



Indirect Land Use Change Comparative Analysis

Final Report

**Prepared for
State of Oregon
Department of Environmental Quality**

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Table of Contents

1.0	Introduction.....	2
2.0	Comparison of Analyses	3
2.1	General Modeling Methodologies	4
2.2	Land Use Change Estimates	9
2.3	Elasticity Assumptions.....	11
2.4	Co-Product Assumptions	12
2.5	Emission Factors and Sequestration	13
2.6	Summary	15
3.0	Comparison of Results	16
4.0	Conclusions and Recommendations	17

1.0 Introduction

The concept of biofuels used in the transportation sector inducing indirect greenhouse gas emissions through changes in land use around the world came to the forefront of environmental policy in late 2007 and early 2008 with the publication of several articles in Science Magazine¹. These indirect emissions are referred to as indirect land use change (ILUC) emissions. ILUC emissions arise when an existing crop is diverted for another purpose such as transportation fuel production. To replace the diverted crop, something else is planted somewhere else. If the replacement crop is planted on land that had previously not been used as cropland, then some amount of carbon might be liberated as a result of bringing that land under cultivation (e.g. removing a forest to plant replacement soybeans).

The Oregon Department of Environmental Quality (DEQ) is currently developing a LCFS. TIAX has been tasked by DEQ to compare the various ILUC calculation methods, assumptions, and results for corn ethanol, soybean biodiesel, and sugarcane ethanol and to make a recommendation as to how Oregon DEQ should incorporate ILUC emissions into the carbon intensity estimates of the fuels complying with its LCFS and what values should be utilized in Oregon's LCFS.

The balance of this report provides a comparison of the predominant ILUC analyses performed to date. The methodologies and major assumptions are compared and the results for corn ethanol, sugarcane ethanol and soybean biodiesel are presented. Finally, some conclusions and a recommendation regarding inclusion of ILUC in the Oregon LCFS carbon intensity estimates are provided.

¹ “Carbon Mitigation by Biofuels or by Saving and Restoring Forests?”, Righetto et al, Science Magazine, August 2007. “Land Clearing and the Biofuel Carbon Debt”, Fargione et al and “Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land Use Change”, Searchinger et al, Science Magazine, February 7, 2008

2.0 Comparison of Analyses

We considered three separate analyses of ILUC emissions and then describe a reinterpretation of the EPA analysis by the Renewable Fuels Association. The specific analyses considered are:

2.0.1 US Environmental Protection Agency (EPA) Analysis

Estimates developed for RFS2² using a combination of the FASOM and FAPRI agricultural models, CENTURY soil emission model and Winrock International land use change emission factors

2.0.1.1 Renewable Fuels Association (RFA)

RFA reinterpreted the EPA RFS2 results. The derivation of the RFA values is documented in a letter sent to U.S. EPA Administrator Lisa Jackson which utilized EPA's results determined for the RFS2³

2.0.2 California Air Resources Board (CARB) Analysis

Estimates developed for the California LCFS using a combination of the Global Trade Analysis Project (GTAP) economic model and Woods Hole Research Institute land use change emission factors⁴

2.0.3 Purdue University and GTAP (Purdue/GTAP) Analysis

These values were determined with an updated version of the GTAP model and Woods Hole Research Institute land use change emission factors⁵

For much of the following discussion, the inputs, elasticities and values for corn ethanol will be used as a surrogate for the other fuels as the same methodologies were employed in modeling all of the fuels. The modeling approaches are significantly different as are the values for many assumptions. We provide here a comparison of:

- General Modeling Methodologies
- Land Use Change Estimates (how much land, where, what was prior use)
- Elasticity Assumptions
- Co-Product Assumptions
- Emission Factors and Sequestration

It is difficult, and therefore we have not attempted, to prioritize and rank the significance of the above attributes to the resulting ILUC emission estimates in each of the analyses.

² US Federal Register, Volume 75, No. 58, Friday March 26, 2010, pg 14769-14818

³ Letter from Bob Dineen, CEO and President of Renewable Fuels Association, addressed to U.S. EPA Administrator Lisa Jackson on August 4, 2010.

⁴ California Code of Regulations, Title 17, Subchapter 10, SUBarticle 7 Section 95480-95490.

⁵ Tyner, Wallace et al, "Land Use Changes and Consequent CO2 Emissions due to US Corn Ethanol Production: A Comprehensive Analysis," Department of Agricultural Economics, Purdue University, July 2010.

2.1 General Modeling Methodologies

In this subsection we will discuss the differences between the general models used for the determination of the quantity of land that is changed by biofuels. In later sections we will discuss the how the reports and models vary between the conversion of land changed to greenhouse gas (GHG) emissions.

Regardless of the specific models used and assumptions made to determine the effect of ILUC, the general methodology for estimating ILUC GHG emissions is illustrated in Figure 1. First, an assumption is made about how much transportation fuel is to be produced and which feedstock will be used. This results in a specified amount of an existing crop being diverted to a new purpose. The next step is to determine which type or types of crops will be used to compensate for the shortfall in the diverted crop, and how much of the new crop/crops will be required, and in what country/region will these new crops be grown.

Once the crop type(s), quantity and location are defined, the prior use of the land upon which these replacement crops are grown must be determined. Once this is decided, an appropriate emission factor is selected and applied to estimate the GHG emissions from changing the use of the land. The result at this point in the analysis is an estimate of the tons of CO₂ emissions liberated due to diverting a crop to transportation fuel production. This total is then divided by the MJ of fuel produced from the diverted crop – a g/MJ estimate. However, the carbon emissions associated with changing the land need to be amortized over a suitable period of time. For example, if the new land is cultivated for 30 years, then it may be appropriate to divide the total g/MJ estimate by 30 years.

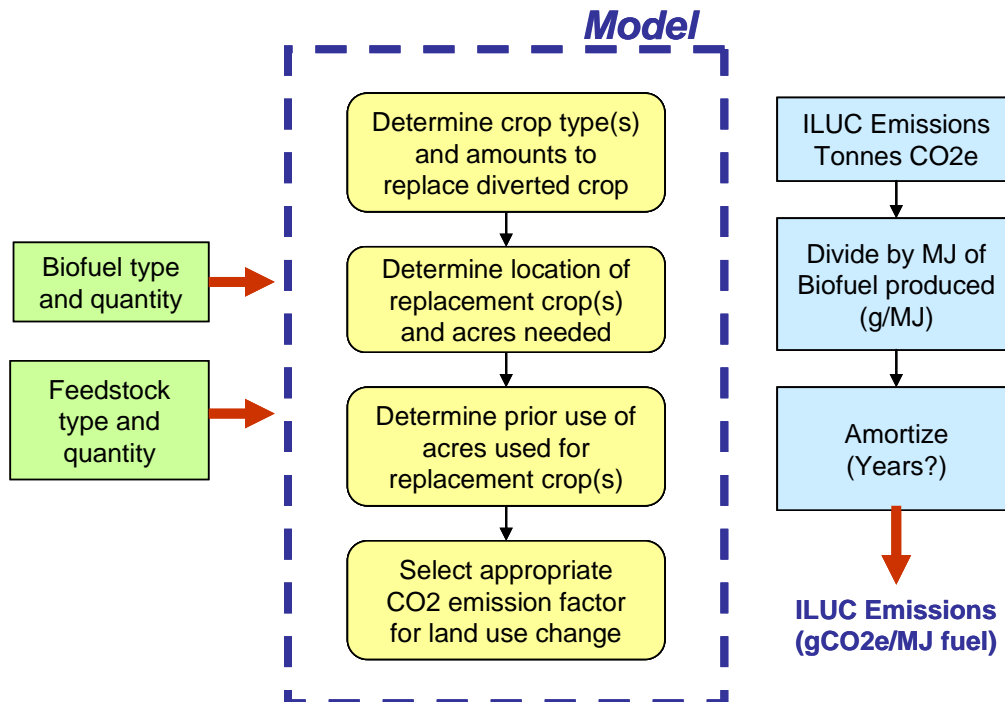


Figure 1. Schematic of General ILUC Emission Estimate Methodology.

2.1.1 EPA Analysis

U.S. EPA worked on transportation fuel lifecycle GHG emissions in support of a revision to the Renewable Fuel Standard mandated by EISA⁶. The revised standard, referred to as RFS2, was finalized in February 2010. The RFS2 requires specific volumes of different categories of biofuels be consumed; each biofuel category has a minimum GHG emission reduction relative to petroleum including ILUC emissions. EPA developed their ILUC emission estimates using the Forestry and Agricultural Sector Optimization Model (FASOM) and the Food and Agricultural Policy Institute (FAPRI) model partial equilibrium economic models of the agriculture sector. They are partial equilibrium models because they only include the agricultural part of the world economic sectors and not all sectors.

FASOM was developed in 1996 by the Department of Agriculture to model the U.S. forest and agricultural sectors. FAPRI was developed in 1984 with funding from the U.S. Congress by researchers at Iowa State University and the University of Missouri Columbia. FAPRI has been used since the 1980s to develop projections of the U.S. agricultural market and international commodity markets. Both the FASOM and FAPRI models have been used extensively to support agricultural sector policy.

FASOM can be used to project domestic land use impacts while FAPRI can be used to quantify international land use impacts. FASOM and FAPRI are net agricultural models that estimate the global response to changes in biofuel consumption across agricultural sectors. Specifically, the models are used to determine the quantity and location of land changed due to diversion of crops to biofuel production. For example, the models can be used to estimate a response to increased corn ethanol production in the United States. The models project domestic and international reactions in the agricultural and livestock sectors to determine types and quantities of crops substituting for corn, the location and number of acres needed to produce the replacement crops, and the impact on livestock population.

FASOM and FAPRI are partial equilibrium models; their combined results determine the total land use change. Although the two models are not automatically interconnected, the FASOM outputs are used as inputs to the FAPRI model. Each model independently reaches equilibrium, and since they are not interconnected, values such as U.S. exports and import quantities and agricultural prices may not match at the end of the model runs. While FASOM determines the amount of land changed and subsequent GHG emissions internally, FAPRI only predict the amount of land use change and location – prior use of the land and the subsequent GHG emissions associated with changing its use are quantified outside of the FAPRI model.

FASOM and FAPRI have beginning and end years for the analysis, and in EPA's RFS2 analysis, the start year is 2010 and the end year is 2022. EPA ran a baseline case without RFS2 and a control case with all the projected RFS2 biofuel volumes increased. To determine the land use impact of each individual fuel type (corn ethanol, sugarcane

⁶ Energy Independence and Security Act of 2007.

ethanol and soybean biodiesel), EPA also ran cases in which the volumes of these fuels were altered while all other biofuel volumes stayed constant.

Most recently, the Renewable Fuels Association (RFA) wrote a letter to U.S. EPA Administrator Lisa Jackson asserting that the RFS2 ILUC values are grossly overstated. RFA points out that EPA's Control Case in which simultaneous increases of all biofuels results in less ILUC than the sum of the ILUC value determined when modeling each individual fuel separately. The ILUC values assigned to each fuel are taken from the individual fuel model runs. RFA believes that the ILUC values assigned to each fuel should be scaled back so that the sum of the individual fuel ILUC values equals the total ILUC value from EPA's Control Case.

2.1.2 CARB Analysis

In early 2008, the California Air Resources Board (CARB) was in the initial stages of developing its Low Carbon Fuel Standard (LCFS). The goal of CARB's LCFS is to achieve a 10 percent reduction in transportation fuel carbon intensity by 2020. The carbon intensity of each fuel includes well-to-wheel direct emissions and emissions associated with indirect land use change (ILUC). CARB and the researchers at Purdue University performed an analysis utilizing the Global Trade Analysis Project (GTAP) equilibrium economic model. CARB published draft and revised estimates of ILUC GHG emissions for corn ethanol, sugarcane ethanol, and soybean biodiesel through February of 2010. Upon adoption of the LCFS in April 2010, CARB was required to convene an Expert Workgroup to "refine and improve" the ILUC analysis and provide recommendations to address any issues identified by January 1, 2011.

GTAP is a global general equilibrium (meaning it contains all economic sectors) model that assesses the economic impacts of changes in biofuel production and the subsequent land use change by region and Agro Ecological Zone (AEZ). The AEZs in GTAP share common climate, precipitation and moisture conditions. The version of GTAP used in the CARB analysis is GTAP-6, based on economic conditions in 2001.

Consistent with the FAPRI (international) section of the EPA analysis, GTAP is used to determine land use change (quantity and location) with prior land use and emission factors applied outside the model. The CARB methodology differs from the EPA methodology in that the modeling is based on current conditions with a 2015 analysis year, versus a 2022 year for EPA. Each of the fuels is modeled separately with a shock in fuel consumption that is expected to occur between 2001 and 2015, while all of the economic conditions are constant. There is no baseline or reference case to compare against in the CARB methodology.

One major concern with the CARB methodology is that there is no interaction between different agricultural sectors. For example, when modeling an increase in U.S. corn ethanol consumption, changes in other agricultural sectors, such as soybeans or livestock, are not taken into account. Moreover, the CARB methodology does not include conservation reserve program (CRP) land as an available land type for production of

crops to replace the diverted biofuel feedstock crop. Many experts believe that CRP land would be one of the first land types converted with the expansion of biofuel production.

2.1.3 Purdue/GTAP Analysis

In July of 2010, the researchers at Purdue University made major changes to the GTAP model to more accurately model ILUC. A new analysis for corn ethanol was published in July of 2010 showing significantly lower emissions than the previous estimate in the CARB analysis. No new values for sugarcane ethanol or soybean biodiesel have been developed or published.

The Purdue/GTAP analysis varies significantly from the earlier CARB analysis even though they both use the GTAP model. For this analysis, a new module was added to the GTAP model; the modified model is referred to as GTAP-BIO-ADV. The updated GTAP model now takes into account crop pasture land in the US and Brazil, and has added CRP land inside the United States. Interactions between agricultural industries, specifically livestock, were added in addition to substitutability between biofuels and petroleum products and interactions between biofuel intermediate and co-products and the rest of the agricultural industry. Finally, the GTAP-BIO-ADV has been updated to take into account 2006 world economic conditions.

The Purdue/GTAP methodology also utilizes a baseline or reference case to compare the full biofuel expansion against. This reference case accounts for annual increases in crop yield and population growth, as a surrogate for crop demand growth. Another significant change between the Purdue/GTAP and CARB analyses is that Purdue/GTAP modeled incremental changes of 2 billion gallons in annual biofuel consumption culminating at 15 billion gallons per year (BGY) (these increments were used as surrogates for time intervals). The outputs from the previous 2 billion gallon increase were used as inputs to the next 2 billion gallon per year increment, thereby updating the economic conditions, something that was not done in the CARB analysis. Figure 2 below shows a timeline of the above ILUC analyses.

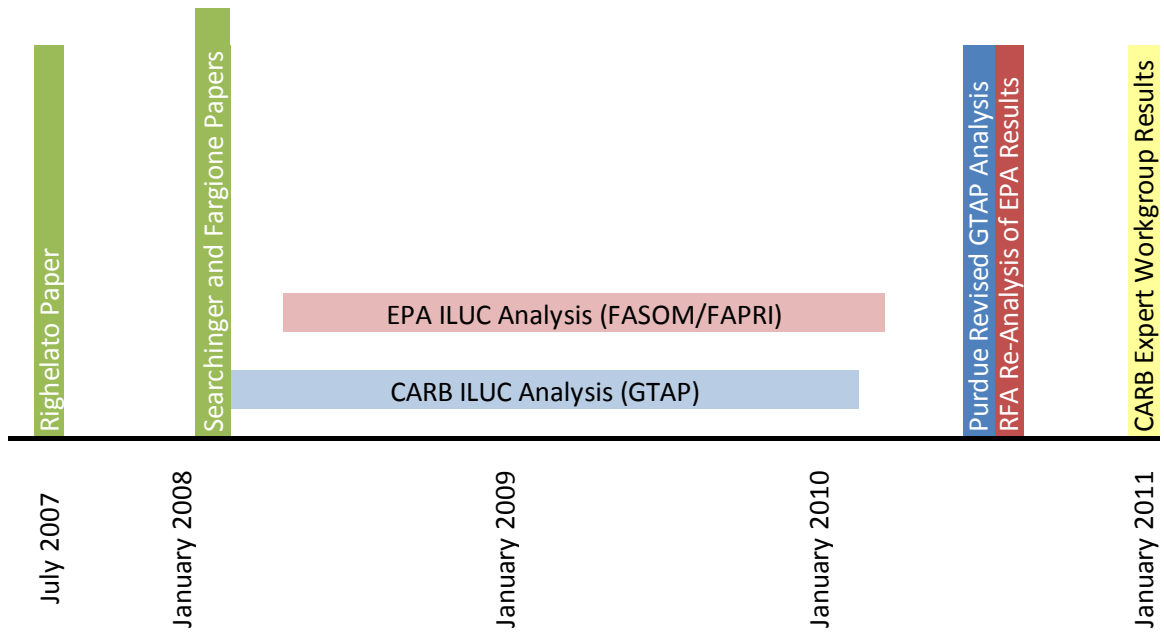


Figure 2. Approximate Timeline of Recent ILUC GHG Emission Estimate Efforts.

2.2 Land Use Change Estimates

Each of the analyses uses very different methods of determining the amount and type of land that the replacement crops are grown on due to diversion of corn, soybean and sugarcane to biofuel production. Not only does the quantity of land, but the type of land have a significant impact on the ILUC emissions estimate as different land types have varying amounts of above and below ground soil carbon that are released when converted to agricultural land.

2.2.1 EPA Analysis

In the EPA methodology, increases in corn ethanol, soybean biodiesel and sugarcane ethanol are modeled simultaneously. FASOM directly determines the amounts and kind of land that is changed within the U.S., and directly calculates the U.S. ILUC GHG emissions. The types of land FASOM selects from include cropland pasture, forest pasture, rangeland, forestland, developed land, and CRP land. For international land use FAPRI determines the amount of land that must be utilized, but does not identify what type of land. To determine the type or prior use of the land converted to produce the replacement crops, EPA utilized satellite data of land use changes from 2001 to 2007 and applied this pattern of land use change to the amount determined in each country. One concern with this methodology is that the land use patterns determined in the satellite data can not be fully attributed to biofuel expansion. Further, it is not clear whether 2001-2007 average land use change should be applied to future crop expansion.

Another concern with the EPA analysis is how the ILUC was determined for the individual fuels. EPA performed modeling assuming simultaneous increases in volumes of all biofuels needed for compliance with RFS2. When modeled together the interrelationship between all of the crops is captured. The result of this model run was used to estimate the impact of RFS2. However, this result was not utilized to determine the ILUC emissions for each individual type of biofuel. EPA estimated the ILUC for each type of the biofuels with independent model runs in FASOM and FAPRI. Table 1 provides EPA's estimate of total international hectares of land use change due to anticipated RFS2 biofuel volumes. When increases of all RFS2 fuel volumes were modeled simultaneously, a total of 794 thousand hectares of land is needed for the replacement crops. The table also shows that when each fuel was modeled separately holding the other fuels constant, the total amount of land use changed is 1863 thousand hectares; more than double the amount of land use change when all of the biofuels were modeled together. Therefore EPA's ILUC estimates for the individual fuels may be overstated. This is the essence of RFA's letter to EPA which is discussed further below.

In RFA's reinterpretation of EPA's results, it was assumed that the total amount of land use changed due to the RFS2 is the result from the case in which increases in all fuels are modeled simultaneously. To determine the impact of each individual fuel, RFA simply proportionally allocated the total land use change to the three fuels based on the amount of land use changed in their individual model runs.

Table 1 – EPA International ILUC Estimates for Single Fuel Runs and the Simultaneous Run⁷

Thousand Hectares	Soybean Biodiesel Only	Corn Ethanol Only	Brazilian Sugarcane Ethanol Only	Total of Individual Runs	All RFS2 Biofuels Together
Land Use Change	678.4	789.3	395.4	1,863.1	794.4

2.2.2 CARB Analysis

In the CARB analysis, GTAP determines the amount and type of land use change inside and outside of the United States. GTAP determines the type of land converted to agriculture based upon the cost to rent land in each of the AEZs. The model is set up as if a “manager” in each AEZ is trying to maximize profits in addition to producing the necessary amounts of biofuels in each region. There is no historical or empirical data used to determine the ratio of forest to pasture land, nor is the cost of preparing non-agricultural land for farming considered. A significant limitation in this analysis is that the only types of land available are pasture land and forests; domestic CRP land and international crop-pasture (dormant crop) land are not an option for the “manager”.

2.2.3 Purdue/GTAP Analysis

The recent Purdue/GTAP analysis uses the same “manager” methodology maximizing rents in each AEZ as in the CARB analysis, except it now includes CRP and crop-pasture land. This is a significant improvement in the quantification of land use to replace diverted corn, soybean and sugarcane.

Table 2 compares the total domestic and international land use change, quantity of biofuel, and estimated acres of land use change due to the increase in biofuel production. The values shown are for corn ethanol. There is a wide range in the amount of land use change estimated per unit of corn ethanol production.

⁷ US EPA Renewable Fuel Standard 2 – Regulatory Impact Analysis, pg 427, Table 2.7-3

Table 2 – Comparison of Land Use Change Quantities for Corn Ethanol Production

Analysis	Land Use Change Location	Quantity (million acres)	Ethanol Volume Increase (Billion gal)	Acres/1000 gal of ethanol
EPA	U.S.	1.40	2.7	1.2
	ROW ⁸	1.94		
	Total	3.34		
CARB	U.S.	3.85	13.25	0.7
	ROW	5.75		
	Total	9.61		
Purdue/GTAP	U.S.	1.04	13.23	0.32
	ROW	3.22		
	Total	4.26		
RFA	U.S.	1.55	2.7	0.88
	ROW	0.83		
	Total	2.38		

2.3 Elasticity Assumptions

There are many assumptions made within the GTAP and FASOM/FAPRI models. Two key assumptions have significant impact on the amount of land needed to cultivate replacement crops for the crops diverted into biofuel production. These two assumptions are the price/yield elasticity and the new land yield elasticity. Price/yield elasticity is the amount of increase in crop yield (e.g. bushels per acre) that will result from an increase in the market price for that crop. For example, a price/yield elasticity of 0.5 means that a price increase of 1% would result in a yield increase of 0.5%. A higher the price/yield elasticity equates to a reduction in the amount of land necessary to replace the displaced crop and therefore a reduction in ILUC emissions.

The new land elasticity is a ratio of new land yield to current land yield. For example, a new land elasticity value of 0.6 means that new land is only 60% as productive as current land. The lower the elasticity, the more acres of land that will be needed to produce replacement crops resulting in an increase in ILUC emissions.

2.3.1 Price/Yield

In the EPA analysis, FASOM and FAPRI have different price/yield elasticities. FASOM has a value of 0 while FAPRI has short term and long term elasticities. The short term is defined as the percent change in yield due to a one-year increase in price while the long term elasticity is defined as the percent change in yield due to a permanent (10 year average) change in price. For corn, the short-term and long-term elasticities in FAPRI are 0.013 and 0.074.

⁸ ROW – Rest of World

The CARB analysis utilized a single price/yield elasticity of 0.32 which is significantly higher than the values used by EPA. The Purdue/GTAP methodology utilized a price/yield elasticity of 0.25, still significantly higher than the EPA methodology.

2.3.2 New Land Yield

There is also a wide variation in new land yield elasticities (Table 3). EPA and CARB assume constant new land elasticity for all regions and land types. The FAPRI elasticity units are slightly different where the percent change in yield (-0.023%) of the total area of a country due to a 1% increase in total area. For example, a 10% increase in land would result in a -0.23% yield for the total area. This is not directly comparable to the FASOM and GTAP elasticity values. The Purdue/GTAP new land elasticity values vary by region and land type. These values were obtained from the Terrestrial Ecosystem Model and vary widely; most of the values are higher than 0.66 (the CARB value), and are between 0.8 – 1.0.

Table 3 - New Land Yield Elasticities

Report	New Land Yield Elasticity
EPA (RFA)	FASOM – 1.0 FAPRI – -0.023*
CARB	0.66
Purdue/GTAP	Varies by Region and Land type, range of 0.49-1.0

*Value not directly comparable

2.4 Co-Product Assumptions

The recognition of co-products and interaction between agricultural industries has a significant impact on the quantity of land use changed due to increases in biofuel production. For example, in producing corn ethanol with the dry mill process, dry distillers grains and solubles (DGS) is co-produced. The DGS is used as animal feed. In the CARB analysis, one pound of DGS displaces one pound of corn feed for cattle (dairy and beef), swine and/or poultry. This displacement reduces the amount of corn farming. The reduced farming is taken as an energy credit when calculating corn ethanol direct carbon intensity with the GREET model. The reduced farming also gets a credit in the land use change calculation (less land needed for corn production). In the CARB analysis, there are no interactions between agricultural industries, so the DGS cannot displace soybean meal (a soybean biodiesel production co-product).

2.4.1 EPA Analysis

In the EPA methodology (and the RFA) interactions between agricultural industries are captured, so DGS displaces some soybean meal in the cattle dairy, swine and poultry industries. The EPA analysis assumes that DGS displaces 1.3 pounds of agricultural products. Of the 1.3 pounds, approximately 1.2 lbs of corn are displaced and approximately 0.1 lb of soybean meal is displaced. The soybean meal displacement has a large impact on land use change since soy has much lower yields per acre than corn. Therefore, the EPA assumptions result in less land use change than the CARB assumptions.

In addition to distiller's grains, EPA assumes 90% of dry mills in 2022 will extract corn oil from distiller grains. This corn oil has additional displacement for soybean oil that is used to produce soybean-derived biodiesel.

2.4.2 CARB Analysis

In the CARB analysis, one pound of DGS displaces one pound of corn feed for cattle (dairy and beef), swine and/or poultry. CARB does not assume the separation of corn oil from distiller's grains.

2.4.3 Purdue/GTAP Analysis

For the Purdue/GTAP analysis, though substitution rates are not explicitly mentioned in the report, the updated model does allow interactions between agricultural sectors and DGS does substitute for some amount of soybean meal. This substitution results in a decrease in the amount of land use change relative to the CARB analysis.

2.5 Emission Factors and Sequestration

Once the amount and type of land use change has been determined, the GHG emissions associated with converting the land must be selected and applied in addition to the amount of carbon sequestered. Higher emission factors and lower sequestration factors result in increased ILUC emissions.

2.5.1 Emission Factors

Two different sources of emission factors are available: Winrock International and Woods Hole Research Institute. The EPA analysis utilized Winrock International emission factors while the CARB and Purdue/GTAP analyses utilized the Woods Hole Research Institute data. These data sets vary in that Winrock International factors are by region within a country while the Woods Hole data is by land type within a region. Direct comparisons are therefore difficult.

Tables 4 and 5 show data for Brazil (Woods Hole values are for Latin America which includes Brazil) from Winrock and Woods Hole where general comparisons can be made.⁹ It appears that on average the Winrock International emission factors are lower than the Woods Hole emission factors.

⁹ Air Improvement Resource, Inc, "A Comparison of Corn Ethanol Lifecycle Analyses: California Low Carbon Fuel Standard (LCFS) Versus Renewable Fuels Standard (RFS2)," prepared for Renewable Fuels Association and Nebraska Corn Board, June 14, 2010.

Table 4 - Winrock International CO₂ Above Ground Emission Factors - Brazil

Region	CO ₂ , T/Ha
Amazon Biome	606
Northeast Coast	145
North-northeast Cerrado	244
Central-West Cerrado	290
Southeast	243
South	225
Average	292

Table 5 - Woods Hole CO₂ Above Ground Emission Factors - Latin America (Forest)

Forest Type	CO ₂ , T/Ha
Tropical Evergreen Forest	733
Tropical Seasonal Forest	513
Tropical Open Forest	202
Temperate Evergreen Forest	616
Temperate Season Forest	367
Average	486

2.5.2 Carbon Sequestration

Carbon sequestration in the context of land use change is the use of wood from land clearing in products or other purposes that would sequester the carbon rather than releasing it to the atmosphere. In the CARB analysis, no such sequestration is considered. In the EPA analysis, no sequestration is assumed for international land use change since it is assumed that forests are largely unmanaged, so burning can occur. For EPA's domestic land use change, FASOM takes into account carbon sequestration in wood products for domestic forest changes. FASOM tracks the fate of carbon overtime in various industries including wood and paper products, mill residue and fuel wood. FASOM assumes that fuel wood displaces fossil fuels.

In the Purdue/GTAP methodology, it is assumed that 25% of the above ground carbon from forest conversion is sequestered. The underlying assumption here is that a certain amount of international forest land is managed which leads to the use of wood in products or industry.

2.6 Summary

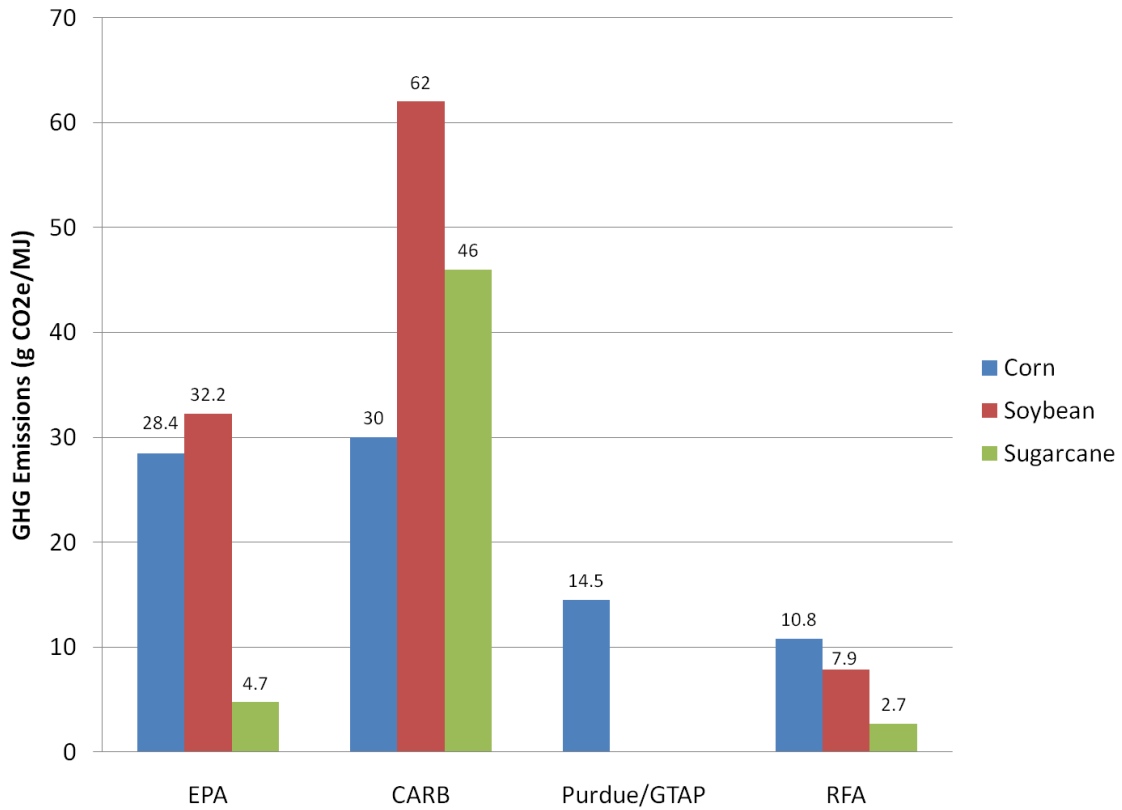
Table 6 below is a summary matrix of the ILUC reports discussed in this section.

Table 6 –Summary Matrix

	EPA (RFA)	CARB	Purdue/GTAP
Quantity and Location of Land Changed	FASOM – domestic FAPRI - international	GTAP – 6 Model	GTAP-BIO-ADV
Cases Considered	Baseline – RFS Each Fuel modeled separately RFA – All RFS2 fuels together	Individual Fuels	Baseline & Corn Ethanol only
Timeframe	Each year 2010-2022	Estimated 2015 volumes (2001 data)	15 BGY (2006 data) increased by 2 BGY
Price/Yield Elasticity	FASOM – 0 FAPRI: Short-term – 0.013 Long-term – 0.074	0.32	0.25
New Land Yield Elasticity	FASOM – 1.0 FAPRI – -0.023*	0.66	Varies by Region and Land type, range of 0.49-1.0
LUC Emission Factors	Winrock International, CENTURY Model	Woods Hole Research Institute	Woods Hole Research Institute
Sequestration	FASOM – some, LUC dependent FAPRI - none	None	Forest – 25% above ground

3.0 Comparison of Results

Figure 3 shows the results of the different modeling methodologies. The values for all biofuels have extreme variation. Although CARB and EPA have similar values for corn ethanol, this appears to be a coincidence. The methodologies for determining the amount and type of land use change (and the subsequent results) and land use conversion factors are so different that this can be the only conclusion. The RFA reinterpretation of EPA's results result in approximately 50 percent lower values since the total land use change when EPA modeled all fuel increases simultaneously was about half of the sum of modeling all fuels in isolation.



4.0 Conclusions and Recommendations

With the wide variations in analysis methodologies and results, it is difficult to determine which set of values is the most representative of actual ILUC emissions. We draw the following conclusions:

- The CARB analysis has serious limitations
 - No domestic CRP land, no international dormant cropland
 - Dated agro/economic data
 - No time steps, no baseline
 - No interaction between different sectors of the agriculture industry
- The EPA analysis is more comprehensive than the CARB analysis but still has limitations
 - Use of historic satellite data for future land use change
 - Attribution of all historic land use change to biofuels
 - FASOM/FAPRI are partial equilibrium models
- The GTAP analysis is a full equilibrium model, but it determines land use change based on economics and rent prices, not empirical data
- None of the analyses (except RFA's reinterpretation of EPA's results) consider simultaneous increases in a variety of biofuels – each estimated in a vacuum.
- Difficult to determine which set of emission factors is more representative

Despite these shortcomings, the methodologies and tools utilized to estimate ILUC emissions have evolved dramatically over the past several years and there are ongoing efforts to continue improving and refining the assumptions, methods and tools. CARB has convened an Expert Workgroup as part of the California LCFS that will make recommendations on how to improve the GTAP based analysis and “assist CARB in refining and improving the land use and indirect effect analysis of transportation fuels and return to CARB no later than January 1, 2011 with regulatory amendments or recommendations, if appropriate, on approaches to address issues identified.”¹⁰ The Expert Workgroup has the following subgroups to discuss specific issues related to ILUC and other LCFS issues:

- Elasticity Values
- Co-product Credits
- Land Cover Types
- Emission Factors
- Uncertainty in LUC estimates
- Indirect Effects of Other Fuels
- Comparative and Alternative Modeling Approaches
- Time Accounting
- Food Consumption

¹⁰ “California Air Resources Board Low Carbon Fuel Standard Expert Workgroup Guidelines”
http://www.arb.ca.gov/fuels/lcfs/workgroups/ewg/lcfs_ewg_guidelines.pdf

The GTAP model has already been improved, presumably utilizing the Expert Workgroup suggestions, and one of the fuel pathways (corn ethanol) has been published with significantly lower results than the earlier CARB analysis, which is the Purdue/GTAP analysis discussed in this report. Purdue/GTAP is not currently performing a similar analysis for biodiesel from soybeans or ethanol from sugarcane.

Given this changing landscape, it is difficult to recommend specific ILUC GHG values that will not be dated in a year. TIAX recommends that DEQ wait until the CARB Expert Workgroup makes its recommendations (January 1, 2011) and EPA responds to RFA's suggestion. It is not known at this time when, or even if, EPA will respond to the RFA letter.

If DEQ must define ILUC values now, TIAX recommends using an average of the two published analyses (CARB and EPA). For corn ethanol, TIAX recommends averaging the recent GTAP value (rather than the CARB value) with the EPA value.