Land Use Change Effects for Soy Biodiesel

On March 05, 2009, the Air Resources Board (ARB/Board) published the Initial Statement of Reasons (ISOR) for the Low Carbon Fuel Standard (LCFS) regulation. In the ISOR, staff presented preliminary estimates for soy biodiesel land use change (LUC) impacts. Since these results were preliminary, they were not included in the LCFS Lookup Table. Working with researchers at UC Berkeley, staff has estimated a new LUC carbon intensity value for soy biodiesel which is presented in this report.

1. GTAP Model Updates for Soy Biodiesel Modeling

ARB uses the Global Trade Analysis Project (GTAP) model for estimating LUC impacts of increased biofuel production. For the preliminary modeling presented in the ISOR, GTAP was severely limited in its ability to represent the soy biodiesel sector. Some key GTAP model limitations were as follows:

- The modeling employed the GTAP 6 global economic data base which used 2001 as the reference year. Very little biodiesel was being produced in 2001 and therefore the economic sector was not well developed.
- The model included an aggregated oilseeds sector and was not capable of specifically modeling changes in soybean demand. Because of this limitation, an external model adjustment for the difference in average fuel yield between biodiesel derived from soy and aggregated oilseeds was required.
- The modeling did not account for market effects of soy meal production and therefore an external adjustment for soy meal co-product credit was required. As an initial estimate, we assumed a 75 percent co-product credit for soy meal.

Since publication of the ISOR, several improvements to the modeling of soy biodiesel were made to address these limitations. Revisions to the model are as follows:

- The present soy biodiesel land use change results are produced using the GTAP 7 data base which uses 2004 as the reference year. The global biodiesel sector was more fully developed in 2004.
- The current modeling separates out soybeans from the aggregated oilseeds sector and therefore is capable of specifically modeling changes in soybean demand.
- The modeling now allocates a feed byproduct within the biodiesel sector. Soybean was assumed to consist of 20 percent oil and 80 percent soy meal by mass.

Based on these changes, staff believes the model results for soy biodiesel are now sufficiently robust to be included in the Lookup Table.

2. Results and Discussion of Land Use Change Effects.

In this section, we present land use change results for soy biodiesel. Results include a sensitivity analysis performed on key model inputs. All land use change carbon intensity values were calculated using the annualized method with a 30 year project horizon.

a. Key Inputs into the GTAP model

Table I summarizes the key inputs for the GTAP analysis. The parameters appearing in this table are briefly described below and more fully described in Appendix C of the ISOR. The primary input to computable general equilibrium models such as GTAP is the specification of the changes that will, by moving the economy away from equilibrium, result in the establishment of a new equilibrium. Parameters such as elasticities are used to estimate the extent which introduced changes alter the prior equilibrium.

Table I
Key Inputs into the GTAP model

Inputs/Parameters	Ranges (if appropriate)
Baseline Year	2004
Soy biodiesel production increase (billion gallons)	0.75
Crop Yield Elasticity	0.2 to 0.4
Elasticity of Harvested Acreage Response	0.5
Elasticity of land transformation	0.1 to 0.3
Elasticity of crop yields with respect to area expansion	0.5 to 0.75
Trade elasticity	Central Values*

*see Table C5-2 in Appendix C of the ISOR

- Fuel production increase: The primary input to computable general equilibrium models such as GTAP is the specification of the changes that will result in a new equilibrium. We modeled a production increase from 0.25 to 1.0 billion gallons of soy biodiesel. A final volume of 1.0 billion gallons is consistent with the Renewable Fuel Standard mandate for biomass based diesel.

- Crop yield elasticity: This parameter determines how much the crop yield will increase in response to a price increase for the crop. Agricultural crop land is more intensively managed for higher priced crops. If the crop yield elasticity is 0.25, a P percent increase in the price of the crop relative to input cost will result in a percentage increase in crop yields equal to P times 0.25. The higher the elasticity, the greater the yield increases in response to a price increase.

- Elasticity of crop yields with respect to area expansion: This parameter expresses the yields that will be realized from newly converted lands relative to yields on acreage previously devoted to that crop. Because almost all of the land that is well-suited to crop production has already been converted to agricultural uses, yields on newly converted lands are almost always lower than corresponding yields on existing crop lands.

- Elasticity of harvested acreage response: This parameter expresses the extent to which changes occur in cropping patterns of existing agricultural land as land costs change. The higher the value, the more cropping patterns will change (e.g. soybean to corn) in response to land costs.

- Elasticity of land transformation across cropland, pasture and forest land: This elasticity expresses the extent to which expansion into forestland and pastureland occurs due to increased demand for agricultural land (driven by higher crop prices).

b. Sensitivity Analysis Results

As shown in Table 2, the model results are sensitive to changes in crop yield elasticity, elasticity of land transformation, and elasticity of crop yields with respect to area expansion and are insensitive to reasonable changes in the biodiesel production increase. This model behavior is similar to that presented in the ISOR for corn, sugarcane, and preliminary soy biodiesel results.

Table 2
Sensitivity Analysis Results for Soy Biodiesel

Input variable	Input Variable Ranges		Percent Change in LUC Carbon Intensity
	Low Value	High Value	
Biodiesel production increase (billion gallons)	0.45	0.75	-5
Crop Yield Elasticity	0.2	0.4	-21
Elasticity of land transformation	0.1	0.3	70
Elasticity of crop yields w.r.t. area expansion	0.50	0.75	-38

c. Calculating the LUC carbon intensity for soy biodiesel

In order to select an appropriate central value for the land use change impact of soy biodiesel production, seven scenarios were performed with varying elasticity values. For these scenarios, staff utilized elasticity value ranges consistent with the corn ethanol analysis presented in Chapter IV and Appendix C of the ISOR. These ranges are as follows:

- Elasticity of crop yield with respect to area expansion: 0.5 to 0.75
- Crop yield elasticity: 0.2 to 0.4

- Elasticity of land transformation: 0.1 to 0.3
- Trade elasticity: central case

For both corn ethanol and sugarcane ethanol, an external adjustment was made to model results to account for changes in feedstock crop yield since the baseline year of the model. Since yields for soybean (three year running averages) have remained relatively stable since the baseline year of 2004, an external adjustment was not necessary for soy biodiesel.

Table 3 shows the LUC and carbon intensity results for seven scenarios. As shown in the rightmost column of Table 3, the mean global land conversion value across the range of runs is 0.51 million hectares. When the total GHG emissions from the conversion of these lands are annualized over a 30-year period, the result is a mean land use change impact of 62 gCO_2e/MJ.

Table 3
GTAP Modeling Results for Soy Biodiesel Indirect Land Use Change

Scenario	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**Mean**
Economic Inputs								
Soy Biodiesel production increase (bill. gal.)	0.75	0.75	0.75	0.75	0.75	0.75	0.75	
Elasticity of yield wrt area expansion	0.50	0.75	0.50	0.50	0.50	0.66	0.75	
Crop yield elasticity	0.40	0.40	0.20	0.40	0.40	0.25	0.20	
Elasticity of land transformation	0.20	0.20	0.20	0.30	0.10	0.20	0.20	
Elasticity of harvested acreage response	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
Trade elasticity of crops	central							
Model Results								
Total land converted (million ha)	0.54	0.36	0.67	0.65	0.39	0.50	0.45	0.51
• Forest land (million ha)	0.23	0.13	0.30	0.29	0.18	0.22	0.18	0.22
• Pasture land (million ha)	0.31	0.23	0.37	0.36	0.21	0.28	0.26	0.29
U.S. land converted (million ha)	0.24	0.16	0.28	0.28	0.16	0.20	0.18	0.21
• U.S. forest land (million ha)	0.11	0.06	0.13	0.12	0.08	0.09	0.08	0.10
• U.S. pasture land (million ha)	0.13	0.10	0.14	0.16	0.08	0.11	0.11	0.12
LUC carbon intensity(gCO_{2e}/MJ)	66	41	84	83	49	61	53	62