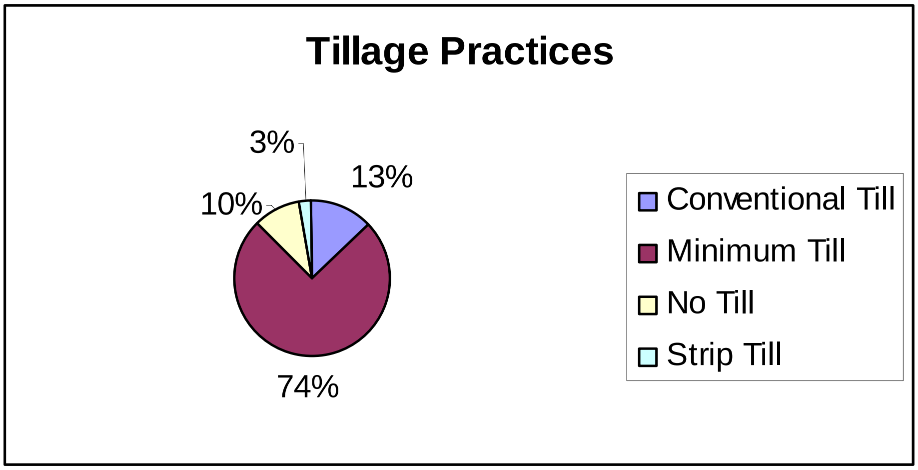

Figure 3: Tillage Practices around IRE

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.

[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.

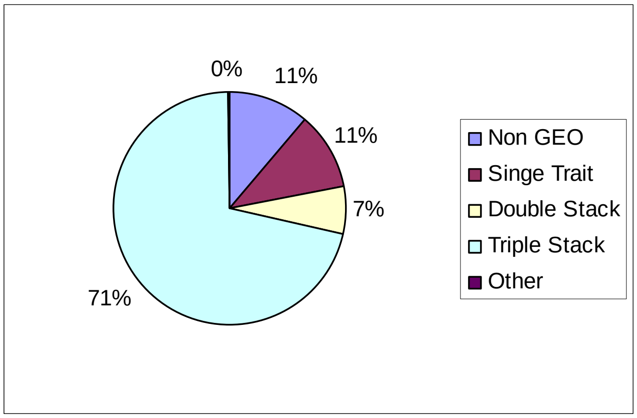

Figure 4: Corn Trait Selection of Farmers Supplying to IRE
Note: N=27

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.

[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

[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.

Gasoline: 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.

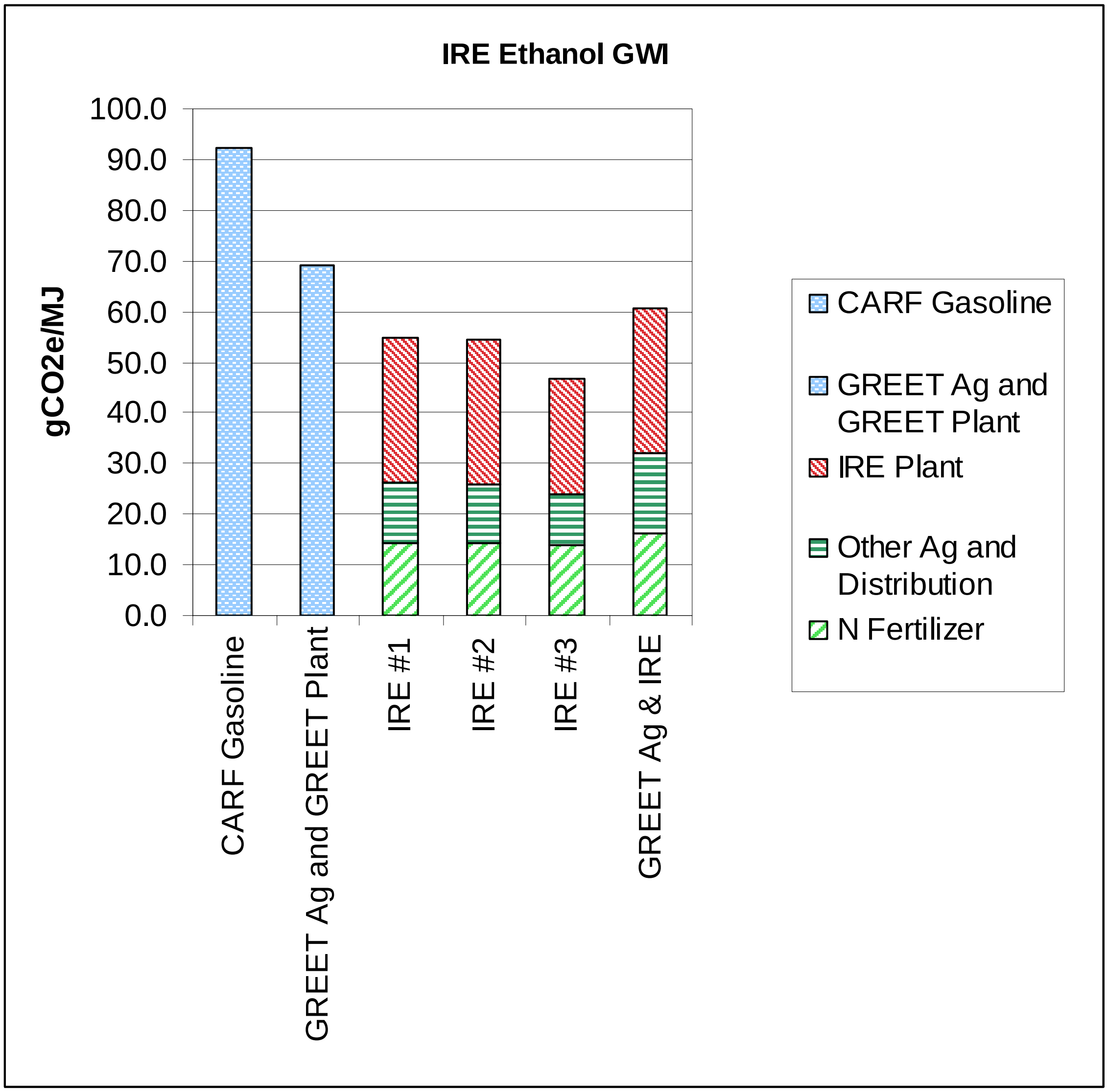

Figure 5: IRE Ethanol GWI

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.

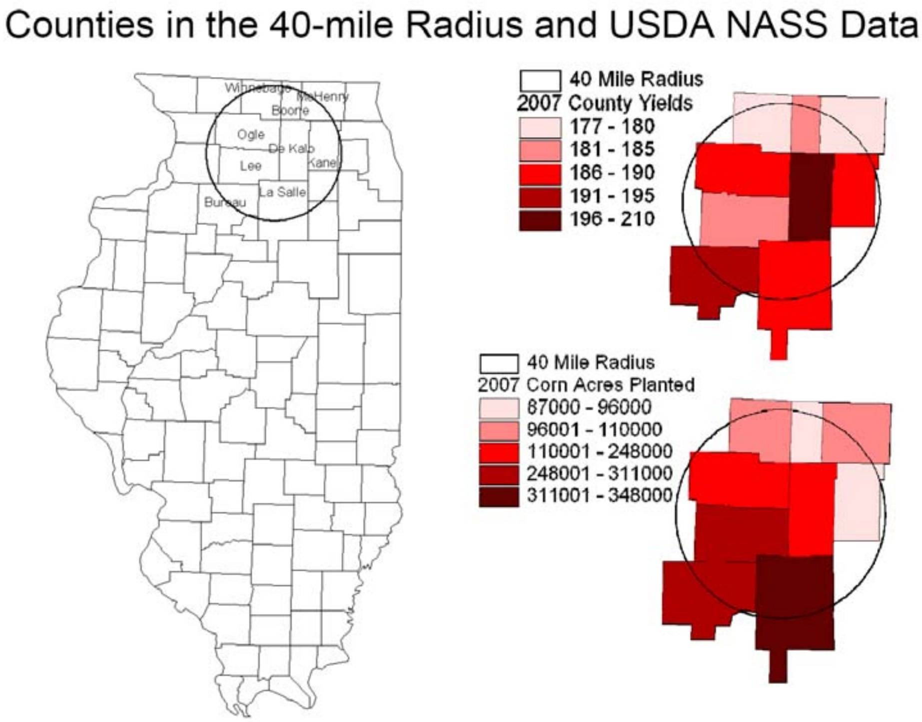

Figure 6: GIS Corn Draw Area

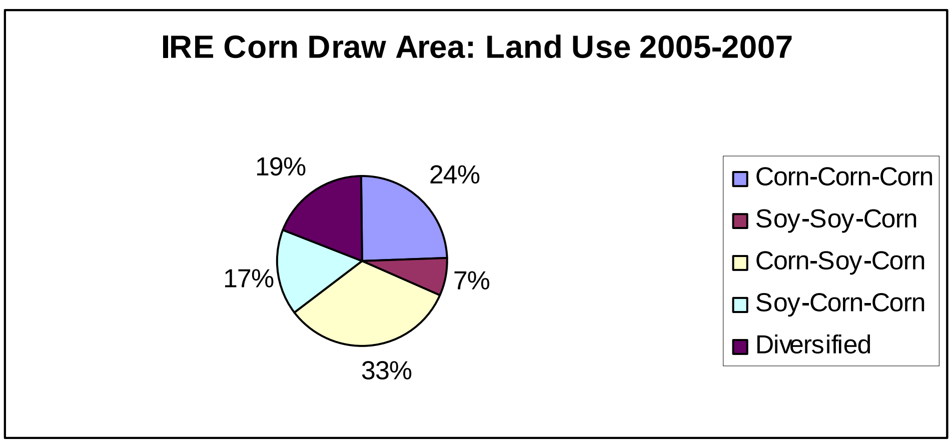

Figure 7: Crop Rotations by Percent of Acreage

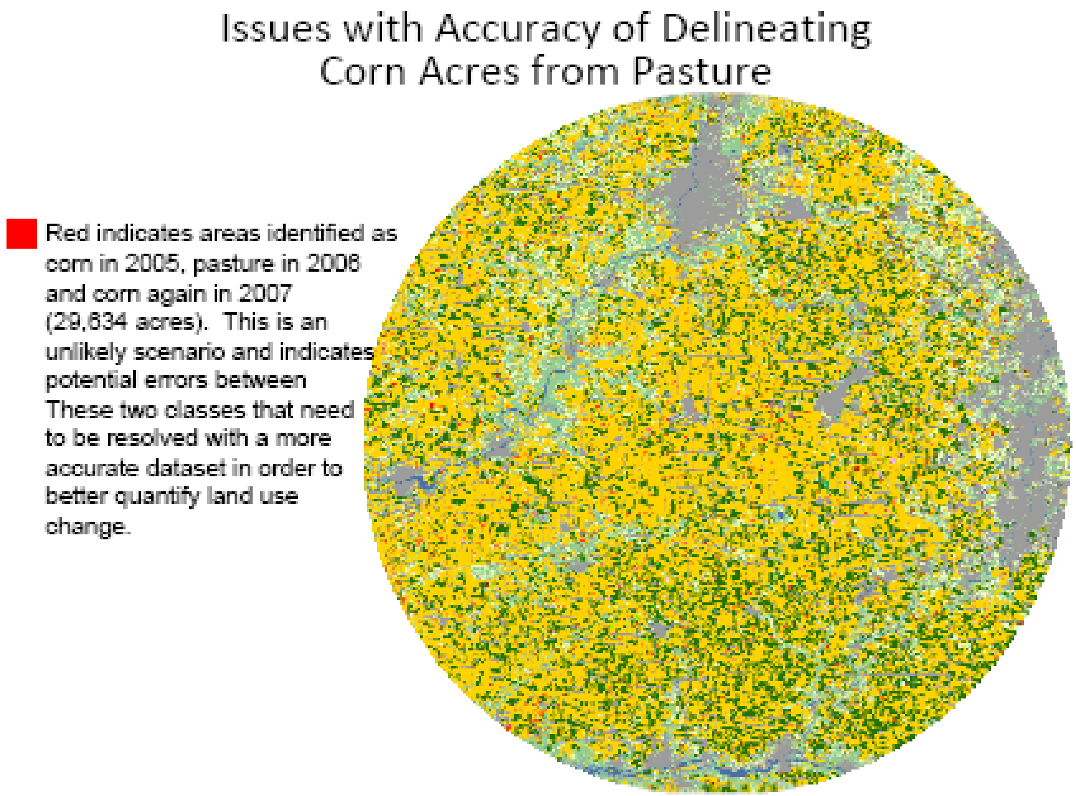

Figure 8: Accuracy of Delineating Corn Acres from Pasture

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.

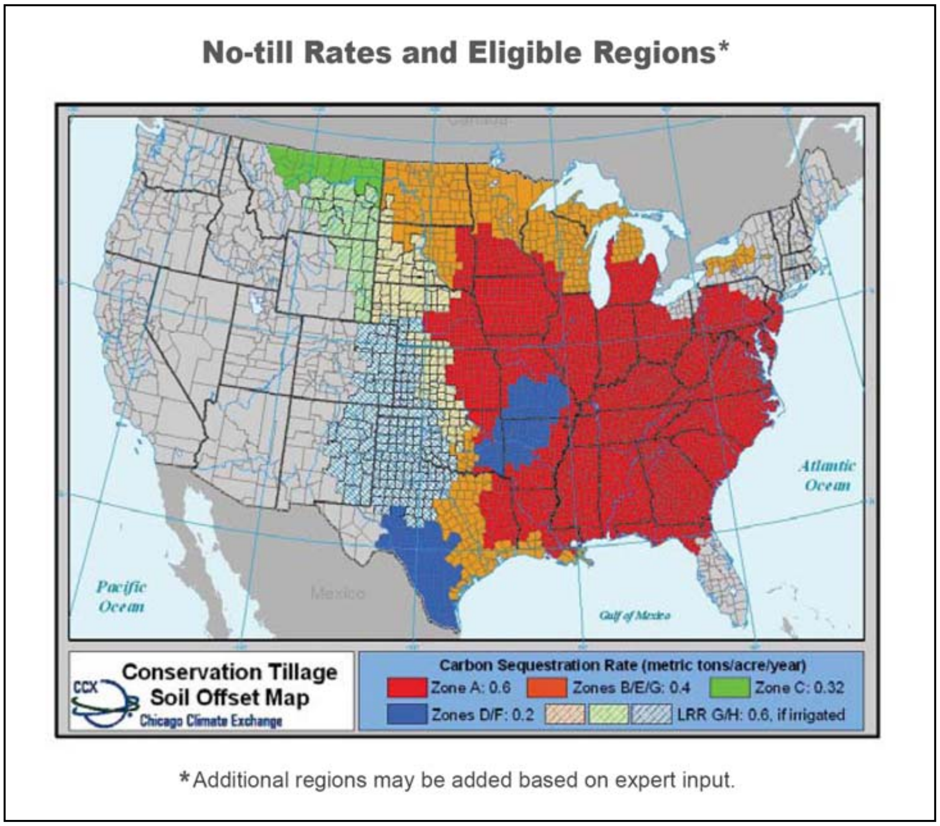

Figure 9: CCX Carbon Sequestration Factors

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

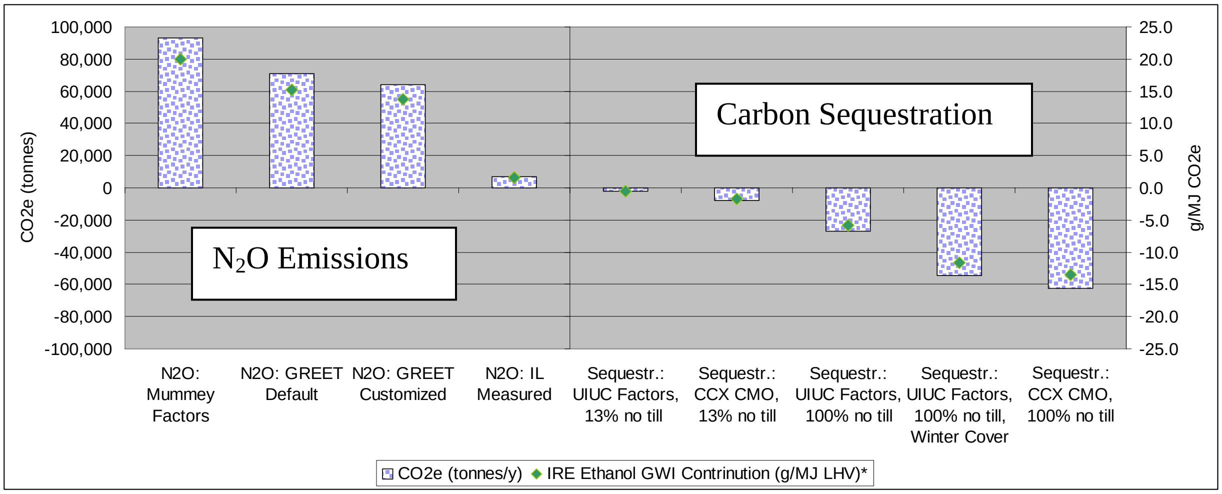

Figure 10: N_2O Emissions and Carbon Sequestration Rates of IRE Supplied Corn

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

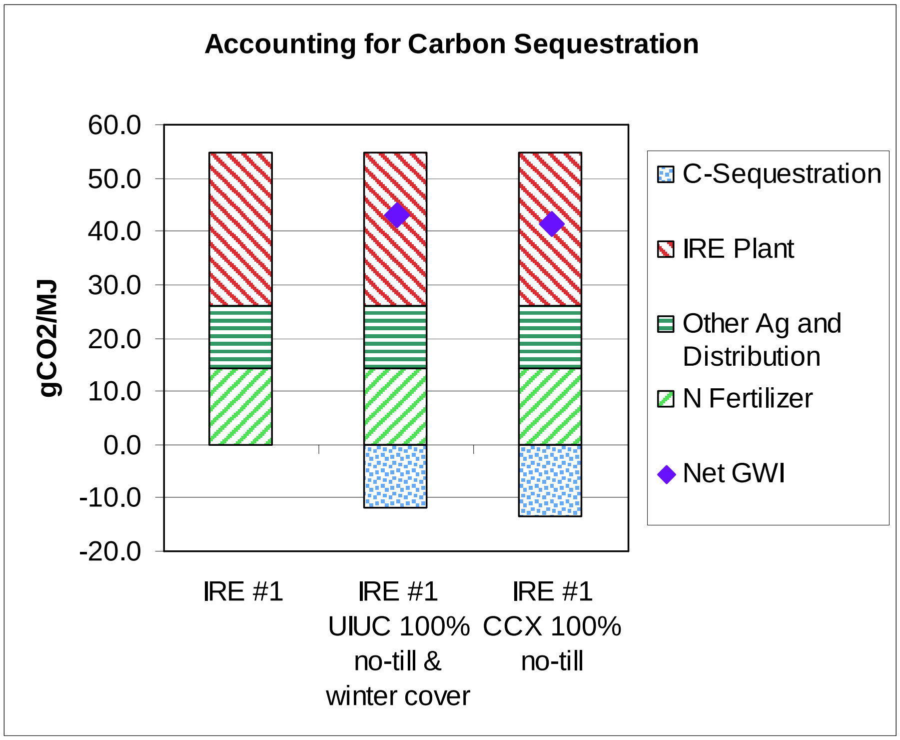

Figure 11: GWI Accounting for Carbon Sequestration (IRE Case #1)

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

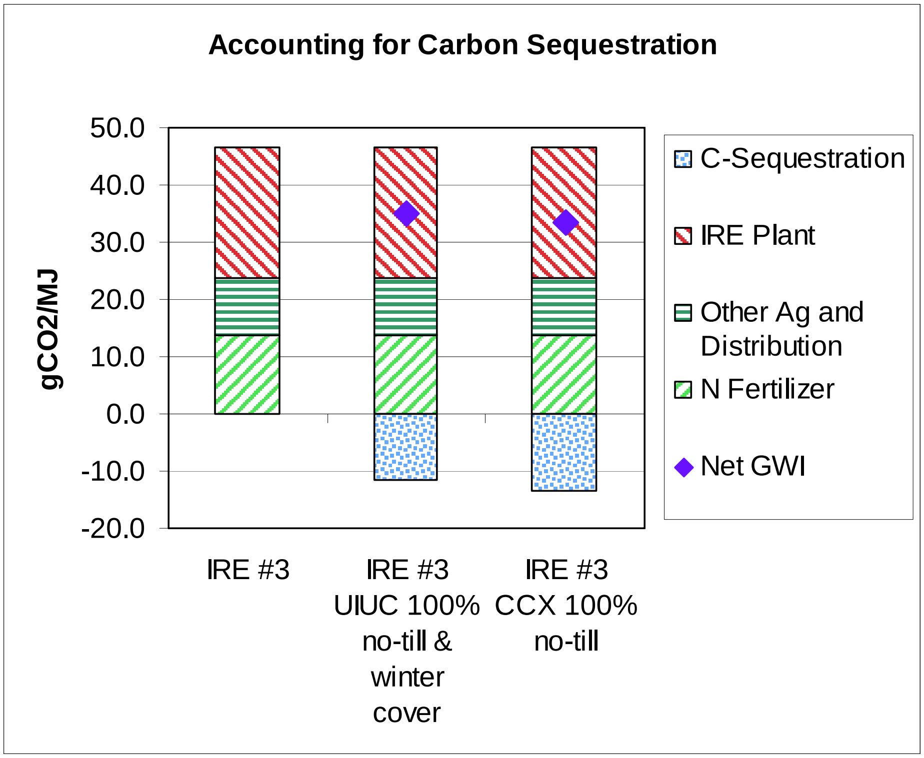

Figure 12: GWI Accounting for Carbon Sequestration (IRE Case#3)

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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A Bottom-Up Assessment of Land Use Related to Corn Ethanol Production

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Executive Summary

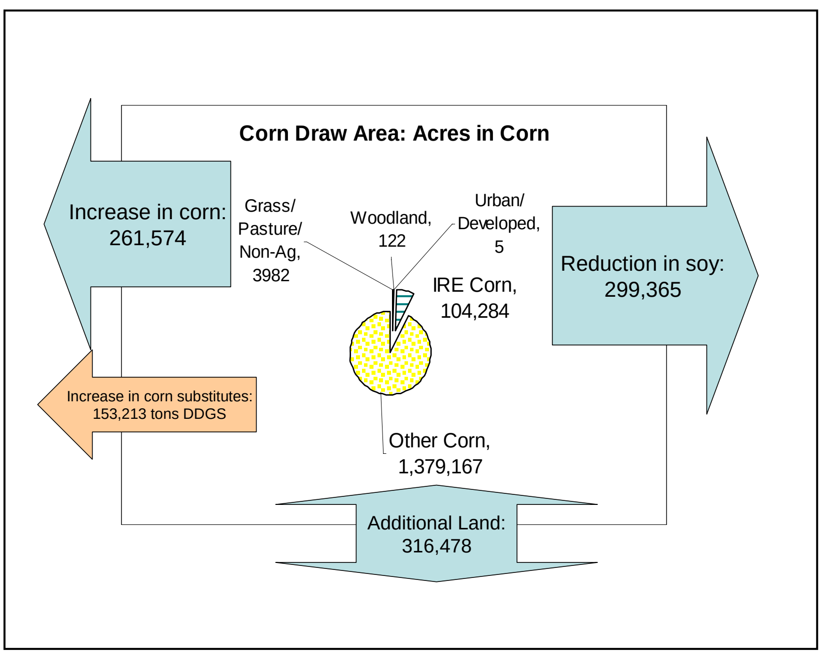
This study conducted by the University of Illinois at Chicago Energy Resources Center determined if corn extensification (conversion of non agricultural land to corn) and corn intensification (conversion of non-corn crop acres to corn or increased yield in current corn acres) occurred within the vicinity of an ethanol plant and if the ethanol plant was the likely cause of these effects. In addition to land use change, the present study also examined the land carbon balance for corn produced to supply the plant. The selected ethanol plant is the Illinois River Energy Center (IRE) with a current capacity of 58 mgpy. The plant is located in Rochelle, Illinois and it started operating in February, 2006.

The study combined remote sensing (USDA NASS cropland data layer derived from AWiFS) with a survey of 29 growers supplying corn to the ethanol plant. The present study determined corn-ethanol related land use changes from the "bottom-up": by carefully examining changes to each acre of land in the vicinity of the selected ethanol plant.

The USDA Cropland Data layer imagery was evaluated by creating a mask of 2007 corn and using it to mask out the same locations in the 2005 and 2006 cropland data layer. Simultaneously, a routine was applied to subtract a ¾ acre buffer along roadways and field edges. This avoided incorrectly categorizing 85,329 acres of corn as land use changes from non agricultural land when in fact field edges and roadway buffers triggered a misclassification.

Besides field edges additional incorrect classifications were avoided for 26,616 acres by confirming that these acres were in continuous crop rotations rather than going from agricultural use to non-agricultural use and back to agricultural use as the NASS data originally suggested. Test samples confirmed that a) roadway buffers and field edges are often classified by NASS as land use changes and b) that ag to non-ag and back to ag land use changes are improbable. With that the study documented that there is a substantial possibility for errors with a tendency toward indicating a greater percentage of land use change (as most mis-classifications are wrongfully identified as change) when applying remote sensing to ethanol related land use studies. Pre-existing datasets should only be used in the context that they were developed with an understanding that errors from year to year will amplify when comparing land use change.

The figure illustrates the corn balance within the growing area as well as exports from the area. From the 2006/2007 growing season only 4,109 acres (3,982+122+5) were converted from non-ag use such as grass, pasture, or woodland to corn growing (0.28% of the 1.487 million acres in corn). Conversion did not occur despite the fact that an additional 316,478 acres of land would have been available for

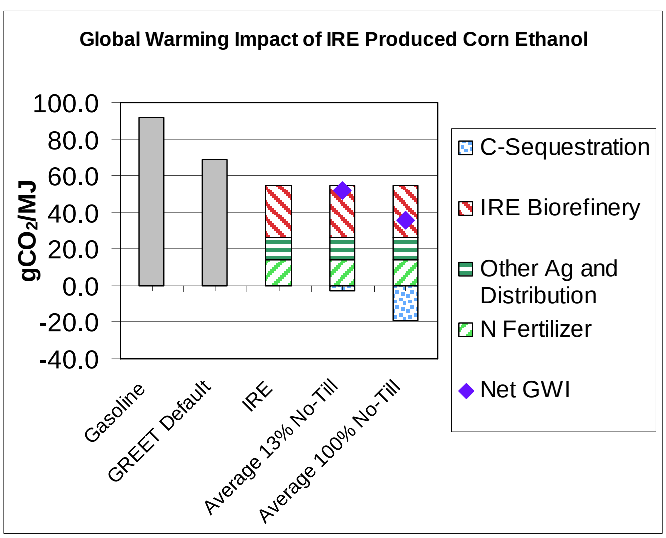


conversion to agriculture within the corn draw area. Therefore, it can be concluded that the start-up of the IRE plant did not promote corn extensification (the conversion of non-ag acres to corn).

IRE requires 20,450,000 bushels of corn to produce 55 mgpy of corn ethanol on an annual basis. At the surveyed yield of 196.1 bu/acre the 2007 land requirements totaled 104,284 acres. However, corn production in the corn draw area went up by 261,574 acres (2.5 times the IRE corn requirements) while soy production went down by 299,365 acres (almost 3 times the acres required for IRE corn production). Clearly, while IRE may have had a small influence towards corn intensification, other variables (maybe economics, high export demand) seemed to drive corn intensification. Furthermore, counting DDGS production as a corn co-product, yield increases within the draw area were sufficient to meet IRE's corn requirements. We realize that yields change over time and that the current study presents a snapshot of events.

Finally, based on the assessed crop rotations and surveyed tillage practices, the study calculated N_2O emissions and carbon sequestration rates according to several methodologies documented in the literature. In summary, N_2O emissions and carbon sequestration effects could be of the same magnitude. The increased carbon sequestration from no-till and winter cover crops can provide significant reductions to the GWI of corn ethanol. Therefore, ethanol plant operators could encourage these practices in their region.

The IRE GWI Study found that the life cycle global warming impact of corn ethanol produced at the plant totals 54.8 gCO_2e/MJ, which is 21% lower than the current GREET default natural gas dry mill corn ethanol plant and 40% lower than gasoline. Subtracting the average sequestration numbers for the 13% of IRE supply acres under no-till/strip till (CCX, UIUC, UIES average values for 13% no-till) from the life cycle of IRE corn ethanol of 54.8 gCO_2e/MJ reduces it to 52.2 gCO_2e/MJ. Subtracting the average sequestration numbers for encouraging 100% no-till on IRE supply acres from the life cycle of IRE corn ethanol reduces it to 35.9 gCO_2e/MJ. Since, as a first order estimate, encouraging 100% no-till in this case is likely equivalent to encouraging 50% no-till and 50% winter cover crops these practices would alternatively result in a GWI of 35.9 gCO_2e/MJ at IRE. These values exclude GWI contributions from indirect/international land use changes since, as demonstrated, IRE did not measurably effect land use.



GWI of IRE Produced Corn Ethanol

1) Introduction

Land use change can be determined according to several methods including a) conducting a census, b) using economic indicators, and c) using remote sensing. The Farm Services Agency does indeed conduct a census and assesses the land use for each field. However, this data is not publicly available. Several economic models (global equilibrium models such as GTAP) use land rent value as a proxy for land use change. We believe that remote sensing provides the second most accurate method for land use change studies next to conducting a census.

The USDA uses satellite data combined with survey data to determine their Crop-Production Report (posted on www.nass.usda.gov). Furthermore, it is our understanding that future land use studies related to corn ethanol may utilize satellite based data sets instead of the land rent assumptions and combine these data sets with national and global economic models.[i]

The present study also utilizes remote sensing combined with survey data. However, in contrast to economic modeling the present study determines corn-ethanol related land use changes from the "bottom-up": by carefully examining changes to each acre of land in the vicinity of a selected ethanol plant.

The ethanol plant is the Illinois River Energy Center (IRE), located in Rochelle Illinois, about 80 miles west of Chicago. IRE produces about 58 million gallons per year with an expansion underway to double capacity. The plant started operation in February 2006. Therefore, the time horizon for the land use analysis spans the years 2005 through 2007.

The study attempts to determine if conversion of non-agricultural land to corn (corn extensification) occurred around IRE and if IRE is its likely cause. Secondly, the study attempts to determine if conversion of non-corn crop to corn (corn intensification) occurred and if IRE is its likely cause. In addition to land use change, the present study also examines the land carbon balance from IRE corn ethanol production. By using remote sensing for this type of "bottom-up" analyses the present study is able to determine the possibilities and limitations of remote sensing for other corn ethanol related land use studies.

The present study builds on an earlier study titled "The Global Warming and Land Use Impact of Corn Ethanol produced at the Illinois River Energy Center." The earlier study will be referred to as the "IRE GWI Study" throughout this report.

2) Data

The present study is based on two data sets: a survey of growers delivering corn to IRE and USDA NASS cropland data layer derived from satellite imagery. Both data sets are discussed below.

2.1) Grower Survey

This data was collected as part of the IRE GWI Study. Since some of the data is used in the present study we will summarize some of the key findings. 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 yield, fertilizer inputs, and tillage practices.

a) Yield

As summarized in Table 1 the survey respondents report steady average yield increases between the 2005, 2006, and 2007 growing seasons. 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			

b) Tillage

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% to 60% 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 Table 2. The analysis assumes that farmers apply the same tillage practices to all of their farm land including land used for IRE production.

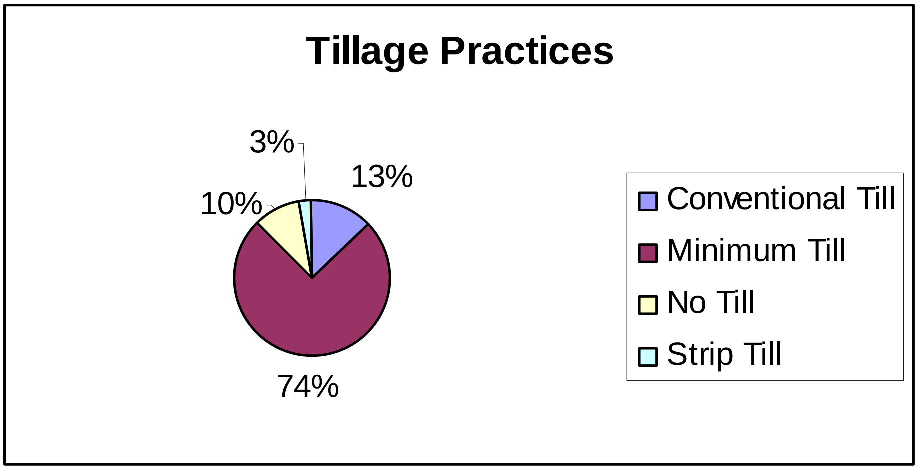


Figure 1: Surveyed Tillage Practices
Note: Graph is based on 2,478,850 delivered bushels. One farm did not report tillage practices

c) Nitrogen

The survey asked respondents what type of fertilizer products they use. Table 2 shows the results.

Table 2: 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.[ii] The resulting fertilizer input values are listed in Table 3.

Table 3: Nitrogen Application

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

2.2) Satellite Imagery

Land use change can be determined according to several methods including a) conducting a census, b) using economic indicators, and c) using remote sensing. The Farm Services Agency does indeed conduct a census and assesses the land use for each field. However, this data is not publicly available. Several economic models (global equilibrium models such as GTAP) use land rent value as a proxy for land use change. We believe that remote sensing provides the second most accurate method for land use change studies next to conducting a census. Therefore, the IRE GWI study used remote sensing in its analysis.

The original IRE GWI Study identified land use change and crop rotation practices over the last three years by correlating the USDA NASS Cropland Data Layer (for crop types) and the national land cover dataset (for non-cropland conversions). While the USDA Cropland Data Layer has been shown to have accurate methods of around 95% for the delineation of corn and soybeans (Johnson 2007a,b) and that dataset is updated every year, the national land cover data set dates back to 2001 and introduces much higher uncertainties for non-agricultural areas.

The IRE GWI Study found that the NASS data suggests land use changes from non-crop land such as pasture land, woodland, etc. to crop land, which must be viewed with great caution. In fact the analysis conducted for the original IRE GWI Study identified several thousand acres of land converting from non ag use to ag use within the corn draw circle. Furthermore, the study found that significant additional acres would have rotated from ag use to non-ag use and back to ag use over the last 3 years, an unlikely scenario. Therefore, the present study analyzes NASS cropland data layers by a) applying an algorithm to the data that subtracts roadway buffers and field edges from the land use data, and b) sampling and closely examining illogical land use changes such as ag to non-ag to ag conversions.

3) Analysis

3.1) Corn Draw Area

The first step in the process was to create a draw area boundary for the Rochelle ethanol plant. Two different methods were used: a circle method and the ProExporter Network Polygon approach. Both methods are detailed below.

The circle method uses the address of the ethanol plant as the center point and survey information on growers delivering from farthest away as the radius. The surveys showed that growers deliver from as far as 40 miles away to the plant. Therefore, a 40 mile radius was developed as a geographic information system (GIS) polygon file (see Figure 2). This circle represents the approximate draw area for corn required for the production of ethanol by the plant.

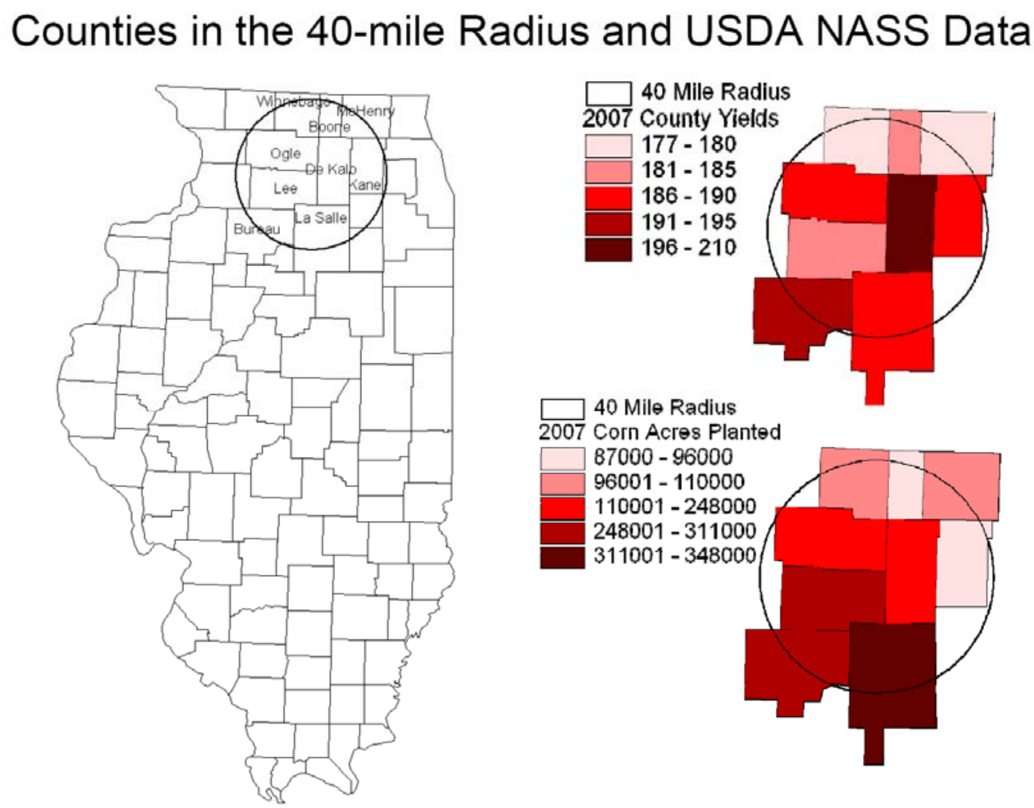


Figure 2: GIS Corn Draw Area

While the circle approach above uses survey information from the growers delivering from furthest away, the PRX Polygon combines survey information with geographic and economic variables.[iii] Geographic variables, for example, include the influence of urban areas on corn draw areas; sample economic variables include competition for grain between grain elevators and ports or railroads supporting export markets. It should be noted that, since this analysis is done at the plant level, the approach fits well within the bottom-up land use assessment context. The PRX Polygon development is offered as a for fee service to grain producers and ethanol plants. Courtesy of PRX, we have obtained the Polygon for the IRE plant in order to compare the Polygon approach to the circle approach.

As can be seen in Figure 3 the PRX Polygon for IRE differs from the circle: The Rockford urban area in the north and the Chicago urban area to the east push the corn draw area asymmetrically to the south. Furthermore, access to highways shape the draw area primarily on the southwestern fringe. However, as can be seen, the 40 mile radius circle chosen in our analysis substantially encompasses the PRX polygon. Therefore, a good match between the PRX Polygon and the 40 mile circle confirms that the analysis substantially covers the IRE corn draw area. For further analysis, the circle method was chosen because we felt that this method could be replicated more easily for future, additional corn draw area studies.

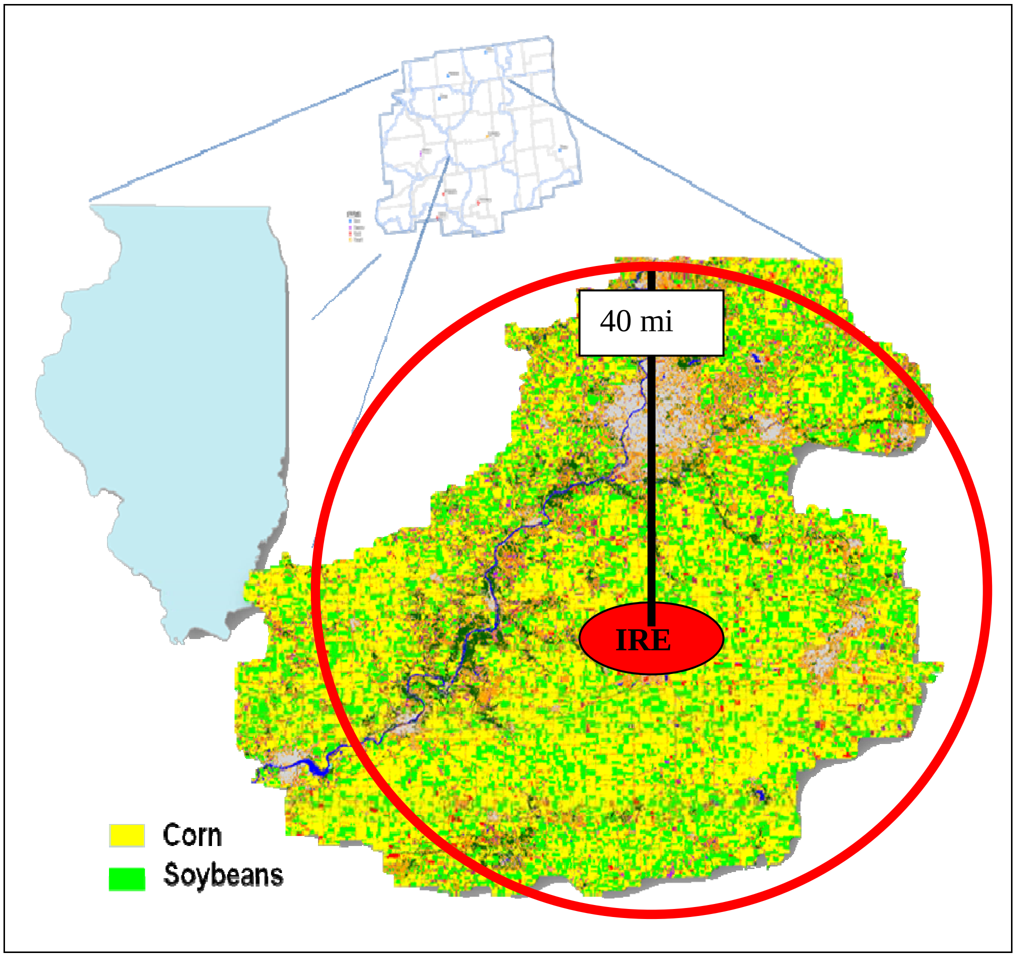


Figure 3: ProExporter polygon for Illinois River Energy plant

3.2) Corn Extensification

Based on the established corn draw area, the analysis in this section determines conversion of non-ag land to corn. The first step of this analysis combined USDA NASS Cropland Data Layer with the circle file (see Figure 4). The USDA NASS Cropland Data

Layer is a spatial crop type map developed from satellite imagery. The Cropland Data Layer has been shown to have accurate methods of around 95% for the delineation of corn and soybeans (Johnson 2007). NASS is only interested in crop land acreage and that data is updated every year. 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). Since the national land cover data set is dated higher uncertainties exist for land covers other than crops assessed in this study.

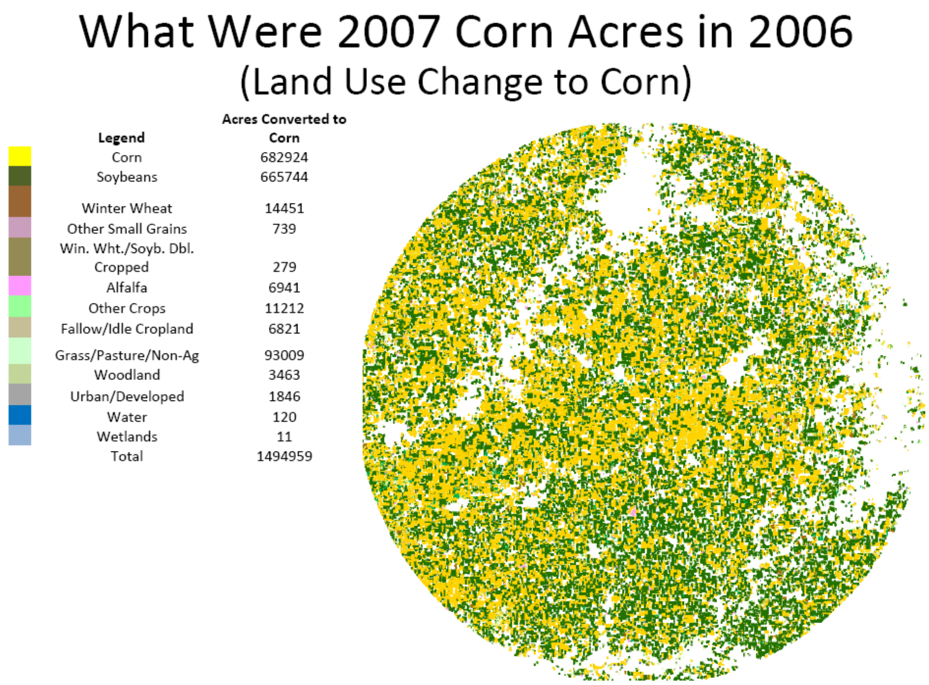


Figure 4: Land Use of 2007 Corn Acres in 2006

Once the crop types were extracted for the ethanol plant draw area using the 2005, 2006, and 2007 Cropland Data Layers, analysis was performed to calculate the acres in corn in 2005, 2006, and the acres in corn in 2007. This is a straightforward process using the spatial data from the satellite classification. Each pixel (minimum discernable ground unit) of the satellite was 30 square meters in 2005 (Landsat satellite) and 56 square meters in 2007 (AWiFS sensor). AWIFS data has a revisit time for every location of every 5 days whereas Landsat has a revisit time of 16 days. Therefore AWIFS exhibits a higher accuracy for crop type detection. Going forward USDA will use AWiFS imagery.

A simple equation converted each pixel to acres to derive the spatial “mask” of corn acres in 2007. The mask of corn acres from the 2007 Cropland Data Layer was used to mask out the same locations in the 2005 and 2006 Cropland Data Layer. Again, the pixels were multiplied by acres to derive acreage for the land use of the masked area in previous years. The acres for each crop type derived with the above approach are listed in column 1 of Table 4 (NASS Unvetted). This data is identical to the data used in the IRE GWI study.

As part of the present study additional vetting of the data was performed by applying a routine to the masked area that subtracted a ¾ acre buffer along the roadways. As a result a total of 85,329 acres that were originally primarily categorized as grass/pasture/non-ag conversion to corn were now correctly identified as a mix of nonag use and corn and treated as neutral. It is generally the case that a mixed parcel consists of small strips of roadway, for example, and a larger area of corn with the roadway prompting the misclassification. The test samples in Figure 6 confirm that these parcels were indeed roadway buffers around agricultural land. Furthermore, an additional 26,616 acres which, in the imagery evaluation routine were classified as ag to non-ag to ag conversion (an unlikely scenario) were categorized separately. Test samples again confirmed that ag to non-ag to ag conversions are misclassifications and that the land was in fact in continuous agriculture (see Figure 6). With 111,945 acres in these two categories a corresponding decrease in the following categories was observed: urban areas to corn; woodland conversions to corn; grass pasture to corn conversions; grass/clover wildflowers to corn; fallow/idle cropland to corn. Additional test samples in each of these categories were taken and analyzed to confirm that, in fact, the decreases in these categories from the applied data vetting routines are justified. All samples showed that no actual land use change had taken place. These test samples are shown in Appendix A.

Table 4: Rotations into Corn from 2006 to 2007

Land Use	2007 Crop Acres in 2006		
	NASS Unvetted Acres	NASS Vetted Acres	
Corn	682,924	680,340	
Soybeans	665,744	661,660	
Winter Wheat	14,451	15,026	
Other Small Grains	739	274	
Win. Wht./Soyb. Dbl. Cropped	279	110	
Alfalfa	6,941	3,060	
Other Crops	11,212	9,428	
Fallow/Idle Cropland	6,821	1,608	
Grass/Pasture/Non-Ag	93,009	3,982	Non-ag to corn (Grass/Pasture/Non-Ag through Wetlands)
Woodland	3,463	122	
Urban/Developed	1,846	5	
Water	120	0	
Wetlands	11	0	
Ag 2005 to Non-Ag to Ag Land		26,616	
Field and Roadway Fringes		85,329	
Total Analyzed	1,487,560	1,487,560	

The vetted data in column 2 of Table 4 indicates that only 4,109 acres were potentially converted from non-ag use to corn growing (0.28% of the 1.487 million acres in corn). Therefore, it can be concluded that the start-up of the IRE plant did not promote corn extensification (the conversion of non-ag acres to corn). Furthermore, conversion did not occur despite the fact that additional land would have been available for conversion to agriculture within the corn draw area. Table 5 below lists all acres additional categories that did not convert into cropland from 2006 to 2007.[iv] As can be seen more than 315,000 acres of additional land in categories where one could have expected a substantial conversion to corn. These conversions did not occur.

Finally, the study documented that there is a substantial possibility for errors when applying remote sensing to ethanol related land use studies. Without applying sophisticated masking routines, 111,945 acres (85,329+26,616) would haven been incorrectly identified as land use changes to corn.

Table 5: Non-ag Land within the IRE Corn Draw Area

Land Use	Acres
Fallow/Idle Cropland	5,227
Grassland herbaceous:	35,359
Grass/Pasture/Non-Ag	16,782
Pasture/hay	259,110
Total:	316,478

Test Samples: Errors from Roadways, Field Edges, and Building Structures were Eliminated with Buffer Routine

Pixels along field edges, roadways, and building structures are often a mixture of signals. These areas may fluctuate between agriculture and non-agriculture from year to year.

Area along roadway | 2006 Aerial Photograph | 2007 Aerial Photograph

This 11 acre area of roadway between two agricultural fields was identified as agriculture in 2006 and urban in 2007. Areas like this are often mis-classified when assessing land use change and were therefore removed from the project analysis.

Areas identified as woodlands in 2006 and corn in 2007 (122 acres were estimated)

Area identified as woodlands to corn | 2006 Aerial Photograph | 2007 Aerial Photograph

This seven acre area was classified as woodlands in 2006 and corn in 2007 but appears to have been in agricultural production both years. Trees surrounding the field may have led to the mis-classification in 2006.

Area identified as urban to corn | 2006 Aerial Photograph | 2007 Aerial Photograph

This five acre area (in red to the left) was identified as a land use change from urban in 2006 to corn in 2007. Aerial photography from each year indicates that the area was an agricultural field in both years. Its proximity to the buildings to the right probably caused the confusion in the classification.

Figure 5: Errors in Land Use Changes from Roadways and Field Edges

Test Samples: Ag to Non-Ag to Ag Conversions Were Excluded as Improbable
Areas identified as agriculture in 2005 to a non-agricultural area in 2006 and then back to an agricultural area in 2007 were excluded from the analysis as improbable scenarios

2005 Ag/2006 Non-Ag/2007 Ag   2005 Aerial Photograph   2006 Aerial Photograph   2007 Aerial Photograph

This 114 acre field was identified as an agricultural area in 2005, a non-agricultural area in 2006 and an agricultural area in 2007. Based on the aerial photography, the area remained in agriculture in 2006. Likely, the field was planted late but even if it was left fallow it would still be considered agriculture.

2005 Ag/2006 Non-Ag/2007 Ag   2005 Aerial Photograph   2006 Aerial Photograph   2007 Aerial Photograph

These 45 and 11 acre fields also appear to be late plantings or fallow in 2006 which may have led to the mis-classification as non-ag areas in 2006, but it is clear that this is not a land use change location.

Figure 6: Errors in Land Use Changes Resulting in Ag to Non-ag to Ag Conversions

3.3) Corn Intensification

The analysis in the last section on corn extensification determined if, potentially driven by the new ethanol plant, non-agricultural land went into new corn production. Conversely, this section looks at corn intensification: whether the new ethanol plant may have influenced crop conversions from non-corn crops to corn.

As shown in Table 6, IRE requires 20,450,000 bushels of corn to produce 55 mgpy of corn ethanol on an annual basis. At the surveyed yield of 196.1 bu/acre the 2007 land requirements totaled 104,284 bushels. However, corn production in the corn draw area went up by 261,574 acres (2.5 times the IRE corn requirements) while soy production went down by 299,365 acres (almost 3 times the acres required for IRE corn production). Clearly, while IRE may have had a small influence on corn intensification, other variables (maybe economics, high export demand) seemed to drive corn intensification.

The current IRE land demand of 104,284 amounts to 7% of the total corn acres within the corn draw circle, a relatively small fraction of corn acres. While 7% of corn acres are diverted to IRE corn ethanol production, yield increases in the corn draw area between 2007/2006 and between 2006/2005 were 5.4% and 11%, respectively. In other words, the corn requirements for IRE were almost met by yield increases in the corn draw area. Counting DDGS produced at IRE as a corn-substitute co-product, IRE's corn supply/co-product balance was likely met by yield increases alone. We recognize that this is a snapshot of past conditions and yields may vary over time.

However, a recent report estimates national yields to reach 289 bu/acre by 2030 (Korves, 2007). If this is the case for the IRE corn draw are, the IRE land requirements would drop from currently 104,284 acres to 70,761. If corn acreage stays the same in the corn draw area, IRE will require only 4.8% of the land for its corn supply.

Table 6: Corn Intensification within the IRE Corn Draw Area

	2007	2006	2005
Corn Yield IRE Grower Survey (bu/acre)	196.1	186.1	167.4
Corn Yield Increase 2007-2006	5.4%		
Corn Yield Increase 2006-2005		11.2%	
IRE Delivered Corn (bu)	20,450,000		
IRE Required Acres	104,284		
IRE Acres as Percent of Corn Draw Area	7.0%		
Corn Acres	1,487,560	1,225,986	1,158,809
	261,574		
Soy Acres	540,975	840,340	851,540
	-299,365		

In summary, we conclude that much larger adjustments in corn vs. soy acres have taken place than could have been prompted by IRE's operation: Corn intensification cannot be attributed to the operation of the ethanol plant.

4) CO_2 Sequestration and N_2O Emissions

Greenhouse gas emissions from most agricultural systems (rice excluded) are primarily driven by the balance between N_2O emissions and carbon sequestration. Emissions and sequestration assessments differ by a large variety of variables (soil type, climate, management practices). Likewise, the employed methods that quantify emissions and sequestration effects differ by the treatment of these variables. The IRE GWI study assessed emissions and sequestration effects for the IRE corn draw area according to several methodologies including those by Mummey et al (1998) and Eve et. al. (2002). Since these assessments depend on crop rotations and since the present study produced more accurate land use change data, we must first reassess crop rotation patterns as well.

4.1) Crop Rotations

Using the vetted land use data detailed in Table 4 a model routine was created to reassess 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, 2006, and 2007 (as opposed to how did the land use change within a masked area analyzed above). Figure 7 and Figure 8 below show land use rotations are dominated by corn-soy-corn (34%) followed by corn-corn-corn (26%). The diversified category includes primarily rotations of wheat, small grains, and other crops to corn.

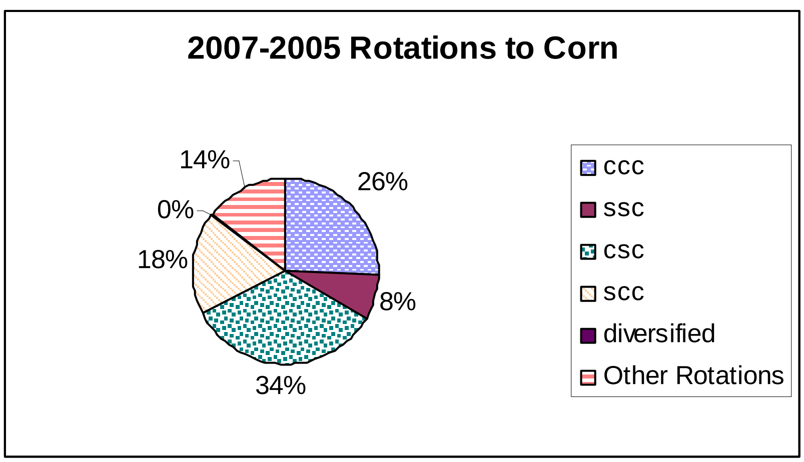


Figure 7: Land Rotations in Percent

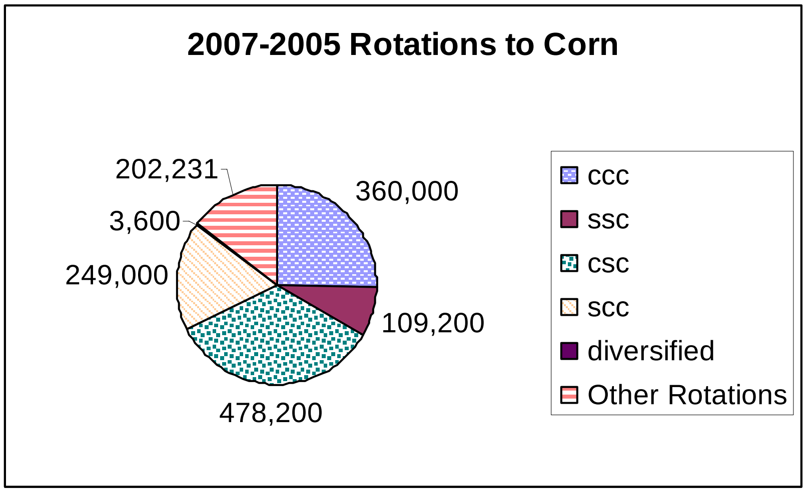


Figure 8: Land Rotations in Acres

4.2) N_2O Emissions and Carbon Sequestration

The N_2O Emissions below are calculated according to several different methodologies. Detailed background on the employed methodologies can be found in the IRE GWI Study.

Using the reassessed crop rotations and the surveyed tillage practices, the N_2O -Emissions based on Mummey et al (informed by Wander) total 15.09 g/bu or 91,403 tonnes CO_2e (from N_2O) for all bushels delivered to IRE (Mummey, 1998).[v,vi,vii] The supporting table is provided in Appendix B. The second methodology followed Argonne's GREET model, which is based on an emissions factor approach. The current GREET default value results in 11.7 g/bu or 70,822 tonnes of CO_2e emissions for IRE's corn demand. Applying the surveyed N-fertilizer inputs (368 g/bu or 0.811 lb of N per bushel) to the GREET emissions factor equation results in 10.6 g/bu or 64,164 tonnes of CO_2e emissions. Finally, several N_2O measurements using measurement chambers at the University of Illinois at Urbana Champaign yielded lower results in the range of 0.94 to 1.41 g/bu of CO_2e emissions (Wander, 1998). The midpoint of 1.2 g/bu resulted in 7,113 tonnes of CO_2e emissions.

While nitrogen inputs of 0.811 lb/bu are already fairly low a potential further reduction in nitrogen inputs could be possible. High fertilizer prices, sophisticated precision agriculture technologies, or government incentives may be potential drivers to reduce N inputs in the future. If we assume an N-input rate of 0.65 lb/bu (294.8 g/bu) close to the theoretical minimum and the GREET emissions factor equation, N_2O emissions drop to 9.1 g N_2O per bushel or 55,085 tonnes for the IRE demand.

CO_2 Sequestration effects were also calculated according to different methodologies. Using the reassessed crop rotations and the surveyed tillage practices, the CO_2 sequestration effects based on Eve et al. (informed by Wander) total 259 g/bu or 5,300 tonnes for all IRE bushels (Eve, 2002).[viii,ix,x] The supporting table is provided in Appendix B. For the Illinois region, the Chicago Climate Exchange (CCX) offers soil carbon management offsets of 0.6 metric tonnes per acre per year for agricultural land treated with conservation tillage practices. At the surveyed rate of 13% no-till/strip till for IRE acres the CCX rate would result in soil carbon management offsets of 8,134 tonnes per year (assumes 13% of 104,450 acres required for IRE supply or 13,560 acres use conservation tillage). A long term study by the University of Illinois Extension Service (UIES) measured carbon sequestration on fields in no-till since 1967. The study summary data is listed in Appendix C. Over a period of 12 years, the study determined an annual sequestration rate of 1.67 metric tonnes per acre, which, at a 13% no-till/strip till rate would result in 22,645 tonnes per year.[xi][xii]

There is further room for improvement. Using Eve et al and encouraging 100% no-till (as opposed to the currently practiced 13%) would increase CO_2 sequestration to 30,820 tonnes on IRE supply acres (but it would in turn slightly increase N_2O emissions in the Mummey model). Eve et al and direct measures show that adding winter cover crops could additionally double the carbon sequestration rates to 61,640 tonnes on IRE supply acres. Using the CCX factors, if we assume 100% no till on all IRE supply acres we calculate 62,570 metric tons of carbon management offsets. Using UIES sequestration values and going to 100% no-till would result in 174,432 tonnes of carbon sequestered per year. Also, since the survey showed no-till practices for 13% of acreage around IRE, carbon sequestration values according to CCX for all acres in the corn draw area were calculated. Based on these assumptions 13% of the 1.48 million acres would sequester 116,030 tonnes of CO_2. Using UIES sequestration values would result in 321,308 tonnes.

The Table 7 and Figure 9 below summarize the carbon assessment findings. The left y-axis displays the total carbon emissions/sequestration values on all acres supplying IRE (104,450 acres). The right y-axis displays the carbon emissions/sequestration values per heating content of ethanol produced. In summary, N_2O emissions and carbon sequestration effects could be of the same magnitude. The increased carbon sequestration from no-till and winter cover crops can provide significant reductions to the GWI of corn ethanol. Therefore, ethanol plant operators could encourage these practices in their region. If ethanol plants in addition to their own suppliers could take credit from encouraging no-till in their region, large additional GWI reductions could be possible.

The solid bars on the right represent the carbon emissions/sequestration values assuming 13% no till across the whole draw area and applying the CCX and UIES sequestration values (rather than for the IRE supply acreage only). If IRE was able to take credit for the sequestration associated with these no till efforts in its whole corn draw area, the contributions using CCX and UIES values would amount to 25 gCO_2e/MJ and 69.1 gCO_2e/MJ, respectively. The potential implication from this assessment is the following question: Should or could an ethanol plant be able to take sequestration credits for its product by encouraging no-till among farmers in an ethanol plant's whole draw area?

The IRE GWI Study found that the life cycle global warming impact of corn ethanol produced at the plant totals 54.8 gCO_2e/MJ, which is 21% lower than the current GREET default natural gas dry mill corn ethanol plant and 40% lower than gasoline (see Table 8 and Figure 10). Subtracting the average sequestration numbers for the 13% of IRE supply acres under no-till/strip till (CCX, UIUC, UIES average values for 13% no-till from

Table 7) from the life cycle of IRE corn ethanol of 54.8 gCO_2e/MJ reduces it to 52.2 gCO_2e/MJ. Subtracting the average sequestration numbers for encouraging 100% no-till on IRE supply acres from the life cycle of IRE corn ethanol reduces it to 35.9 gCO_2e/MJ. Since, as a first order estimate, encouraging 100% no-till in this case is likely equivalent to encouraging 50% no-till and 50% winter cover crops these practices would alternatively result in a GWI of 35.9 gCO_2e/MJ at IRE. These values exclude GWI contributions from indirect/international land use changes since, as demonstrated, IRE did not measurably effect land use.

Table 7: N2O Emissions and Sequestration Values

Metric Tons Sequestered on IRE Acres	CO2e for IRE Supply Acres (tonnes/y)	IRE Ethanol GWI Contribution (g/MJ LHV)*
N2O: Mummey Factors	91,403	19.6
N2O: GREET Default	70,822	15.2
N2O: GREET IRE Customized	64,164	13.8
N2O: GREET N-Application Optimized	55,085	11.8
N2O: IL Measured	7,113	1.5
Sequestr.: UIUC Factors, 13% no till	-5,300	-1.1
Sequestr.: CCX CMO, 13% no till	-8,134	-1.7
Sequestr.: UIES, 13% no till	-22,645	-4.9
Sequestr.: UIUC Factors, 100% no till	-30,830	-5.8
Sequestr.: UIUC Factors, 100% no till, Winter Cover	-61640	-11.7
Sequestr.: CCX CMO, 100% no till	-62,570	-13.4
Sequestr.: UIES, 100% no till	-174,432	-37.5
Whole Draw Area: CCX CMO 13% no till	-116,030	-25
Whole Draw Area: UIES 13% no till	-321,308	-69.1

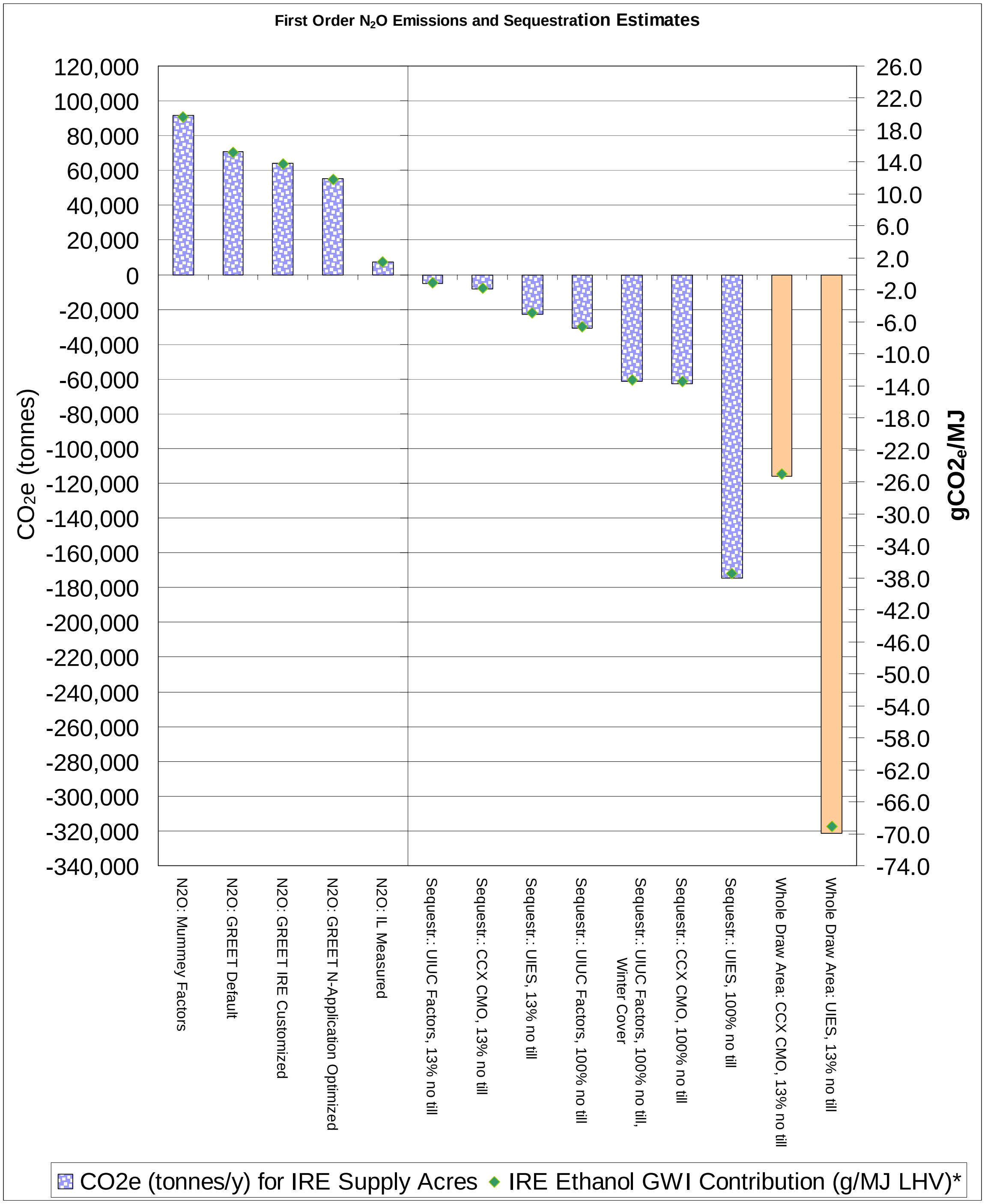


Figure 9: Carbon Assessment Summary

Table 8: GWI of IRE Produced Corn Ethanol

	Gasoline	GREET Default	IRE	IRE & Avg 13% No-Till	IRE & Avg 100% No-Till
N Fertilizer			14.2	14.2	14.2
Other Ag and Distribution			11.9	11.9	11.9
IRE Biorefinery			28.7	28.7	28.7
C-Sequestration			0.0	-2.6	-18.9
Net GWI	92.1	69.1	54.8	52.2	35.9

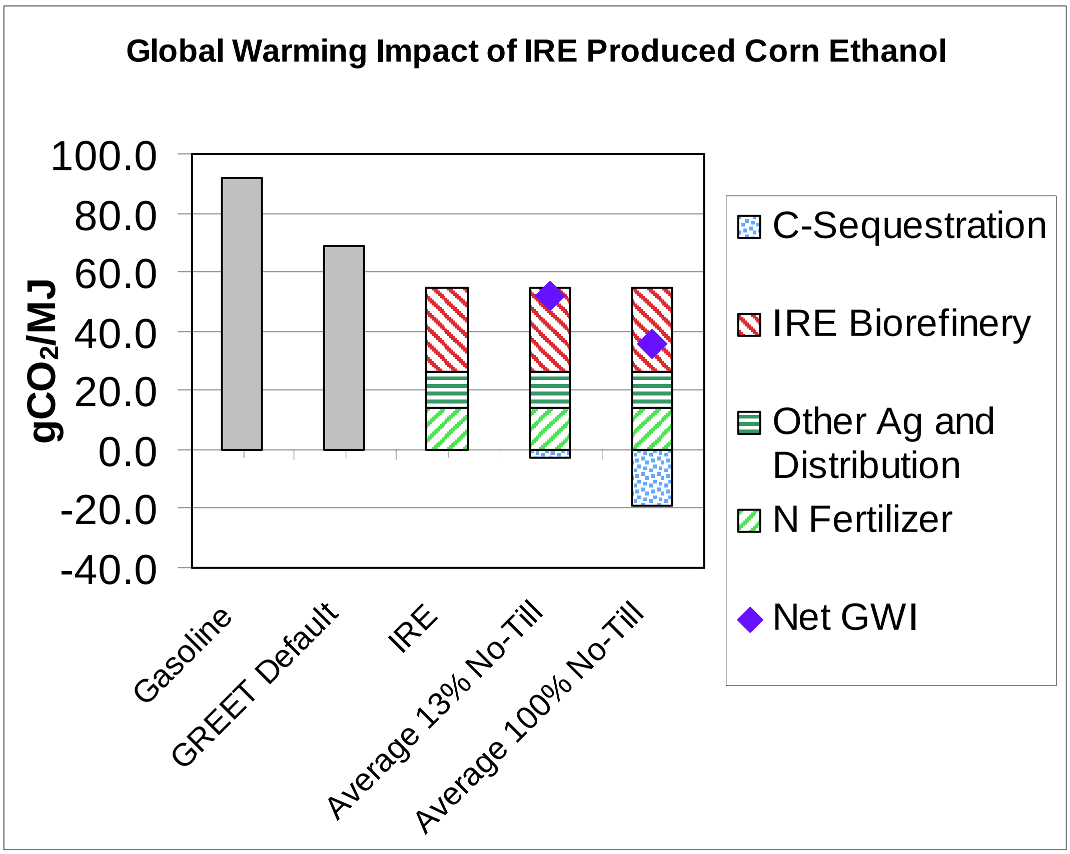


Figure 10: GWI of IRE Produced Corn Ethanol

Appendix A: Examples of Errors in Non-Agriculture Land Use Change

Test Samples: The test samples below confirm that the data vetting routines correctly eliminate errors in land use change classifications. The decreases in several categories (woodlands to corn, grass/pasture to corn, grass/clover/wildflowers to corn) reflect the correct classifications.

Area identified as woodlands to corn 2006 Aerial Photograph 2007 Aerial Photograph

This six acre area that was classified as woodlands in 2006 and corn in 2007 appears to have been in woodlands both years according to the aerial photography from each year. Again, its narrow east to west dimensions may have led to pixels with a combination of agriculture and forestry being identified as each class in 2006 and 2007.

Grass/Pasture/Non-Ag in 2006 to Corn in 2007 (3,982 acres were estimated)
Area identified as grass to corn 2006 Aerial Photograph 2007 Aerial Photograph

This 21 acre field appears to be in bare soil but an agricultural field in the 2006 image which may have led to it's classification as a non-agricultural area in 2006, but in corn production in 2007.

Area identified as grass to corn | 2006 Aerial Photograph | 2007 Aerial Photograph

This 6.5 acre area along a roadway was identified as grassland in 2006 and corn in 2007. The aerial photography, however, does not indicate any land use change between these two years.

Areas identified as grass/clover/wildflowers in 2006 and Corn in 2007 (216 acres)

Area identified as grass/clover to corn | 2006 Aerial Photograph | 2007 Aerial Photograph

This 4.5 acre location identified as grass/clover/wildflowers in 2006 and corn in 2007 appears to be a home site with grass surrounded by agricultural production which probably led to the errors in classification.

Area identified as grass/clover to corn | 2006 Aerial Photograph | 2007 Aerial Photograph

This seven acre area which appears to be a stream buffer does not indicate, from a review of the aerial photograhy, any land use change associated with a grass/clover/wildflower area being converted to agriculture. The area appears to be grass in both years.

Appendix B: N2O Emissions and Carbon Sequestration Calculations

		CSC,SSC, Other Rot.	SCC/CCC	Other Rotations, Diversified
N-Emissions Factors		kg N2O-N/ha per y	kg N2O-N/ha per y	kg N2O-N/ha per y
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, Minimum Till (%)	0.13			
Blended Emissions Factor (kg N2O/ha per y)		3.765	2.991	4.774
Blended Emissions Factor (kg N2O/acre per y)		1.524	1.210	1.932
Bushels Delivered to IRE	20,450,000			
Average Yield	196			
Corn Acres Needed for IRE Supply	104,337			
What were 2007 IRE Acres in 2005 (%)		42%	43%	14.7%
What were 2007 IRE Acres in 2005 (acres)		43,707	45,314	15,315
Emitted N2O-N (kg/y)		66,596	54,851	29,590
Total Emitted N2O-N on IRE Acres (kg/y)	151,037			
Total Emitted N2O-N of IRE Del. Corn (g/bu)	7.39			
Total Emitted N2O of IRE Del. Corn (g/bu)	11.61			
Indirect Emissions Factor	30%			
Total direct and indirect emissions (g/bu)	15.09			

		CSC,SSC, Other Rot.	SCC/CCC	Other Rotations, Diversified
CO2 Sequestration Factors		tC/acre per year	tC/acre per year	tC/acre per year
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 Squestration Factor		0.011	0.070	-0.144
Bushels Delivered to IRE	20,450,000			
Average Yield (bu/acre)	196			0
Corn Acres Needed for IRE Supply	104,337			
What were 2007 IRE Acres in 2005 (%)		42%	43%	15%
What were 2007 IRE Acres in 2005 (acres)		43,707	45,314	15,315
Sequestered Carbon (t/y)		494	3,149	-2,198
Total Sequestered Carbon on IRE Acres (Mt C/y)	1,445			
Total Sequestered Carbon on IRE Acres (MT CO2/y)	5,300			
Total Sequestered Carbon on IRE Acres (MT CO2/acre)	0.05			
Total Sequestered Carbon on IRE Del. Corn (g CO2e/bu)	259			

Appendix C: Carbon Sequestration Using No-till Production in Southern Illinois

Michael Plumer, University of Illinois Extension

The study was conducted at the University of Illinois Extension Ewing Field site near Mt. Vernon, Illinois. Established in 1969 this site has the oldest continuous no-till plot in the Midwest. The plot has been in continuous no-till production since that time and is in a corn soybean rotation. An adjoining plot was in conventional tillage, moldboard plow and disk system until 1992 when it was converted to continuous no-till. This plot is in a corn, corn, soybean, wheat rotation. The soil type is a *Cisne gray prairie claypan silt loam, fine, smectitic, mesic Mollic Albaqualfs*. Both sites started with the same organic matter level of 1%.

Each site has 15 sample points and the data represents the average value for those samples. Sampling has been done in 1" increments to a depth of 8"and in 2" increments to a depth of 14". The A horizon is at a depth of 8"with an acidic subsoil in the range of 4.5 to 5.0 pH. Both plots received a lime application initially and again in 1983. No lime has been added since and soil tests do not require any pH modification.

No-till planting has been done on a timely basis, and as early as soil moisture conditions would allow. All nitrogen was surface applied as 34-0-0 until 1995 when nitrogen was injected as liquid fertilizer 28%. Residue was not disturbed from harvest till spring planting. Fertility was applied based on crop removal. The following table represents the changes in carbon in the soil profile.

	Ewing Field Carbon			
Surface Depth	1992 long no-till carbon (#/a)	2003 long no-till carbon (#/a)	1992 conv.1992 carbon (#/a)	2003 conv. 1992 Carbon (#/a)
0-1	6045.0	6692.7	1727.1	5181.4
1-2	4533.7	6692.7	2374.8	5181.4
2-3	4102.0	6692.7	2158.9	5181.4
3-4	3454.3	6692.7	2158.9	5181.4
4-5	3022.5	6692.7	2158.9	5181.4
5-6	1727.1	6908.5	1727.1	5397.3
6-7	2374.8	6908.5	1079.5	5181.4
7-8	2590.7	6260.9	1079.5	4317.8
8-10	4317.8	12521.7	2158.9	8635.7
10-12	3022.5	10362.8	3886.1	7772.1
12-14	4317.8	7340.3	4749.6	7772.1
Sum	39508.2	83766.1	25259.4	64983.5
	Carbon Increase in Continuous No Till System:		Carbon Increase in Converting Conventional Till to No Till System:	
Difference (#)	44257.9		39724.1	
Difference per Year (#)	3688.2		3310.3	
Difference per Year (Mt)	1.67		1.50	

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Endnotes:

[i] The US EPA is starting to use satellite based data from Winrock International in their ethanol lifecycle modeling efforts.
[ii] 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.
[iii] The Proexporter Network (PRX) is a consulting firm specialized in U.S. grain flows, transportation demand, and the impact of these items on cash grain markets. Besides mapping systems for detailed analysis of U.S. grain movements PRX has also developed a geographic tool that assesses the corn draw areas around ethanol plants (the PRX Polygon).
[iv] This data has not been vetted to the above described standards but provides a first estimate of land additional land.
[v] Michelle Wander is the Director of the Agroecology and Sustainable Agriculture Program at the University of Illinois at Urbana-Champaign and Associate Professor of Soil Fertility and Ecology.
[vi] Emissions factors by Mummey et al informed by Wander:

	CSC,SSC, Other Rot.	SCC/CCC	Other Rotations, Diversified
N-Emissions Factors by Mummey et al.	kg N2O-N/ha per y	kg N2O-N/ha per y	kg N2O-N/ha per y
Conventional Till	3.7	2.9	4.8
No Till	4.2	3.6	4.6

[vii] This value is slightly lower than the IRE GWI study due to the adjusted crop rotations. The CO2e emissions in the IRE GWI study were 92,917 tonnes.
[viii] 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.
[ix] CO2 sequestration factors by Eve et al. informed by Wander:

	CSC,SSC, Other Rot.	SCC/CCC	Other Rotations, Diversified
CO2 Sequestration Factors by Eve et al.	tC/acre per year	tC/acre per year	tC/acre per year
Conventional Till	0.01	0.05	-0.15
No Till	0.02	0.2	-0.1

[x] This value is higher than the IRE GWI Study due to the adjusted crop rotations. The value in the IRE GWI Study was 2,160 tonnes
[xi] The 13% no-till/strip till include 3% strip till. The carbon sequestration rates of strip till are probably slightly lower than for no-till (about 10% lower per Michael Plumer, UIES). However, IRE is located in a slightly colder region than the Ewing plots, which should increase carbon sequestration. Therefore, the sequestration value of 1.67 Mt should be close for the assessed tillage practices.
[xii] The soil type from this sequestration study may not be fully reflective of the soil type surrounding IRE. However, the Uof I Extension study was able to document (for the studied conditions) long-term continuous sequestration effects.

Use of Remote Sensing to Measure Land Use Change from Biofuels Production

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Abstract

The introduction of remote sensing datasets into the assessment of land use change associated with bio-fuels production seems obvious. Remote sensing offers the opportunity to image the extent of land use change but the errors associated with the classification must be taken into account. The present study assesses the accuracy of both direct and indirect land use changes predicted with different sensors (AWiFS, SPOT-VEGETATION, MODIS) for different regions (Illinois, Brazil) and different ecosystems (forest, cropland, savannah).

We found that direct land use changes for biofuels production can be assessed using higher resolution imagery from sensors such as Landsat Thematic Mapper and AWiFS (30m and 56m, respectively) if the data is further vetted for field and roadway fringes. The accuracy of this process is likely in excess of 95%. In contrast, indirect land use change assessments for biofuels production using imagery from SPOT-VEGETATION or MODIS (1km and 500m spatial resolution, respectively) produce results with high inaccuracies. In fact, the combined error range may exceed the predicted land use change between important ecosystem transitions for biofuels analyses such as the conversion of tropical rainforest to cropland in Brazil.

Regulatory agencies such as the California Air Resources Board and the US EPA, which are in a rule making process to incorporate land use considerations for biofuels production, must consider the limitations of remote sensing for this purpose. We recommend that land cover products based on the resolution of AWiFS imagery or better for transition regions associated with indirect land use change are created.

Introduction

Over the last three years increased biofuels production has frequently been recognized as a means to reduce the United States' dependence on foreign transportation fuels. However, several studies assert that crop demand for biofuels production may prompt conversion of native ecosystems to agriculture. This conversion process of ecosystems may result in carbon releases from native biomass and negatively impact the greenhouse gas (GHG) profile of biofuels (Righelato 2007, Searchinger 2008). Two agencies, the California Air Resources Board and the US Environmental Protection Agency are currently in advanced stages to develop rules on how to quantify and include GHG emissions when comparing the environmental impact between different fuel pathways (California Environmental Protection Agency 2009). The initiating legislation for the rule making process are the California Low Carbon Fuel Standard (LCFS) and the Federal Renewable Portfolio Standard (RPS), which require that the GHG emissions from biofuels have to be assessed on a full life cycle basis including contributions from direct and indirect land use change.

GHG emissions from direct land use change are generally considered to include those emissions associated with the direct supply chain of biorefineries (Plevin 2008). For corn ethanol this includes emissions from land converted to corn crop to meet the incremental demand of an ethanol plant. Economics-based indirect land use change models take market forces into account which act to induce land use change on domestic but mostly foreign land that is not part of the direct supply chain (Kim 2008). For example, one proposition of these model efforts is that increased ethanol production in the US leads to increased planting of corn which reduces available areas for soybean production thus reducing soy export from the US. In turn, other countries, such as Brazil will adjust their agricultural land use and ultimately convert native land to meet the soybean shortfall created by US biofuels production.

The quantification of the GHG impact from this process is captured by models in a two stage process: a) the adjustments in land surface area converted to crop in different countries is quantified for various US biofuels production scenarios (i.e. amount of new hectares in corn, soybeans, etc. in each country), followed by b) an assessment of what types of ecosystems are being converted to crop production (i.e. hectares of rainforest to corn, hectares of savannah to soybeans, etc.). Most datasets that are used to assess the types of ecosystems conversions taking place for biofuels production are based on remotely sensed imagery. However, we are not aware of a sound assessment that determines the accuracy of remote sensing with a focus on land use changes for biofuels production. The hypothesis of this study is that the accuracy of these global remotely sensed information products is insufficient for determining land use changes from biofuels production.

The use of remotely sensed imagery for the determination of land cover is well documented. Since the 1970s, with the launch of the first Landsat satellite by NASA, this imagery has been classified with a good level of success into land cover parcels. From the type of cover, it is usually self-evident what the land use is. For instance, if the land cover is pavement, it is safe to assume the land use would be human development or urban. In addition, when compared from year to year, satellite imagery can identify land use change. If an area is identified as agriculture one year and human development the following year it may be assumed that the area is one of urban encroachment.

Comparison of Spatial Resolutions for Different Sensors

The recent introduction of remote sensing datasets into the assessment of land use change associated with the possible expansion of agriculture to accommodate bio-fuels production seems obvious. Remote sensing offers the opportunity to directly image the extent of land use change but the errors associated with the classification must be taken into account. For instance, if 15% of forested areas are incorrectly identified in year one and 10% are incorrectly identified in year two, the error range totals 25%. Another common problem with land use change is the nature of the occurrence itself. Land use change usually occurs in transition areas between two land cover types such as forestry and agriculture. These transition areas are prone to mis-classification from a mixed pixel effect. A pixel is the minimum area on the ground for which one value associated with the intensity of light reflected from the earth's surface is being recorded. If the area within a pixel consists of more than one land cover type it can be mis-classified, especially from one year to the next. These errors may seem minor but when assessing land use change on a regional scale over millions of hectares, small percentage errors can indicate large, incorrect changes. The higher the number of pixels recorded by a sensor for a given surface area the higher is the spatial resolution of the imaging system.

Figure 1 below shows a 1 km area in Illinois captured with sensors onboard different satellites. Depending on the spatial resolution of the sensor on the satellite the 1 km area is divided into different amounts of pixels. The square on the top left in Figure 1 shows an aerial photograph of the scene with agricultural land, water, urban/buildings and roadways. Buildings and roadways make up a significant part of the scene.

The square on the top right shows the same scene with the 30 m resolution Landsat Thematic Mapper (TM) sensor, which was used by USDA for the NASS Cropland Data Layer from 1999 to 2005. We can see how the USDA NASS Cropland Data Layer classification for 2004 using the Landsat TM captures the waterway, the grass, the forest, and the urban areas. Currently, USDA NASS is using the AWiFS sensor for the Cropland Data Layer with a resolution of 56 m, which is close to Landsat (AWiFS also has a shorter re-visit time of 5 days versus 17 days for TM, which increases accuracy).

The square in the lower left corner of Figure 1 shows the same scene with the 2004 Global Landcover Classification's 500 m resolution from the MODIS sensor. US EPA has stated that their modeling efforts for life cycle analyses of the Renewable Portfolio Standard are relying on MODIS satellite data. We see that with MODIS significant reductions have been made and that one pixel now combines forest, crop and urban areas into one "crop" category.

Lastly, the lower right corner of Figure 1 shows the Illinois scene with a 1km resolution from the SPOT-VEGETATION sensor, which is, for example used for the "New IPCC Tier-1 Global Biomass Carbon Map for the Year 2000" (Ruesch 2008). With this sensor, the complete scene is further reduced and characterized as cropland. Figure 2 provides a similar demonstration for a more homogeneous land cover scene in Illinois. As can be seen the MODIS and SPOT sensors combine the mixed land cover in that scene into one cropland category.

For the present study we chose the best possible sensors to determine the accuracy of modeling direct and indirect land use while acknowledging the tradeoff between resolution and cost (availability). Therefore, direct land use change was modeled using the higher resolution AWiFS sensor whereas indirect land use change was modeled using MODIS since this sensor produces a global land cover product. The region chosen for direct land use was modeled based on the corn supply area for an ethanol plant in Illinois; indirect land use change was modeled for Illinois and Brazil.

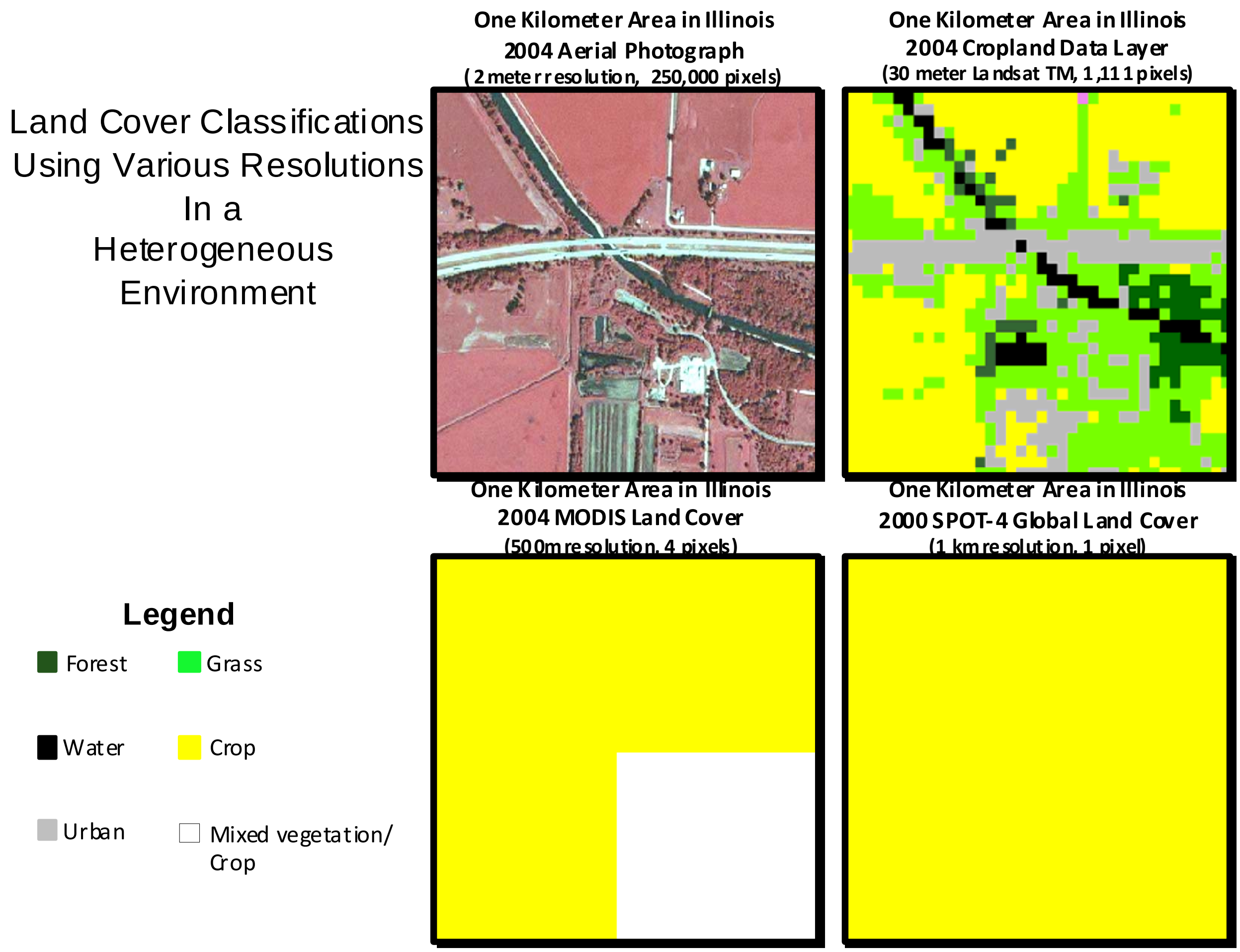


Figure 1: Example Scene 1 in Illinois. Satellite Imagery with Different Resolutions

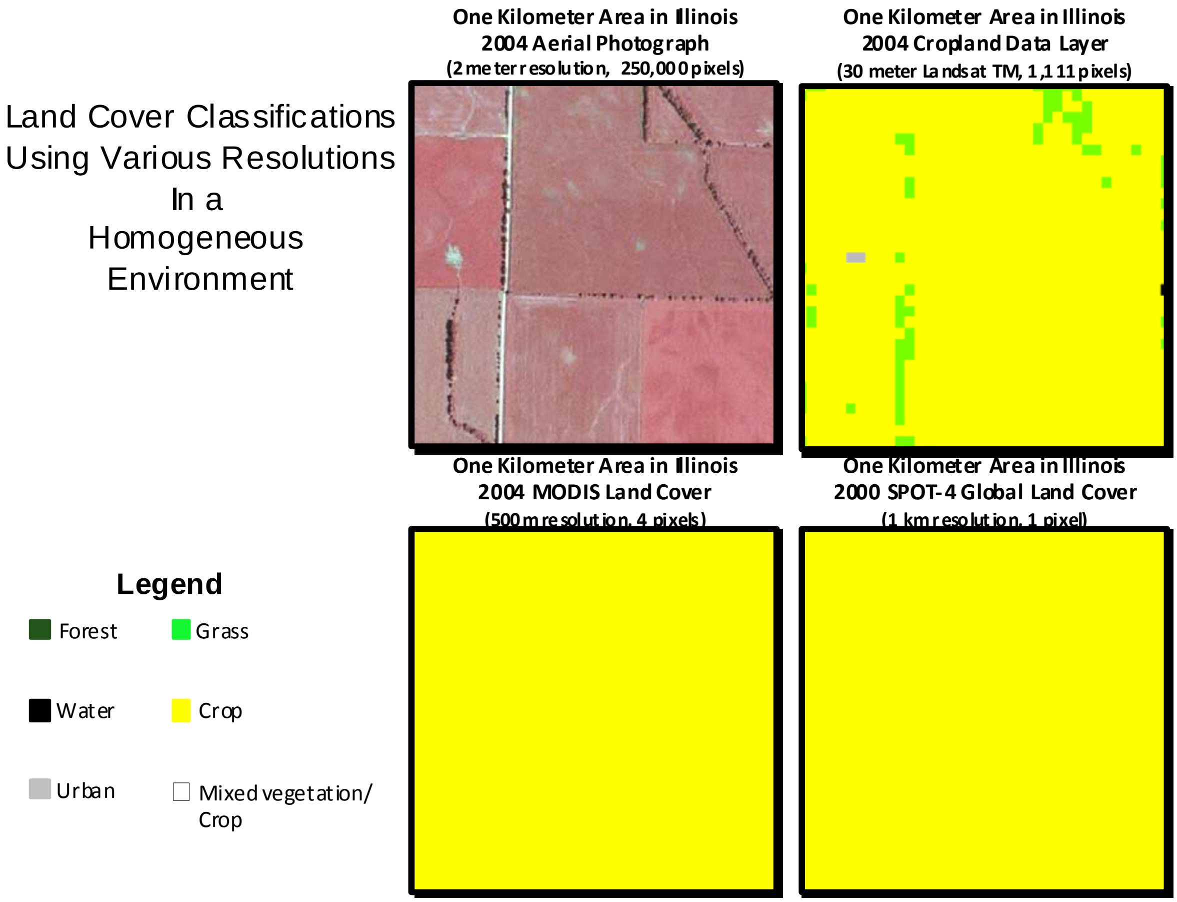


Figure 2: Example Scene 2 in Illinois. Satellite Imagery with Different Resolutions

Direct Land Use Change

In a previous study we assessed land use change for a 40 mile circle surrounding an ethanol plant in Illinois (Mueller 2008). For the present study we have further analyzed the data since it is representative of the accuracies that can be achieved for direct land use change assessments. The assessment uses the USDA NASS Cropland Data Layers for 2005, 2006 and 2007 (developed by USDA NASS using AWiFS imagery with 56 m resolution and 5-day revisit time for agricultural areas) combined with the 2001 National Land Cover Data (NLCD) set for non-agricultural classifications (which is currently the most recent version with a new version expected in 2010).[1] The overall accuracy of the cropland data for Illinois in 2007 is 97.6 % (cropland data includes agricultural classes only).[2] The error range for land use change between two years, in this case for Illinois, would approximate 2*(1-0.976)=4.8% .

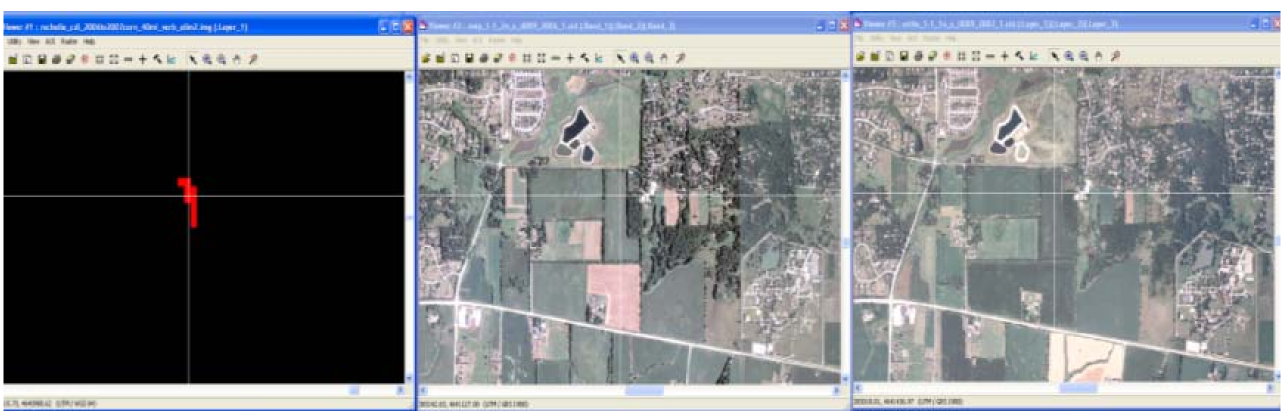
[1]Information on the National Landcover Dataset is available from the website of the Multi-Resolution Land Characteristics Consortium (MRLC) at http://www.mrlc.gov

[2]Accuracies for all USDA NASS Cropland data layers are available at http://www.nass.usda.gov/research/Cropland/metadata/meta.htm

However, the accuracies of the 2001 NLCD are lower and not consistently assessed. No formal accuracy assessment of the NLCD has been performed on a national basis, but overall accuracy assessments have been estimated at 83.9% (Homer et al. 2007). Furthermore, roadways and field fringes introduce further inaccuracies. Therefore, the accuracy assessment of our direct land use parcel employed an additional vetting routine.

The data showed that 39,841 hectare out of the 601,994 hectares in corn during the study year 2007 would have been predicted to change from non-ag use to corn, a predicted change of 7%. However, in a further analysis step, an additional vetting of the data was performed by applying a routine to the masked area that subtracted a 0.3 hectare buffer along the roadways. Subtracting the roadway buffers resulted in a significant drop of the non ag categories from a total of 39,841 hectares to 1,663 hectares or 0.27% of predicted non ag land use change. We took about 50 test samples with areal photography to confirm that these parcels were indeed roadway buffers or field fringes around agricultural land (see Figure 3). The characteristics of roadway buffers and fringes are such that very minor change in vegetation can prompt change in land use classifications. Furthermore, an additional 10,771 hectares which, in the imagery evaluation routine were classified as ag to non-ag to ag conversion (an unlikely scenario) over the three year period 2005-2007 were categorized separately. Test samples again confirmed that ag to non-ag to ag conversions are misclassified as continuous corn rotations.

We conclude that for direct land use change assessments for biofuels production where changes from non agricultural land to agricultural land are the focus, the lower accuracy of the NLCD as well as roadways and field fringes may lead to significant overestimations of land use change (39,841 hectares from non ag use to corn vs. 1,663 hectares). Therefore, additional vetting of the data needs to be performed for the purpose of direct land use assessments. Since the additional vetting affected primarily (non-agricultural) NLCD classifications, it can be asserted that the vetting process raised the lower accuracy associated with the NLCD to cropland data levels (in excess of 95%).



This 2.8 hectare area was classified as woodlands in 2006 and corn in 2007 but appears to have been in agricultural production both years. Trees surrounding the field likely led to the misclassification in 2006.
Figure 3: Field Fringe Test Sample

Land Use	2007 Crop Area in 2006			
	NASS Unvetted Hectares		NASS Vetted Hectares	
Corn	276,370		275,324	
Soybeans	269,417		267,764	
Winter Wheat	5,848		6,081	
Other Small Grains	299		111	
Win. Wht./Soyb. Dbl. Cropped	113		45	
Alfalfa	2,809		1,238	
Other Crops	4,537		3,815	
Fallow/Idle Cropland	2,760		651	
Grass/Pasture/Non-Ag	37,639	39,841 hectares Non-ag to corn	1,611	1,663 hectares Non-ag to corn
Woodland	1,401		49	
Urban/Developed	747		2	
Water	49		0	
Wetlands	4		0	
Ag 2005 to Non-Ag to Ag Land	0		10,771	
Field and Roadway Fringes	0		34,531	
Total Analyzed	601,994		601,994	

Table 1: Unvetted and Vetted AWiFS Crop Data

Indirect Land Use Change

NASA offers a global land cover product which has been developed from the agency's MODIS sensors on-board the Terra and Aqua satellites. As pointed out above the MODIS remote sensing data has been considered for land use change modeling of biofuels for regulatory purposes. Therefore, the accuracy of land use change predicted with MODIS land cover data was selected for further assessment.[1] The MODIS sensor collects images at 250 meter, 500 meter and 1 kilometer resolution pixels over every location on the earth's surface on a daily basis. The MCD12Q1 is processed at the 500 meter resolution. The global land cover product has been developed on an annual basis from 2001 to 2005 by combining cloud free MODIS images throughout the year and analyzing these multi-temporal datasets for land cover based on the reflectance and a detailed network of ground truth information.

The MODIS MCD12Q1 land cover dataset comes with a number of land cover classes identified. The MCD12Q1 actually comes in different land cover classification schemes including one develop by the University of Maryland and another that breaks agriculture into cereal and broadleaf crops. For this analysis, the International Geosphere Biosphere Programme (IGBP) land cover classification land cover types were used but aggregated to facilitate data analysis (see Table 2).

[1] The MODIS dataset, known as MCD12Q1 is available free of charge for download by the general public at ftp://e4ftl01u.ecs.nasa.gov/.

Table 2: Reclassification of IGBP Classes

IGBP Classification Scheme	Classification Scheme Used for This Analysis
Water	Water
Evergreen Needle-leaf forest	Forest
Evergreen Broad-leaf forest	Forest
Deciduous Needle-leaf forest	Forest
Deciduous Broad-leaf forest	Forest
Mixed forest	Forest
Closed shrublands	Shrub
Open shrublands	Shrub
Woody savannas	Savanna
Savannas	Savanna
Grasslands	Grassland
Permanent wetlands	Wetland
Croplands	Crop
Urban and built-up	Urban
Cropland/Natural vegetation mosaic	Mixed
Permanent snow and ice	Other
Barren or sparsely vegetated	Other

An analysis of land cover predicted for Brazil for 2001 and 2004 by the MCD12Q1 dataset does show a decline in the number of hectares in forest and shrub lands and an increase in cropland but it also shows a considerable increase in savanna and a significant decrease in the mixed/crop class (Table 3). These classifications indicate that there is some potential confusion in the amount of natural vegetation that is being converted into cropland.

Table 3: Number of hectares for NASA MCD12Q1 land cover classification dataset

Land Cover	2001	2004	Difference
Forest	393,451,000	382,090,000	-11,361,000
Shrub	5,394,000	2,720,000	-2,674,000
Savanna	272,622,000	312,837,000	40,215,000
Grassland	45,449,000	23,965,000	-21,484,000
Wetland	10,450,000	11,296,000	846,000
Crop	27,869,000	28,110,000	241,000
Urban	3,924,000	3,921,000	-3,000
Mixed/Crop	85,737,000	79,866,000	-5,871,000
Barren/Snow	705,000	225,000	-480,000

The accuracy associated with these MCD12Q1 land cover classifications needs to be taken into consideration when determining the relevance of change measured with these datasets. The NASA land cover team gathered ground truth points from various locations throughout the world and then compared those points to the results from the land cover classification. The current version of the MCD12Q1 is version five. There are no published errors for this land cover version. The most recent published errors are for version three (Boston University 2009). It is unlikely that version five will have obtained a significant increase in accuracy for purposes of this analysis. Therefore, the accuracies associated with version three will be used. Table 4 lists the confidence value which indicates the probability that each pixel will meet the accuracy of the ground truth used to develop the map.[2]

Table 4: Global Confidence Values by Land Cover Class

	IGBP Land Cover Class	Confidence Value (%)
1.	Evergreen Needleleaf	68.3
2.	Evergreen Broadleaf	89.3
3.	Deciduous Needleleaf	66.7
4.	Deciduous Broadleaf	65.9
5.	Mixed Forest	65.4
6.	Closed Shrubland	60.0
7.	Open Shrubland	75.3
8.	Woody Savanna	64.0
9.	Savanna	67.8
10.	Grasslands	70.6
11.	Permanent Wetlands	52.3
12.	Cropland	76.4
14.	Cropland/Natural Veg	60.7
15.	Snow and Ice	87.2
16.	Barren	90.0
17.	Water	(Not Available)
	Average Value, All Classes	70.7
	Area-Weighted Average	78.3

If a class has a confidence value of 70%, each location in this class has a 30% probability of incorrect classification. When assessing changes in a class from year to year, then, it is necessary to take this error into account. If the amount of change in the class is less than the amount of potential error than there is a legitimate chance that the change may be incorrect. For instance, if a class consists of 1,000,000 hectares in 2001 and 800,000 hectares in 2004 but its accuracy is 70% then that class could be off by up to 300,000 hectares in 2001 and 240,000 hectares in 2004 creating a total error of +/- 540,000 hectares. With the potential error of 540,000 hectares for a 200,000 hectares change it may be difficult to use this change with a high level of confidence.

For this analysis, the potential error for each class was applied to the 2001 and 2004 MODIS datasets. The error was applied to the hectares for each individual class and then combined to ensure accuracy (see Table 5). These errors, when applied to the data, bring into question efforts to calculate change from a number of these classes to or from crop. The combined error range for forested hectares land use change, for instance, could total 90 million hectare. The total amount of land in crops in Brazil is around 28 million hectare each year. Figure 4 illustrates the scale of these values. The combined error range for land use change for savanna is even greater at almost seven times as many hectares in question (192 million) as land in crops (28 million). If the error range far exceeds the predicted change for land use transitions asserted for biofuels production, then these datasets are not suited to support sound analyses in this field. In fact, the

[2] The table is reproduced from http://www-modis.bu.edu/landcover/userguidelc/consistent.htm

Global Landcover Validation Report states that the purpose of the MCD12Q1 datasets are to assess global land cover and should not be used to assess inter-annual change (Strahler 2006).

Table 5: Possible Hectares in Error from MODIS Land Use Change Analysis

Land Cover	Possible Hectares in Error in 2001	Possible Hectares in Error in 2004	Total
Forest	46,910,000	43,070,000	89,980,000
Shrub	1,870,000	980,000	2,850,000
Savanna	89,910,000	102,500,000	192,410,000
Grasslands	13,360,000	7,050,000	20,410,000
Crop	6,580,000	6,630,000	13,210,000

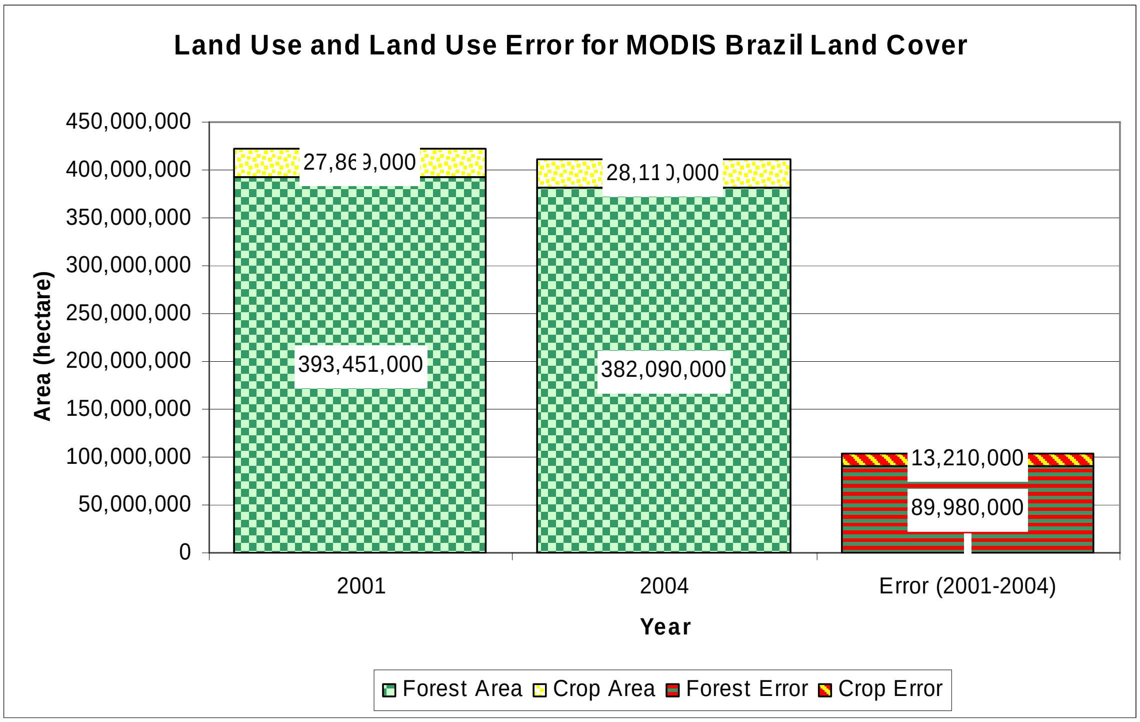
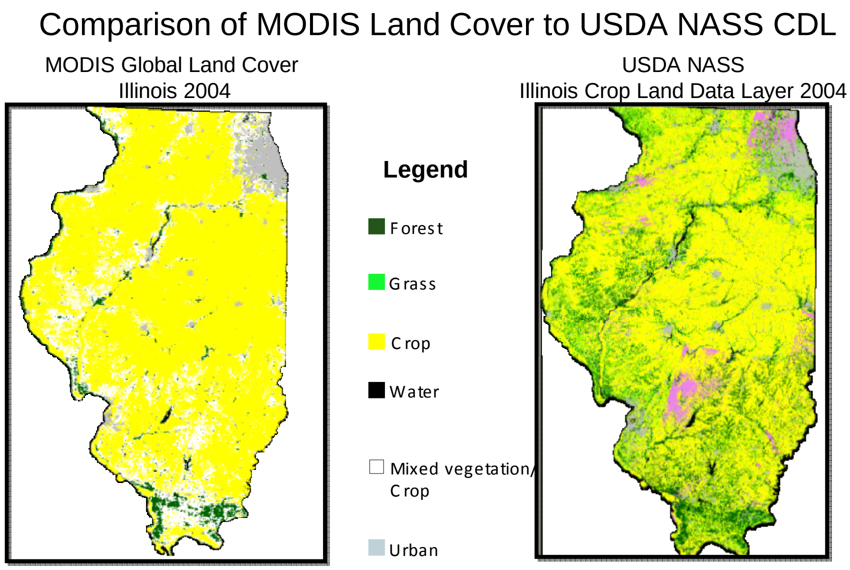


Figure 4: Land Use and Error Determined with MODIS for Brazil

Lastly, we analyzed MODIS imagery for Illinois and compared the results to tabular survey data compiled by the US Forest Service and the USDA NASS. Figure 5 shows that for forest area MODIS under estimates the surface area by 71%, whereas for cropland MODIS over estimates the surface area by 27%. We conclude that the MODIS datasets are fairly inaccurate for predicting land use changes from or to forested areas in Illinois and areas with similar ecosystems (such as other Midwestern states).



Class	MODIS Acres for Illinois in 2004	Tabular Data
Forest	1,127,000	4,423,000
Cropland	26,989,000	23,515,000

Figure 5: MODIS Imagery for Illinois

Conclusions

The accuracy of remote sensing for land use analyses generally varies by the type of land use and the resolution of the sensor. For changes in crop types between two years, for example, Landsat or AWiFs imagery can achieve a combined error range as low as 4.8% (Illinois, 2.4% error for each year), which is sufficiently accurate in combination with survey data for many types of crop land statistics (including the USDA NASS Cropland Data Layer sets).

For the present study we assessed the accuracy of remote sensing for land use changes expected from biofuels production. We looked both at direct and indirect land use changes. We conclude that for direct land use change assessments for biofuels production in the US where changes from non agricultural land to agricultural land are the focus, the lower accuracy of the current National Land Cover Data (NLCD) set as well as roadway and field fringes may lead to significant overestimations of land use change. Without additional vetting we would have predicted land use changes from non ag land to ag land of 39,841 hectares (or 7% of all hectares in corn in a given area) whereas the vetted data showed that likely only 1,663 hectares were converted to agricultural land (or 0.27% of all hectares in corn in a given area). Since the additional vetting affected primarily (non-agricultural) NLCD classifications, it can be asserted that the vetting process raised the lower accuracy associated with the NLCD to cropland data levels (in excess of 95% for land use change assessments).

Looking at indirect land use changes in Brazil, we found that for land use changes such as those potentially prompted from biofuels production (forest to cropland) the combined error range between two years was larger than the predicted change: The combined error range for forested hectares land use change, for instance, could total 90 million hectare, whereas the total amount of land in crops in Brazil is around 28 million hectare each year. If the potential error far exceeds the predicted change then using these datasets is tenuous at best.

With respect to indirect land use change in Illinois we showed that for forest ecosystems MODIS under estimates the surface area by 71%. For cropland MODIS over estimates the surface area by 27%. We conclude that the MODIS datasets are fairly inaccurate for predicting land use changes from or to forested areas in Illinois and areas with similar ecosystems (such as other Midwestern states).

In summary, direct land use changes for biofuels production can be assessed using higher resolution imagery from sensors such as Landsat and AWiFS (30m and 56m, respectively) if the data is further vetted for field and roadway fringes. The accuracy of this process is likely in excess of 95%. Assessing indirect land use changes for biofuels production using imagery from SPOT-VEGETATION or MODIS produces results with high inaccuracies. In fact, the combined error range may exceed the predicted land use change between important ecosystems such as the conversion of tropical rainforest to cropland in Brazil. Regulatory agencies such as the California Air Resources Board and the US EPA which are in a rule making process to incorporate land use considerations for biofuels production must consider the limitations of remote sensing for this purpose. We recommend that land cover products based on high resolution AWiFS imagery for transition regions associated with indirect land use change are created.

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