Summary of the August 2009 Forum
Center for BioEnergy Sustainability (CBES)
"Land-Use Change"

Keith Kline began the Forum by inviting the audience to list current concerns with bioenergy. People in attendance noted that higher food prices, environmental impacts such as tropical deforestation, and high greenhouse gas emissions from crop-based fuels were among the most important issues. Keith noted that *land* and more specifically, some recent estimates of the land-use impacts of biofuels, underlies all these concerns. And the studies reporting indirect land-use change are based on models that rely on highly uncertain data and questionable assumptions. But these are the best models available so they have been applied to estimate the environmental and land-use effects of the increase in U.S. biofuel production under EISA. Many of the studies have focused on projected impacts of expanding US corn-ethanol production up to the 15 billion gallon per year maximum volume allowed from conventional sources under Energy Infrastructure and Security Act (EISA) of 2007.

Meanwhile, over the past year, 9.8 billion gallons of ethanol were produced in the United States[1]. This is nearly two-thirds of the 15 billion gallon EISA maximum. Rather than relying solely on models, we can learn a lot about what is *really* happening in terms of impacts and land use by simply taking the time to analyze empirical data associated with the recent increase in production. Is the expanded production causing the *direct* effects in the U.S. that models assume will occur in order to drive the "indirect" land-use changes?

The July 15 edition of *The Economist* featured a series of articles discussing the global financial collapse titled, "What went wrong with economics?" One problem identified was that of excessive reliance on models fitted to outdated data. Could we learn from that experience?

Many scientists believe that biofuel policies and regulations are being proposed without proper scientific analysis. Important points of reference can be identified if we gather and analyze comprehensive empirical data about what is actually happening to land, and why, around the world.

Debo Oladosu presented his findings from a study that examines the assumptions and operations of models applied in the recent past to assess the effects of biofuel production on land use. He illustrated how the MTBE content of gasoline dropped significantly beginning in 2001 and fell to zero by 2008. The MTBE was replaced by ethanol. The ethanol content of gasoline started increasing significantly in 2001 and fuel ethanol grew by 20% per year, on average, from 2001-2004, as it replaced MTBE, and even more rapidly from 2005 onward, as other ethanol polices were put in place.

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[1] Renewable Fuel Association Industrial Statistics. http://www.ethanolrfa.org/industry/statistics/ Data from "Monthly US Fuel Ethanol Production/Demand" for the most recent 12 months with data: June 2008-May 2009. Accessed August 12, 2009.

The first widely publicized study that attempted to estimate "indirect" land-use effects of expanding bioenergy production was by Searchinger et al. (2008). The main assumptions in that exercise were that:

- Global food and feed uses of corn are inelastic
- Global rate of yield growth remains constant
- DDGS replaces one-third of the feed otherwise diverted

And the resulting estimates of impacts included:

- Ethanol would divert 12.8 million ha of corn land in the United States in 2016
- U.S. crop exports would be severely affected:
    - corn by -62%
    - wheat by -31% and
    - soybean by -28%
- Prices would also be significantly affected: corn (by +40%), wheat (by +17%), and soybean (by +20%)
- Global replacement corn land would be 10.8 million ha. (This is the "indirect" land use, the area that the rest of the world would need to make up for the corn used for fuels.)

The reactions to the Searchinger et al. article included

- Wang and Haq (2008), who said that general-equilibrium modeling was needed
- Kolmes (2008) and Wassenaar and Kay (2008), who said that dietary changes could reduce land conversion and not all other land uses are critical to society
- Khosla (2008) and Mathews and Tan (2009), who said that price increases boost yields, one cannot ignore potential yield contributions, and new technologies hold the promise of rapid yield increases
- Kline and Dale (2008), who said that land-use change has multiple causes, biofuels may encourage more sustainable land use, and Searchinger's analysis omits current land uses (fires) and realistic reference cases

One major response of the modeling community was to employ a general equilibrium model, GTAP, to evaluate the issue. GTAP is well documented, widely-used, and had been adapted for biofuels by Birur et al. (2008). But, most of the assumptions used for the Searchinger analysis remained the same in the first GTAP model run – so it produced similar results in terms of indirect land-use change. However, the GTAP simulations found that the direct land-use effects were much lower than Searchinger's. While the indirect land-use effects were initially estimated by GTAP to be similar to Searchinger (Hertel, 2008), subsequent improvements in GTAP simulations and assumptions led to lower indirect land-use estimates (Hertel et al. 2009; Tyner et al. 2009).

There are many differences between models and the real world. The Purdue GTAP-BIO model allows yield to respond to prices in the model, but the net land conversion results from the model are exogenously adjusted by a factor of 0.66 based on an assumption that new land is less productive than existing cropland. But in the real world, there are intensive yield changes, extensive yield changes, technology changes, and continuous land-use realignments that have historically played a significant role in improving yields as cropland expanded. When historic corn-production changes are decomposed, yield turns out to play a crucial role in production. The ratio of domestic corn use to corn exports fluctuated widely over the past twenty years. Since 2001, the decomposition of empirical data shows that exports' shares of production have been constant or increased in all but two years (2004 and 2007). In the model, supply and demand must match. In the real world, stocks (storage) and "disappearances" can absorb excess corn in years where supply exceeds demand and the stocks later help bolster supply when demand exceeds annual output.

In reviewing many past simulations and the results from running an ORNL simulation based on GTAP, a new issue was identified; i.e. how the increase in biofuel production is imposed on the models. Searchinger et al (2008) and the early GTAP simulations made crucial assumptions to bring ethanol into the simulated markets. Searchinger et al (2008), assumed that there are no bottlenecks to ethanol use and introduced a $10/bbl price shock, while the initial GTAP study imposed a 136% increase in oil price.

The problem is that the price increases alone will cause changes that have nothing to do with the introduction of biofuels into the market. To examine this more carefully, Debo constructed a version of the GTAP model which

- Reflects the EISA "mandate" for corn ethanol
- Incorporates a physical land cover sub-model
- Incorporates co-products of corn ethanol
- Uses the "GTAP 6 Database" with a 2001 base year for land productivity and the world economy

Several simulations were then run to examine the effects of the petroleum "biofuel drivers" versus the effects of ethanol production alone in model simulation results. ORNL-GTAP mimicked prior GTAP modeling to look at land-use change effects under similar assumptions; the simulation was repeated with only the oil price change except that the production of ethanol in the U.S. was held constant. This allowed us to examine the effects on land-use change estimates that were inherent in the other model assumptions (independent of US ethanol production). The results showed that the estimated indirect land-use effects are nearly the same in both cases (e.g. with and without ethanol production). See Figure 1. It appears that the models used to estimate the effects of ethanol were actually simulating land-use changes induced by higher petroleum prices.

Another issue identified was the co-mingling of baselines. To produce comparable results, models must make a comparison of events at the same point in time. Empirical data show dynamics are inherent in agricultural markets and ongoing land-use changes are especially large and complex. When a model depends on a single snapshot in time, or simply compares two years, it is very risky to place much trust in the results in terms of replicating real world behaviors or estimating future behavior. More valid approaches to comparative statistics are possible, but take more time. In this case, the increase in ethanol that could be validly imposed on a 2001-based model looking at land-use change in 2006 with no yield change is only about a quarter of the total increase, because 74% of the increase in output was actually due to yield. When we did this calculation in ORNL-GTAP, we found an increase of corn ethanol of 3.1 billion gallons from 2001 to 2006 is associated with a new land conversion of only 0.004 percent globally. Under this simulation, the effects on exports were also small (decrease in coarse-grain exports of 0.2 million tons representing export share of 0.3%) and increase in area harvested of only 0.3 million ha.

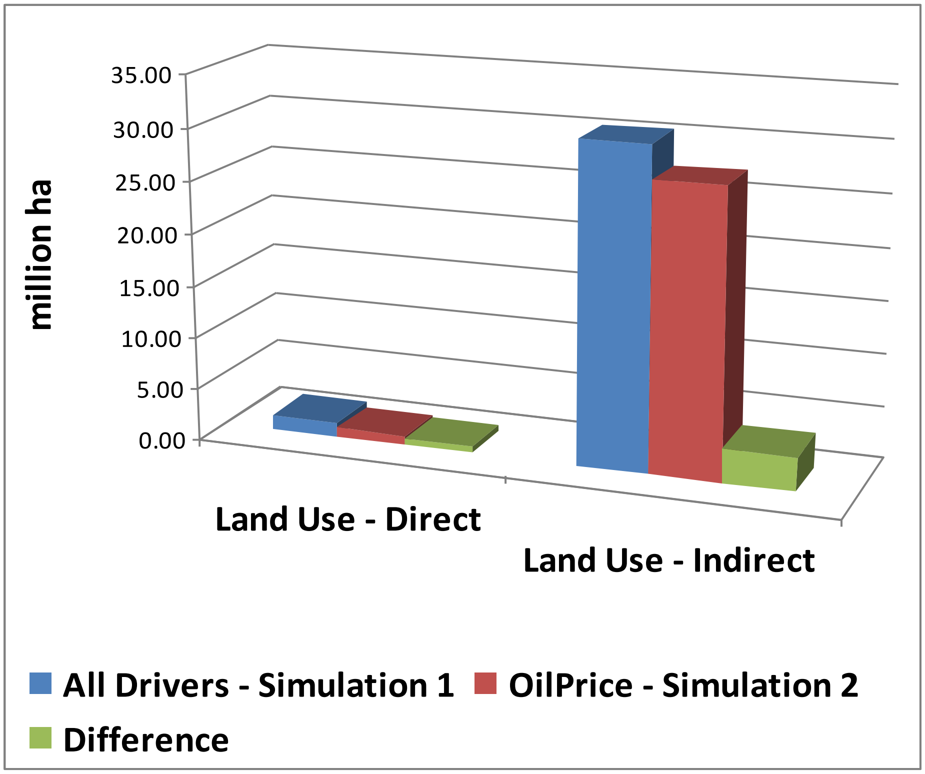

Figure 1: The difference (in green) between Simulation 1 (similar to original GTAP-BIO with all drivers and biofuel production) and Simulation 2 (same as Simulation 1 except biofuel production is not allowed to change) is only about 10% of total.

While the land-use impacts in percentage terms are minimal compared to those modeled in other simulations, the estimated effects in terms of hectares per 1000 gallons of ethanol appear large. This highlights yet another issue identified in the current modeling: uncertain baseline data. The land area data set used as a baseline for ORNL-GTAP is larger than that used by other GTAP analyses and therefore the same modeled change in percentage terms produces very different results in hectare terms.

Linear extrapolations should be avoided because dynamics are inherent to agricultural markets. Land-use data, model specification, and better analysis of empirical data are all necessary to support improved modeling in the future. We need to develop valid dynamic baseline scenarios for the economy, land use/cover, and emission accounts. We also need to improve the structure of economic models, develop new methods for linking models at various scales, perform uncertainty evaluation and standardize approaches for model comparisons.

In discussion that followed the presentation by Debo, it was noted that GTAP has been used in California and has been referenced by the Environment Protection Agency to support the current proposed rules and regulations that include significant “indirect land-use change” estimates for biofuels. The questions raised by the ORNL-GTAP simulations and other peer reviewers should be addressed prior to moving forward with indirect land-use change factors in these policies. How much of the indirect land-use change is actually attributable to non-ethanol production factors in model specifications (e.g. petroleum price increases)? And how much would the indirect land-use change estimates change if yield assumptions were adjusted to reflect empirical data and the baseline co-mingling issues were resolved?

Debo Oladosu pointed out that the GTAP model looks only at the percentage change in key factors. To get absolute values and make comparisons, that percentage must be applied to production values, land areas, etc. And when it comes to land use, these values are highly uncertain and variable. The baseline chosen for the application of the percentage can dramatically change the results; this could account for some of the variation seen in published results for land-use change effects thus far using similar modeling techniques. Yield changes between the baseline year and the current (or projected) year also have huge influences. If they are ignored, land-use change estimates will be overstated. But if they are imposed, land use change estimates might be under-stated. Either way, they contribute significant uncertainty.

Once the effects of other drivers are accounted for, the simulations reported here indicate a small indirect land-use change due to the increase in biofuel production in the US from 2001-2006. As shown in Figure 1, the changes after correcting for yield and petroleum prices are a small fraction of what other modelers estimated. This analysis has implications for a shift to cellulosic ethanol because many cellulosic production scenarios also involve land. Reductions in direct emissions are much larger for cellulosic ethanol than they are for corn, leaving the estimated "indirect land-use change" emissions as a primary concern. However, that is a topic for future research since we cannot say, based on the current analysis, whether the land-use implications are similar for the two systems.

Debo pointed out that oil is intertwined with everything in the world. These models depend on relative prices so when oil prices change it affects the supply and consumption of all commodities and consequently land-use.

In response to questions, it was noted that exotic species and genetic manipulation may allow increased biomass yields and decreased requirements for inputs (land, fertilizer and water). But there are many environmental, legal, social and institutional issues to address related to those developments. And again, it is risky to linearly extrapolate anything; e.g. test plot yields are not a good indicator of commercial potential. There will be many influences on markets, production and prices.

The various analyses of exports, yields, and production to date provide little empirical evidence to suggest that ethanol production in the US is forcing other crops out of production and inducing indirect changes. Shifts in production that fit well within historic trends have allowed more than sufficient US farmland to be available to meet the demands for increasing ethanol production. A decade of economic losses in cotton production have driven cotton farmers to seek other products and the increasing reliance on feedlots rather than pasture for livestock are two examples. But perhaps the most significant shift has been within coarse grains where between 2001 and 2009, the area planted in non-corn coarse grains fell 2.5 million hectares (or 28%). This can increase system efficiency in multiple ways as yields can jump by 50-150% and ethanol co-products replace the feed values of the prior coarse grains. As the U.S. has attained 65% of the EISA target for conventional ethanol as of 2009 (approaching 10 billion gallons per year), the total US land area planted in crops has fallen by 1.5 million hectares (still comparing to 2001 as the baseline used for GTAP and several other modeling simulations). Contrary to the simulations that estimated corn ethanol would cause major reductions in soybeans and wheat, the area and production for soy beans and wheat are higher than in 2001. Clearly many other factors are interacting with land-use decisions and global markets.

Keith Kline pointed out that globally there are many different potential impacts from biofuel policies and these go far beyond anything that current models attempt to estimate via supply (production), demand and price analysis. In many nations, biofuels are promoted to help address rural poverty and put marginal, underutilized lands into productive use. Emphasis on sustainable production is having significant effects by improving cultivation practices and conserving forests, soils and water supplies that were abused for decades under traditional practices. The losses, inefficiencies and distortions caused by policies leading to overproduction of low-priced grains in the 1990's, and the detrimental effects on food security and agricultural investment caused by exporting excess supplies to less developed nations, are examples of many factors not taken into consideration in these models. Food-feed-fiber-fuel production systems of the future may be fully integrated rather than competitive and involve complementary mixes of species and complex rotation systems, making current modeling assumptions irrelevant.

Although the direct land-use changes that models projected would occur due to biofuels appears to be the opposite of the empirical evidence thus far, that does not really prove anything one way or another when it comes to indirect impacts, which by their very nature, may be impossible to directly measure. But the empirical data should certainly give pause to putting too much credence on the current modeling results. We should carefully examine the theories, assumptions and input specifications that are driving the land-use change estimates in models to determine which are valid and which need to be revised and improved.

Presentation Slides