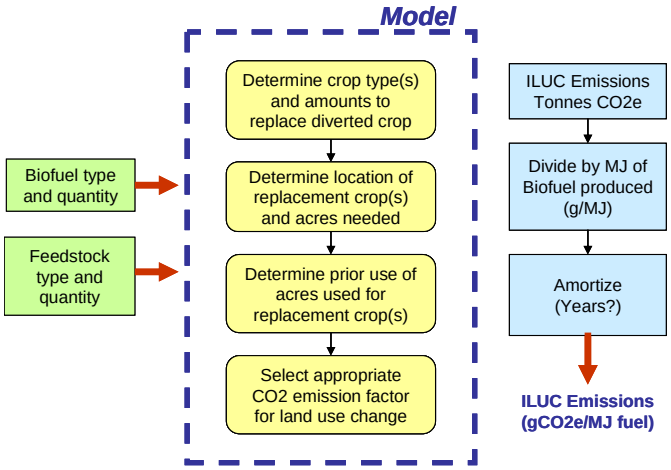
GHG Emissions Associated with Indirect Land Use Change (ILUC)

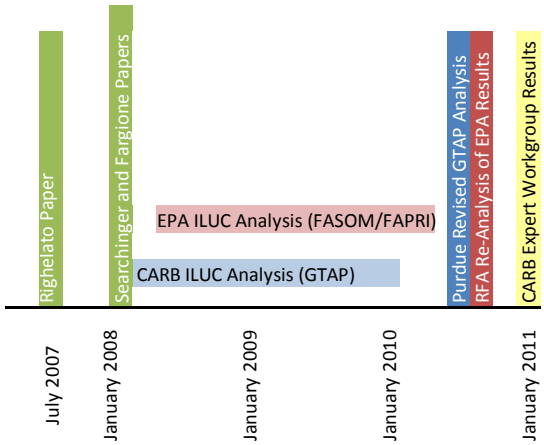
- ILUC emissions can occur when a crop is diverted to biofuel production. When the replacement crop is planted on land that was not previously used for crop cultivation, then some level of carbon emission could occur due to bringing the land into cultivation
- Example: Divert soybeans to biodiesel production.
  - Replacement crops would be planted elsewhere in the world.
  - If forests or grassland is cleared to plant the replacement crop, the carbon in the forest/grassland and soil is lost
  - The carbon emitted due to this change is quantified and amortized over an appropriate time period and divided by the amount of biodiesel produced from the diverted soybeans

ILUC Emission Quantification

Regardless of model, same basic steps



ILUC Emission Quantification -- Progress



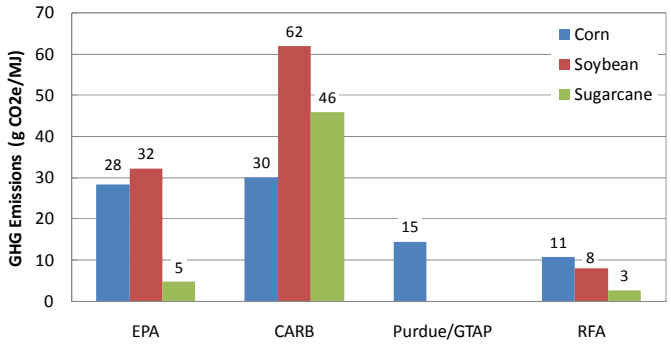
- ILUC from alternative fuels emerged in ~ 2007
- Two main efforts began in 2008 to quantify ILUC emissions
  - CARB LCFS (GTAP)
  - US EPA RFS2 (FASOM/FAPRI)
- Revisions/refinements ongoing

"Carbon Mitigation by Biofuels or by Saving and Restoring Forests?", Righeleto 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, Feb 7, 2008

ILUC Emission Quantification – Progress

- EPA RFS2 – FASOM/FAPRI Models and Winrock International emission factors[1]
- CARB LCFS – GTAP model and Woods Hole emission factors[2]
- Purdue/GTAP: Updated version of the GTAP model and Woods Hole emission factors[3]
- RFA: Reinterpretation of EPA's RFS2 results[4]



1. US Federal Register, Volume 75, No. 58, Friday March 26, 2010, pg 14769-14818
2. California Code of Regulations, Title 17, Subchapter 10, SUbarticle 7 Section 95480-95490.
3. 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.
4. Letter from Bob Dineen, CEO and President of Renewable Fuels Association, to U.S. EPA Administrator Lisa Jackson on Aug 4, 2010.

Compare different studies

- General Modeling Methodologies
- Elasticity Assumptions
- Co-Product Assumptions
- Land Use Change Estimates (prior use)
- Emission Factors and Sequestration

General Approaches

- Concerns with EPA approach
  - Partial equilibrium
  - Sum of individual LUC runs (acres) is greater than LUC when all modeled together
  - Modeled with change between RFS and RFS2 volumes in baseline
- Concerns with CARB approach
  - No interaction between different agriculture sectors (e.g. soybean/corn/livestock)
  - No baseline for comparison, one year only rather than incremental changes
  - Old economic data
  - Fuels modeled separately
- Concerns with Purdue/GTAP approach
  - Fuels modeled separately

Study	Quantity & Location of Land Changed	LUC Emission Factors	Cases Considered	Timeframe
EPA RFS2	FASOM[1] FAPRI[2]	Winrock International, CENTURY model	Baseline (RFS) All RFS2 fuels together Each fuel modeled separately for ILUC	Each year 2010-2022
CARB	GTAP[3] model	Woods Hole Research Institute	Individual fuels	2015 (2001 data)
Purdue-GTAP	GTAP-BIO-ADV	Woods Hole Research Institute	Baseline & Corn ethanol only	2015 (2006 data) increased by 2 BGY to 15 BGY

1. Forestry and Agricultural Sector Optimization Model, U.S. Department of Agriculture
2. Food and Agricultural Policy Research Institute, Iowa State University and University of Missouri
3. Global Trade Analysis Project, Purdue University

Amounts of Land Use Changed

- Very different estimates of LUC quantities for corn ethanol

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
	Rest of World	1.94		
	Total	3.34		
CARB	U.S.	3.85	13.25	0.7
	Rest of World	5.75		
	Total	9.61		
Purdue/GTAP	U.S.	1.04	13.23	0.32
	Rest of World	3.22		
	Total	4.26		
RFA Re-analysis of EPA Results	U.S.	1.55	2.7*	0.88
	Rest of World	0.83		
	Total	2.38		

* RFS volumes in baseline

Amounts of Land Use Changed

- To determine impact of RFS2 program on ILUC emissions, EPA modeled all biofuels together (reference case)
- To determine ILUC value for each fuel, EPA modeled changes in the fuel of interest while keeping all other volumes constant
- The sum of land changed for the individual runs is greater than the amount of land use change in the reference case.
- This is the essence of RFA's assertion that the EPA ILUC estimates are significantly overstated

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**

Elasticity Assumptions

- Price Yield Elasticity
  - How responsive crop yields are to changes in market price
  - Elasticity of 0.5 = 1% price increase results in an 0.5% increase in yield
- New Land Yield Elasticity
  - Expected yield from new land brought into cultivation relative to existing yields
  - Elasticity of 0.6 = new land as 60% of the yield of existing land
- Large differences explain the large difference in quantities of LUC estimated

	Price Yield Elasticity	New Land Yield Elasticity
EPA RFS2	Domestic: 0 International short-term: 0.013 International long-term: 0.074	Domestic: 1.0 International: -0.023*
CARB	0.32	0.66
GTAP/Purdue	0.25	0.49 to 1.0

* Not comparable to other values – different units. 0.023% decrease in yield due to a 1% increase in land available

Co-Product Assumptions

- Co-Products and their use in different agriculture sectors is important in determining the amount of land use change
- Example: corn ethanol production
  - DGS is produced from dry mill corn ethanol production
  - DGS can be used instead of corn meal and soybean meal in animal feed
  - Therefore less land is needed for corn and soy cultivation
  - Amount of land not needed depends on displacement ratios
- Because soy oil is so land intensive, displacing small amounts of soybean meal has large impacts on land use change quantities
- In addition to displacement of corn and soybean meal, EPA estimates that corn oil will be co-produced. The corn oil will allow more soybean oil to produce biodiesel.

	1 pound of DGS displaces …	
	Corn Meal	Soybean Meal
EPA RFS2	1.2	0.1
CARB	1	0
GTAP/Purdue	Not stated	Not stated, >0

Estimating Prior Use of Land Changed

- Concerns with EPA approach
  - May not be correct to attribute all 2001-2007 LUC to biofuels
  - May not be correct to project 2001-2007 LUC practices to future
- Concerns with CARB approach
  - Limited types of land – no CRP land
  - Rent method to determine what type of land is converted may not be as accurate as using empirical historic data
- Concerns with GTAP/Purdue approach
  - Rent method to determine what type of land is converted may not be as accurate as using empirical historic data

Study	Prior Use of Land Changed
EPA RFS2	Domestic: FASOM (cropland pasture, forest pasture, rangeland, forestland, developed land and CRP) International: Satellite Data (changes from 2001 to 2007)
CARB	GTAP: pasture or forest. Use of land in each zone of the model is determined based on rent prices and what use provides most profit.
Purdue-GTAP	GTAP: pasture, forest, crop-pasture, CRP. Use of land in each zone of the model is determined based on rent prices and what use provides most profit

Emission Factors

- Once amounts, locations and prior use have been determined, emission factors can be applied to determine total carbon emissions per acre
- Winrock International factors
  - Used by EPA
  - Factors based on geographic region
- Woods Hole factors
  - Used by CARB and GTAP/Purdue
  - Factors based on temperate zones
- Difficult to compare, but on average, Winrock factors are lower

Winrock International

Region	CO2, T/Ha
Amazon Biome	606
Northeast Coast	145
North-northeast Cerrado	244
Central-West Cerrado	290
Southeast	243
South	225
Average	292

Woods Hole Research Institute

Forest Type	CO2, T/Ha
Tropical Evergreen Forest	733
Tropical Seasonal Forest	513
Tropical Open Forest	202
Temperate Evergreen Forest	616
Temperate Season Forest	367
Average	486

Source: 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.

Summary and Recommendation

•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 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

•The total volumes of fuel modeled are different: EPA models RFS2 increases, CARB models RFS+RFS2 volumes

•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

Summary and Recommendation (concluded)

•CARB has convened an expert workgroup to make recommendations on how to improve the GTAP analysis – recommendations are due at the end of the year

•Many of the problems with the CARB analysis were improved in the recent Purdue/GTAP analysis for corn ethanol.

•A response by EPA to RFA's re-interpretation of results will provide new insights

•Our recommendation is that Oregon waits until the results of CARB's expert work group are presented in January 2011 and EPA responds to RFA's analysis