Summary of Findings

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We were asked by the National Biodiesel Board to help them understand the modeling results presented by CARB in the publication titled "Land Use Change Effects for Soy Biodiesel" and to make any recommendations based on the results of our study. We draw five main conclusions from our analysis:

1. The CARB approach to estimating land use change is not consistent with actual agricultural land use changes in the United States since 1996.
2. The restrictions imposed by use of the Constant Elasticity of Transformation supply function are not consistent with the data used to estimate the land transformation elasticity.
3. Although GTAP cannot explicitly account for double cropped acres, the yield elasticity with respect to price can be adjusted to account for the expansion of double cropping in response to increased crop demand.
4. There is no empirical support in Brazil for the assumption that yields in Brazil on new land are lower than yields on old land. For the United States, large overall acreage declines and significant shifts between crops since 1996 suggest that one parameter cannot capture important differences between crop yields on new land.
5. The biodiesel byproduct results modeled by CARB are difficult to rationalize because of discrepancies between the U.S. and rest of world price impacts and the limited price impact in the United States.

Each of these observations is the topic of a short paper. The current versions of these papers are provided as attachments to the comments from the National Biodiesel Board. They will eventually appear as CARD Policy Briefing Papers. The main findings of the papers are summarized below.

1. **The CARB approach to estimating land use change is not consistent with actual agricultural land use changes in the United States since 1996.**

The GTAP model used by CARB allocates land between crops, pasture (livestock land), and forests. Land is allocated by equalizing marginal returns across land cover type. Because marginal returns are equal and positive, an increase in one land cover type necessarily results in a decrease in others. In the GTAP model, there is no possibility of idle land which could be drawn on if the demand for cropland increases. This is an inherent deficiency for use to analyze policy and is not consistent with actual agricultural land use changes in the United States since 1996. The history of land use in the United States since 1996 shows large annual fluctuations in the amount of land planted to major field crops. A significant portion of these fluctuations is caused by changes in double cropped acres. After accounting for double cropped acres there still exist fluctuations that are not accounted for by changes in pasture or CRP. The standard deviation of the unexplained fluctuations is 4.18 million acres from 1997 to 2009, which is about six times as large as the maximum amount of new cropland that CARB estimates will be needed to meet expanded biodiesel demand.

The data are consistent with a systemic decline in crop acreage since 1996, at least part of which could be explained by increases in idle cropland, urban use and/or forests. The cumulative stock of land that has left crops is approximately 22 million acres. The large fluctuations in crop acres since 2006 are consistent with at least a significant portion of the 22 million acres being available for planting, which suggests the existence of cropland land that is idle or significantly underutilized. Because planting on idle cropland likely involves few marginal GHG emissions when it is brought into production, the current approach of not accounting for the replanting of idle land overestimates the emissions from indirect land use change. It is important to modify modeling approaches to account for the stock of idle cropland at any point in time.

2. **The restrictions imposed by use of the Constant Elasticity of Transformation supply function are not consistent with the data used to estimate the elasticity of land transformation.**

The way that GTAP allocates land between crops, pasture, and forest is to use a function called the constant elasticity of transformation (CET) supply function. This is a function that allocates land based on a function that depends on the share of revenue from each type of land cover and the elasticity of land transformation. This function is used because it allows for reasonably easy solutions to be found. However, the convenience of this function imposes restrictions that are inconsistent with the underlying data that were used to estimate the central value of the elasticity of land transformation.

The central value of the elasticity of land transformation in CARB's biodiesel analysis is -0.2. This central value was determined by taking the weighted average value of values that were estimated from historical data. The estimated values for this elasticity of land transformation for the each type of land cover can be found in Figure 3 of GTAP documentation.[1] These values are approximately -0.006 for forest, -0.26 for pasture, and -.25 for crops.

[1] See Ahmed, S.A., T. W. Hertel, and R. Lubowski. "Calibration of a Land Cover Supply Function Using Transition Probabilities." GTAP Research Memorandum No. 14. October 2008.

The most important factor affecting the magnitude of the change in greenhouse gas emissions from land use changes is the response of forest land to an increase in crop prices. The degree of responsiveness in GTAP is determined by the elasticity of land transformation and the revenue share. GTAP must use a single value for the elasticity of land transformation. This means that the single value is too low relative to crops and pasture and too high relative to forests. This means that GTAP forces the responsiveness of crops and pasture to be lower than the historical data warrants. More critically, however, GTAP forces the responsiveness of forest cover to be much higher than is indicated by the historical data. Too much responsiveness in GTAP means that CARB's estimates of the amount of forest being converted to cropland in response to a change in crop prices is far too high. We estimate that the responsiveness of forest cover to an increase in crop prices is too high by a factor of 30 relative to what is indicated by the historical data that is reported in Ahmed, Hertel, and Lubowski. Because the emissions of converting forest land are so high compared to conversion of pasture, too much responsiveness on forest implies that CARB's estimates of emissions are far too high for the United States.

3. **Although GTAP cannot explicitly account for double cropped acres, the yield elasticity with respect to price can be adjusted to account for the expansion of double cropping in response to increased crop demand.**

When analyzing land use changes in response to biofuels expansion it is important to account for changes in production due to double cropping because increased production from double cropping systems does not require additional land. It is difficult to account for double cropped acres in GTAP because there is no crop category called double cropping. However, GTAP's capability of allowing for yields to increase in response to higher crop prices provides a mechanism to account for the additional production. Treating the additional production as coming from current acres is the same thing as increasing crop yields by an additional amount. Formulas are derived that show how much upward adjustment should be made to the current GTAP yield elasticity with respect to price. Estimates are made for the United States and Brazil soybeans. The adjustments are much higher for Brazil because of the greater importance of double cropping in Brazil. The recommended adjustments are 0.08 for the United States and 0.24 for Brazil for soybeans, which is the crop involved in double cropping in both countries.

4. **There is no empirical support in Brazil for the assumption that yields in Brazil on new land are lower than yields on old land. For the United States, large overall acreage declines and significant shifts between crops since 1996 suggest that one parameter cannot capture important differences between crop yields on new land.**

CARB asserts at the beginning of its presentation of results that "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 cropland." This assumption is tested using data in Brazil, which has converted more land to agriculture than any other country in the last 20 years. The rate of land conversion has varied dramatically across regions of Brazil. This cross section variation allows for a comparison across regions of yield levels and yield growth rates. A simple comparison of yield levels in recent years across regions and a comparison of regional yield growth rates since 1996 shows, if anything, that the regions that have expanded the most have higher yields and higher yield growth rates. A regression analysis of yield changes on the share of new land being cultivated in a region shows no statistical support for the assumption that soybean yields on new land are lower than on old lands even within regions.

The U.S. data do not allow for either a direct visual comparison or a straightforward statistical analysis because of significant declines in crop acreage for many crops and large shifts in acreage towards corn and soybeans. One explanation for this shift is that corn and soybean yields have been growing faster than the yields of crops that have declined in acreage cultivation. This suggests that overall, yields have increased on the land that remains in production, but much of this production increase per acre has likely come about because of shifting to corn and soybeans rather than being solely due to land leaving agriculture. A careful analysis that estimates how marginal land leaving crop production in the United States has affected crop yields would need to account for the regional shifts between crops, which implies that the impact of declining acreage on yields likely varies significantly between crops. Time did not permit an estimation of crop specific yield effects.

5. **The biodiesel byproduct results modeled by CARB are difficult to rationalize because of discrepancies between the U.S. and rest of world price impacts and the limited price impact in the United States.**

The biodiesel byproduct (soybean meal) results for one of the scenarios run by CARB indicate that a 29% increase in U.S. soybean meal production results in only a 1.07% decrease in U.S. soybean meal prices. Such a small decrease in U.S. meal prices caused by such a large increase in meal supply implies a large export demand elasticity. However, the model shows soybean meal prices in most of the rest of the world increase in response to an increase in the supply of U.S. soybean meal. This should not happen in the real world. There seems to be something clearly wrong with the soybean byproduct sector. More information about exactly how the GTAP oilseeds sector was disaggregated into a soybean sector and a rest of oilseeds sector is needed.