

Summary of

NBB Sustainability and Land Use Change Workshop

September 26-27, 2018

St. Louis, MO

A. Introduction

On September 26-27, 2018, the National Biodiesel Foundation (NBF) hosted a workshop in St. Louis, Missouri, which focused on technical issues associated with sustainability and land use change (LUC) as they relate to production of biodiesel fuels. This was the third in a series of bi-annual workshops organized by NBF and focused on LUC issues. The stated goals and objectives of the Workshop are the following:

- Quantify sustainability aspects of biodiesel, including impacts of land use and GHG emissions.
- Provide updates on recent research related to sustainability and LUC.
- Identify information gaps where additional research is needed.
- Promote collaboration among groups working in the areas of sustainability and LUC.
- Promote publication of technical work on topics discussed at the Workshop.

The workshop had approximately 45 attendees, including representatives from government bodies (including National Laboratories), industry, academia, and non-governmental organizations (NGOs). Fifteen technical presentations were given. In addition, an organized discussion was held to identify and prioritize areas where additional research is needed.

This Summary report highlights the topics discussed at the Workshop, as well as the knowledge gaps and future research priorities identified by the participants. The complete workshop agenda is available on the National Biodiesel Foundation website provided [here](#).

This report is organized into the following sections: (A) Introduction, (B) Overall Workshop Highlights, (C) Summaries of Individual Presentations, and (D) Priorities and Next Steps. A glossary of terms used during the Workshop is included as an appendix.

B. Overall Workshop Highlights

Given below are brief overall impressions and highlights from the Sustainability and Land Use Change Workshop. This list is not comprehensive, but attempts to capture the most important observations, significant take-home messages, and common themes that emerged from the presentations and discussions.

- Promotion and acceptance of biodiesel is hindered by well-publicized criticisms in both the U.S. and the EU. Much of this criticism derives from exaggeration of anecdotal evidence (e.g., deforestation) and lack of context to document actual causal drivers of change. Additional work is needed to address misunderstandings and provide a credible and holistic view of sustainability and land use change (LUC) issues as they relate to biodiesel fuel.
- Application of LCA to define carbon intensity (CI) of transportation fuels, including biodiesel, has become accepted, as regulations have moved forward and affected parties are focused on how to comply in the most effective and economical manner. There are still questions, however, about the appropriateness of applying LCA to assumed LUC. Analyses that combine the results of attributional LCA and consequential LCA to derive final CI values for particular fuel pathways are also problematic. Most national and international standards bodies have rejected consequential LCA for the core LCA, and most have accepted consequential for the ILUC analysis.
- Over time, the CI values calculated for biodiesel (and other fuels) have gradually declined. These reductions are attributed to improved efficiency in the production and conversion of biofuel feedstocks; better data; improved economic estimation of substitution and other parameters; improved modeling frameworks; more accurate data on emissions associated with any given LUC; and many other modeling and data improvements. There is concern that the methods and data utilized by government agencies such as CARB to calculate today's CI values may not be the most up-to-date, and that incorporating newer information could reduce the CI values further.
- The issue of indirect (or induced) land use change (ILUC) remains complex and controversial. GHG emissions associated with ILUC contribute a substantial portion of the total CI value assigned to a specific biofuel pathway. Different modeling approaches used to estimate ILUC emissions can result in very different CI values.
- Underlying reasons for these differences include varying assumptions regarding causal relationships, international trade, expansion of palm plantations, secondary livestock impacts, and many other factors. While the ILUC emissions gap between models is shrinking, significant differences persist.
- It is very difficult to completely "validate" emissions estimates from computable general equilibrium (CGE) models because many other things change in the economies around the world besides just biofuels. However, tests can be done to determine the extent to which LUC estimates seem to conform to the reality on the ground. More of that research needs to be undertaken. Science-based approaches are needed to conduct causal analysis and test hypotheses based on observations. When causal attribution is applied to all LUC, ILUC ceases to exist.

- Growth in production of palm oil is of concern because of the high GHG emissions associated with clearing tropical forests and draining peat lands, primarily in Southeast Asia. It is clear, however, that factors besides increased demand for biodiesel contribute to increased palm production. Most palm oil is used for food and chemical applications. The substitution of palm oil for other vegetable oils within food markets is an important and complex area.
- Significant increases in U.S. agricultural productivity have led to more calories being produced per acre and a diminished need for farmland. Production of more grain for livestock feed, as well as a gradual shift from cattle to poultry, have reduced the need for pasture land. These trends have implications for ILUC emissions that may not be fully captured by current modeling systems.
- Watershed-scale hydrologic models have been developed having sufficient reliability and granularity to estimate the impacts of agricultural changes – including conservation measures – on downstream water quality. Application of these models may be a useful way to assess the sustainability aspects of LUC.
- Deforestation remains a problem in some areas of the world, but is typically driven by a range of complex social and political issues at the local scale, not by the demand for additional land to support food or biofuel production. Deforestation in the U.S. is no longer considered a significant issue with respect to biofuel production.
- The terminology used to define and classify land cover, land use, and LUC varies among different data sources and models. This can lead to inconsistencies by analysts who use these sources for various purposes. Methodological changes in land use classifications have also occurred over time, which can lead to erroneous conclusions if users of this information are not aware of the changes.
- Various satellite-based remote sensing techniques are being used to identify and classify land cover, use, and change over time. Challenges inherent in such approaches include poor spatial resolution, fuzzy boundaries, seasonal changes, cloud cover interference, and others. Further, satellites observe land cover characteristics rather than land use. Also, analysis of remote sensing data is insufficient to determine the causal chains responsible for changes in land cover. Despite significant improvements in this area, further work is needed to improve the consistency and reliability of classifications by these remote sensing methods. The Conservation Technology Information Center and The Nature Conservancy have a project in this area applied to major agricultural regions of the US.
- In some situations, biofuels may provide important economic and environmental co-benefits not fully recognized by the existing regulatory methodologies used to define CI values. Economic benefits from diversifying commodity markets may provide incentives to invest in technological improvements across the agricultural sector. For example, growth of winter annual oilseed crops in California not only provides feedstock for biodiesel production, but also contributes to improved utilization of highly productive land while reducing water demands. Similarly, production of biofuels can contribute to improved forest health, reductions in open agricultural burning, and control of methane emissions from dairies and other sources.

- Among key areas for future research are: (a) documenting and filling gaps for EPA Triennial Reports on the effects of the US RFS; (b) conducting consequential analysis of biofuel policy on land management practices in the US including the total factor productivity (TFP)-intensification elasticity response to policy-driven market growth; (c) establishing “historical US agricultural scenarios” and corresponding data sets to facilitate the analysis of the impacts of the RFS via comparison of actual data to a hypothetical counterfactual scenario (e.g., business-as-usual based on trends prior to the ethanol boom); (d) translating ILUC uncertainties into more useful forms for policy makers; and (e) documenting drivers of deforestation over the past decade to improve attribution among causes and to distinguish among policies that can serve as buffers versus those that serve as catalysts.
- EPA is considering a “biofuels reset.” Analysis may be needed on the consequences of any proposed changes in biofuel policy or RFS levels that might emerge from the reset proposal.

C. Summaries of Individual Presentations

André Paula Santos [European Biodiesel Board (EBB)] “Latest Developments in EU Legislation Impacting Biofuels.” Santos began his presentation by describing the EBB, its membership, and its activities. EBB has over 75 members from 21 countries, and represents approximately 80% of total EU biodiesel production. Current annual EU biodiesel production is about 3.3 billion gallons (bg), while the installed capacity is 6.1 bg. The EBB serves its members by promoting scientific, technological, legal, and research activities; and by representing the members at relevant EU institutions and other international organizations.

European legislation is currently in effect requiring attainment of three energy and environmental goals by the year 2020: (1) GHG reductions of 20%, (2) incorporation of 20% renewable energy sources (with 10% from the transport sector), and (3) energy efficiency improvements of 20%. New legislation has recently been adopted that will require further improvements in all three areas by 2030. The Renewable Energy Directive (RED II) sets the 2030 requirements by calling for 32% total renewable energy, with 14% occurring within the transport sector. However, implementation is further complicated by a cap on crop-based biofuels to their 2020 consumption levels (with a maximum of 7%) in each EU Member State, double counting of biofuels produced from certain feedstocks, and multipliers applied to other renewables such as electricity in transport.

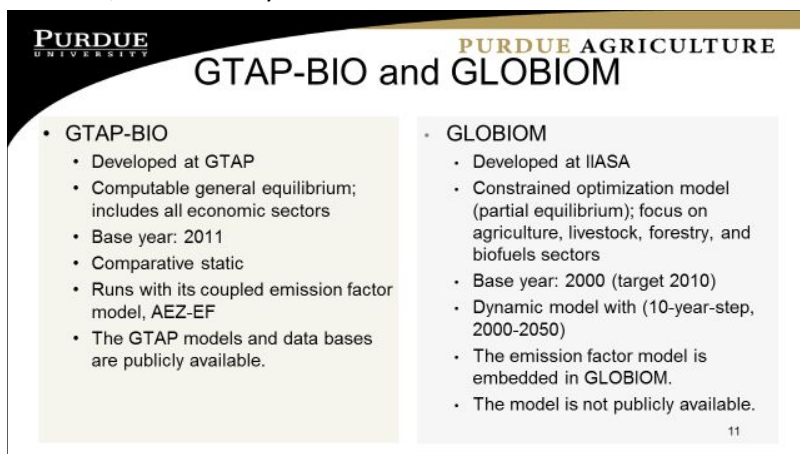
Although ILUC factors remain in the RED II only for reporting, there are several studies, activities, and options driven by concerns that biofuels are a factor contributing to indirect land use change. For example, individual Member States may choose to set lower volume limits on biofuels produced from oil-based crops, and this would allow them to lower their transport target in the same proportion. RED II considers that ILUC occurs when the cultivation of crops for biofuels displaces traditional crops for food and feed purposes. However, it is acknowledged that the magnitude of the ILUC effect depends on many factors such as the type of fuel feedstock being used, the level of feedstock demand, and the extent to which land with high carbon stocks is protected. The highest ILUC risks for biofuels are considered to occur with feedstocks “for which a significant expansion of the production area into land with high carbon stock is observed.” These “high ILUC-risk biofuels” are to be capped at 2019 consumption levels. These are to be defined by the European Commission in early 2019, and then be phased-out as of 2023, with a decreasing trajectory aiming at 0% in 2030. “Low ILUC-risk biofuels” are not to be phased-out. This will limit the amount of palm oil-derived biodiesel, but will not ban this biofuel completely, as some had recommended.

Additionally, a “traceability database” will be put in place by the European Commissions for all biofuels that are eligible towards the EU’s 2030 environmental targets. This database will include sustainability characteristics, including life-cycle GHG emissions, for all batches of biofuels that enter the marketplace. Santos concluded his presentation by discussing the public perception problems that biodiesel faces in the EU, and by identifying specific research topics to address these problems both in the US and the EU. These topics include the following:

- How to better define low and high ILUC risk biofuels
- How to better explain the protein/food security argument for biodiesel
- How to counteract the negative narrative on palm oil and deforestation
- How to push for LCA examination of all renewable energy sources, including electric vehicles (EVs)

Wally Tyner (Purdue Univ.) “Comparison between GTAP-BIO and GLOBIOM for Estimating Biofuels ILUC Change Emissions.” Tyner began with a brief history of the computable general equilibrium (CGE) economic model called GTAP, which celebrated its 25th anniversary in 2017. The version of GTAP which has been developed and used to study the economic and environmental impacts of biofuel production and policy is called GTAP-BIO. This model utilizes a 2011 database of world economic conditions. The standard GTAP database is being updated to 2014 and includes 57 economic sectors in 140 countries and regions. GTAP-BIO has yet to be updated beyond the 2011 database. Within GTAP-BIO, land areas are divided into 18 agro-ecological zones (AEZs). GTAP-BIO has been used widely within the U.S. to assess market-mediated responses to increased biofuel requirements, including the response of induced land use change (ILUC) that can occur if biofuel demand in one region induces LUC in another region to compensate for the loss of biofuel feedstock commodities. The GHG impacts of such market-mediated LUC are estimated by coupling GHG emission factors (from the AEZ-EF model) with the amount of land conversion occurring in each AEZ type to calculate an ILUC carbon emission intensity (CI), expressed in units of g CO_{2eq} per MJ of fuel produced.

A different economic model, called GLOBIOM, is commonly used to determine ILUC emission intensities for EU biofuel pathways. Because GTAP-BIO and GLOBIOM have different model structures, data sets, emission factors, and other aspects, it is not surprising that they often produce quite different results for the same biofuel. The figure shown here summarizes some of the major differences between these two models.



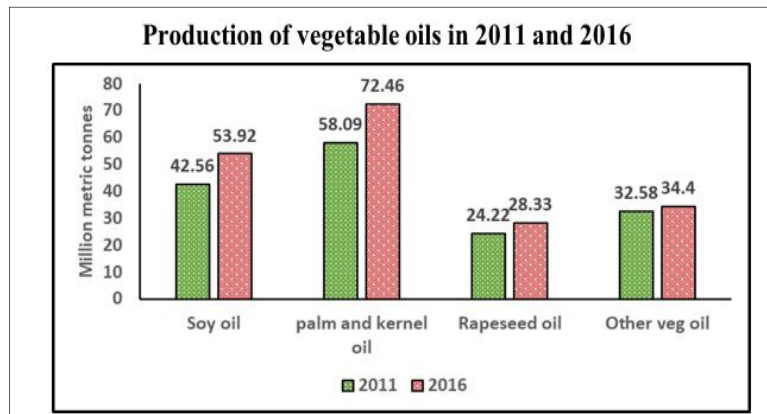
Tyner described a research study undertaken in collaboration with

Hugo Valin to compare the GTAP-BIO and GLOBIOM models in a consistent manner and explain the key factors responsible for the differences in ILUC emissions that they produce (<https://ageconsearch.umn.edu/record/275967/files/2358.pdf>). Biofuel pathways were evaluated for oilseeds, cellulosic crops, and sugar/starch crops. Calculated ILUC emissions were generally higher with GLOBIOM, with the differences being largest for biofuels derived from oilseeds (e.g., soy oil and rapeseed oil). A major driver for this difference is the “livestock rebound effect,” which is much more prominent in GLOBIOM than in GTAP-BIO. This effect is based on the notion that increased production of seed oils for biofuels is accompanied by increases in protein-rich meal used in the livestock industry. Additional meal requires production of additional cereal grains to mix with the meal for proper animal feed rations. Together, the additional feedstock results in more meat to be produced and consumed. Thus, the GHG impacts of these additional agricultural activities and expansion of livestock are attributed to the biofuel being produced. In one GTAP-BIO modeling scenario investigating production of hydro-processed esters and fatty acids (HEFA) from soy oil, the livestock rebound values used in GLOBIOM were substituted for the standard GTAP-BIO values. This single change increased the overall ILUC emissions intensity from 20 to 50 g CO_{2eq}/MJ, which explained most of the difference between the GTAP-BIO and GLOBIOM results. Tyner pointed out that there are no empirical data to support the large livestock rebound effect in GLOBIOM.

A second major area of difference involves the handling of international trade, with GLOBIOM having larger trade responses than GTAP. As a consequence, a given biofuel shock with GLOBIOM results in more crops being produced in other regions (having lower yields), and higher international deforestation. The impacts of palm oil expansion are also treated differently between the two models. Because much of the pristine swamp forests in Malaysia and Indonesia have already been degraded, historical GHG emission factors for palm expansion in peat soils are probably too high for today's situation. GTAP-BIO uses an emission factor of 38 tonnes CO_{2eq}/ha/yr, as compared to 61 tonnes CO_{2eq}/ha/yr used in GLOBIOM. Emission factors revised based on IPCC values by Miettinen et al. suggest that the factors for peat oxidation are too high in both ILUC models. Tyner concluded that the ILUC emissions gap between GTAP-BIO and GLOBIOM has been explained through this reconciliation effort, though further areas for investigation remain.

Farzad Taheripour (Purdue Univ.) “Vegetable Oil Production, Substitutions, and Emissions.”

Between 2011 and 2016, global harvested area of oilseed crops increased by 29 million ha, which represents about ½ of the total global harvested area increase during that time. The largest oilseed increases have occurred with soybeans (in the U.S., Brazil, and South America) and palm (in Malaysia and Indonesia) – two potential feedstocks for biodiesel (notwithstanding USEPA and CA policies lacking regulatory pathways for palm). As shown in the figure, these changes in crop areas are also reflected by increased vegetable oil production volumes between 2011 and 2016.



(<https://ageconsearch.umn.edu/record/277291/files/1567.pdf>)

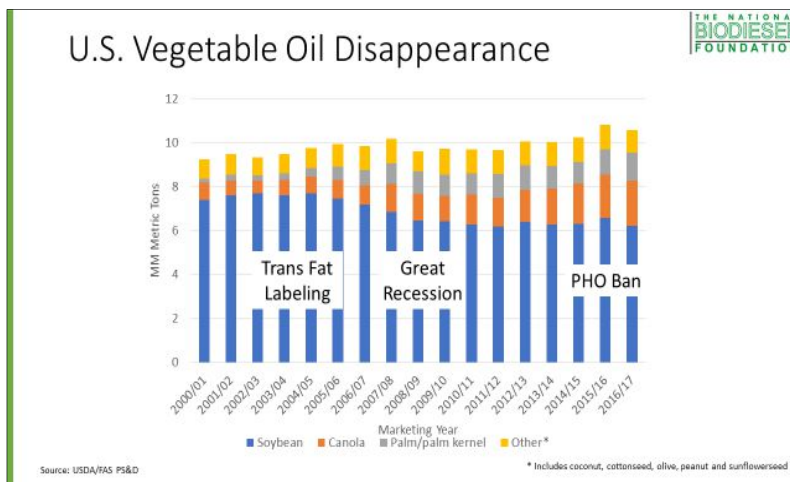
From a sustainability standpoint, production of palm oil is of much greater concern than production of other vegetable oils, due to the very high GHG emissions associated with LUC on peat soils where the palm can be grown. Additionally, increased production of soybeans reduces demand for pasture land (due to increased soy meal used in livestock feed), while this benefit does not result from increased palm production. Because of these issues, there is concern that increased demand for biodiesel creates pressure for increased palm production – both from direct use of palm-derived biodiesel and by substituting palm oil for soybean oil that is displaced to produce soy-derived biodiesel.

Taheripour examined the issue of vegetable oil substitution using the GTAP-BIO model. An important factor in determining ILUC is the assumed elasticity of substitution among vegetable oils in different locations around the world. The current version of GTAP utilizes an elasticity value of 0.5 for the U.S., Brazil, and South America; but a higher value of 5-10 for the EU and many other regions. These elasticities are based on existing data and historical trends and shifts in trade patterns. In this work, modeling simulations were conducted to examine the sensitivity of predicted ILUC emissions to changes in the substitution elasticity factors in different regions. These simulations were done to represent three different U.S. biofuel shocks: (1) increase corn ethanol by 1.07 bg/y, (2) increase soy biodiesel by 0.5 bg/y, and (3) increase rapeseed biodiesel by 0.5 bg/y.

Results showed that in the corn ethanol pathways, changes in elasticity values had very little effect on the predicted ILUC emissions, which varied from 12.0 to 12.3 g CO₂eq/MJ over the range of elasticities examined. With the biodiesel pathways, however, changes in elasticity values had some impact on predicted LUC emissions. With both biodiesel cases, changes in elasticity values from the model's baseline values of ± 25% had minimal effect on the final ILUC emission values. However, assigning a substitution elasticity value of 1.0 uniformly throughout the world reduced the ILUC emissions substantially – from 17.5 to 10.2 g CO₂/MJ for soybean biodiesel, and from 11.7 to 7.7 g CO₂/MJ for rapeseed biodiesel. While this experiment illustrates the impact on ILUC emissions resulting from different elasticity scenarios, existing data support the elasticity values currently in use by GTAP-BIO.

Sharon Bard (Centrec Consulting Group) “U.S. Demand for Palm Oil.” Palm oil usage in the U.S. has increased substantially over the past 15-20 years. Some analysts have simplistically attributed this increase to the expansion of U.S. biodiesel production that occurred over the same time period. The work presented by Bard was conducted to examine a wider range of factors responsible for this increased palm oil usage. As shown in the figure, U.S. soybean oil usage has decreased by approximately 1 million metric tons (MMT) since 2000, while total vegetable oil usage has increased by about 2 MMT. The loss of soybean oil has been compensated by increases in several other oils, including palm oil and canola oil.

As indicated in the figure, several major events unrelated to biodiesel production also occurred during this period, which likely impacted the substitution among the various vegetable oils. For example, the U.S. Food and Drug Administration (FDA) decision in 2003 to require labeling of trans fat content in foods created pressure to substitute low trans fat oils (such as palm and canola) for high trans fat oils (such as partially hydrogenated soybean oil). This pressure was intensified by FDA's subsequent decision to completely ban the use of partially hydrogenated oils (PHOs) in food products.



Bard presented an overview of the palm oil processing industry, and explained how various oil fractions resulting from different processes are used in a variety of edible and inedible applications. The demand drivers for the edible and inedible palm oil markets are different, but most previous economic research on vegetable oil supply and demand did not account for this complexity. Also, most research treated vegetable oils as end products rather than as intermediate goods, which is inappropriate for some oils, particularly palm oil. Furthermore, most studies focused on simple price relationships, while overlooking other factors that are important for palm oil, such as the impacts of trans fat labeling and the PHO ban.

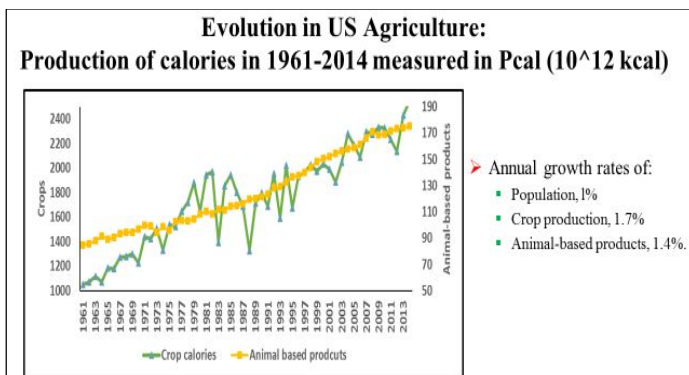
Monthly vegetable oil prices from 2004 to May 2018 were analyzed to assess Granger causality* between soybean oil and palm oil, and between canola oil and palm oil. While not a test for true cause-and-effect relationships, this analysis did reveal Granger causality in these vegetable oil price behaviors.

* Granger causality is a statistical concept of causality that is based on prediction.

Another analysis was performed to define U.S. monthly palm imports as a function of several other factors, such as oil prices, overall food demand, seasonality, and structural changes like the ban on PHOs. Preliminary results from this econometric analysis suggest that palm oil imports are positively impacted by soybean oil prices, domestic demand, and a structural change beginning in 2006; and are negatively impacted by palm oil prices. Further refinement of this work may attempt to separate the effects on edible and inedible palm oil demand.

Farzad Taheripour (Purdue Univ.) “Production and Consumption of Protein, Fats, and Carbs in the U.S.: Role of the Livestock Sector.” A study was undertaken to assess changes in U.S. agricultural productivity over the past 50 years, as measured by energy (calorie) content and nutrient profiles, rather than by the conventional metrics of mass, volume, and monetary value. In this study, 92 crops were included (both food and feed) as well as animal-based foods (beef, poultry, and pork) and dairy products. As shown in the figure, the amount of calories has continuously increased during this time period, for both crops and animal products. Also, the rate of increase in calories is significantly higher than the 1% rate of population increase during this time. This figure below also shows that calories from crops are an order of magnitude higher than calories from animal products.

Other analyses show that while total harvested cropland area has remained fairly constant, the share of corn and soybeans comprising the harvested crops has increased, and hence, the share of total crop calories from corn and soybeans has also increased. Between 1961 and 2013, the corn and soybean share of total harvested area increased from approximately 30% to 50%, while the share of crop calories from corn and soybeans increased from 40% to 70%.



Total U.S. food consumption calories – as well as calories from protein, carbohydrates, and fats – have increased at annual rates of 1.3-1.5%, which are all well above the population growth rate of 1.0%. Over the past 50 years, the ratio of crop-based/animal-based total food calories has increased from 60/40 to 70/30. This change results largely from reductions in animal-based fats, while animal-based proteins have remained flat at 65-70% of total proteins. A reasonably close balance exists between supply and demand of animal-based food calories, whereas the supply of crop-based calories vastly exceeds the demand. Some conclusions from this study that are relevant to the topics of biodiesel and ILUC include the following:

- Increased crop yields, and increased shares of corn and soybean crops, have resulted in substantial calorie-production increases, i.e., more calories per acre.
- A major shift in the livestock sector has occurred, with a decreased share of beef and increased share of poultry.
- A major substitution between feed and land has occurred within the livestock sector. Production and use of more crop-based feed has led to decreased demand for pasture land.

According to Taheripour, some models used to estimate ILUC emissions for biofuels do not properly account for these agricultural trends of increased productivity, increased land intensification, and

substitution between feed and land. GTAP-BIO does account for these factors, although the treatment of feed and land substitution is now being updated.

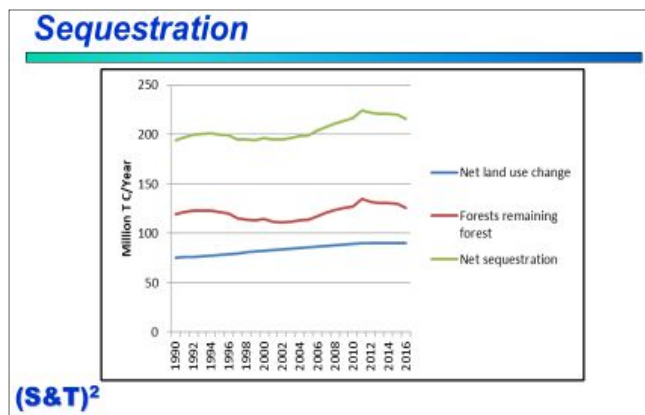
Don O'Connor (S&T Squared Consultants), "CARB's AEZ Model." The AEZ model, when coupled with the GTAP model, is used to derive estimates of carbon emissions resulting from land use change (LUC). In this two-step calculation process, GTAP is first utilized to estimate the amount, location, and type of land that is converted in response to a biofuel shock. The AEZ model provides emission factors per unit conversion of each land type. Combining the GTAP output with these AEZ emission factors provides an estimate of overall emissions associated with the fuel shock being investigated.

Within GTAP simulations for biofuel applications, there is generally much more conversion of pasture land to crops than conversion of forests to crops. However, carbon emissions resulting from forest conversion are much greater than from pasture land, so small changes in forest conversion can have significant impacts on the final ILUC emissions calculated for a particular biofuel pathway. This is the motivation for O'Connor's study to investigate forest carbon data currently used in the AEZ model, and to compare this with other information available from the U.S. Forest Service (USFS).

The AEZ model accounts for carbon in forest lands in seven distinct "carbon pools:" above ground biomass, below ground biomass, understory, deadwood, litter, soil carbon, and foregone sequestration. For most AEZ categories, the largest contributors to total forest carbon are above ground biomass and soil carbon. The USFS is in the process of adopting a new approach to forest carbon accounting. The Forest Carbon Accounting Framework (FCAF) will incorporate consistently-measured annual forest inventories, including each carbon pool. This carbon pool data is currently available at the state level, but not the AEZ level. Also, the currently available on-line data are not ideal, as the forest area data come from 2010, while the carbon pool data come from 2014.

Recognizing these data limitations, O'Connor determined average forest carbon pools across all the states using the USFS data, and compared the results with the forest carbon pools used in the AEZ model. Most carbon pools were found to be higher in the AEZ data compared to the USFS data. The total of above ground biomass, below ground biomass, deadwood and litter was 31% higher with AEZ – 104 vs. 79.5 tonnes C/ha (tC/ha) – whereas soil carbon values were very similar between the two, at about 60 tC/ha.

Issues of carbon sequestration by forests were also investigated. As shown in the figure, U.S. forests are increasing in sequestration, due to both expansion of forests into new areas and continued growth of existing forests. From this USFS data, a net sequestration rate of 0.48 tC/ha-yr is calculated, which translates to a foregone sequestration rate of 14.5 tC/ha over a 30-year period. In contrast, the foregone sequestration rate used in the AEZ model is 20 tC/ha.

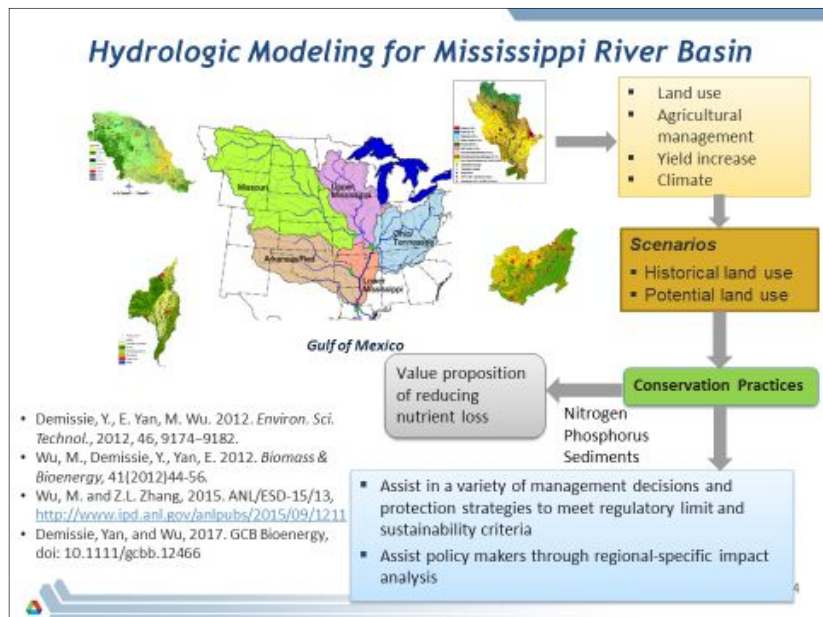


Given that LUC involving U.S. forests is no longer a large driver of ILUC emissions for domestic biofuel crops, it is questionable whether the types of updates and modifications described by O'Connor are worthwhile pursuing. If they are, two specific areas for improvement are recommended: (1) update the

USFS forest area data from 2010 to 2014 and (2) convert the state-wide carbon pool data into AEZ regions.

May Wu (Argonne National Laboratory), “Water Quality: Nutrients and Sediment Runoff.” Wu described an integrated modeling and analysis approach to study potential impacts of bioenergy crops on water quality throughout the Mississippi River Basin (MRB). The overall approach is illustrated in the figure shown below. Through modeling of various scenarios, multi-scale geospatial and temporal analyses are used to investigate the potential impacts of various agricultural and conservation practices upon water quality. The quality indices of greatest interest include nitrogen and phosphorous runoff, nitrate, and suspended sediment (SS). Besides considering the entire MRB, hydrologic models were developed and validated for several tributary river basins and smaller-scale regional river basins. This water quality modeling included application of the Soil Water Assessment Tool (SWAT). (SWAT is a spatially and temporally distributed model that utilizes weather information, topography, soil properties, and land management practices to simulate hydrologic, soil erosion, nutrient, and pesticide responses.)

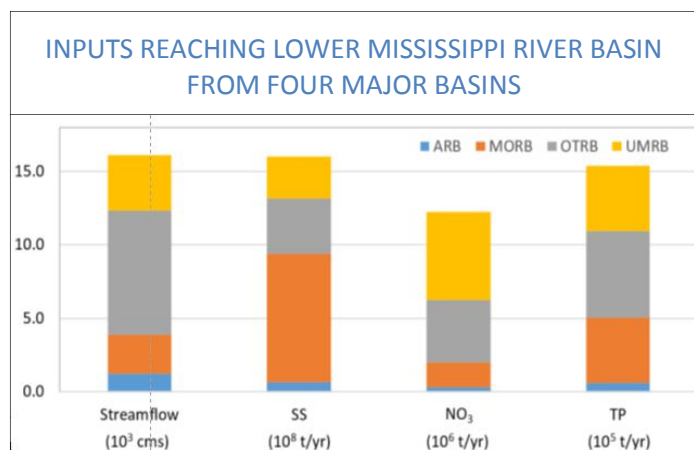
Wu presented several examples to illustrate the usefulness of this approach in assessing the potential impacts of increased biofuels production and the efficacy of agricultural conservation practices – such as use of riparian buffers, cover crops, slow-release nitrogen fertilizers, and tile drainage. For example, corn ethanol simulations in the Upper Mississippi River Basin (UMRB) identified changes in nitrate, total phosphorous (TP) and suspended sediment (SS) in specific areas, with a high degree of granularity. Similar modeling



in the Ohio River Basin and the Missouri River Basin identified “hot spots” predicted to have high concentrations of nitrogen, TP, and SS.

The figure shown below provides results from a modeling study to apportion streamflow and pollutants observed in the Lower Mississippi River Basin (LMRB) to upstream sources from four tributaries. In the case studied, over one-half of total streamflow originated in the Ohio River Basin, while the Missouri River Basin was the largest source of SS and the UMRB was the largest source of nitrates.

Modeling of conservation practices within the Iowa River Basin showed that use of riparian buffers was the most effective conservation practice for reducing SS, while



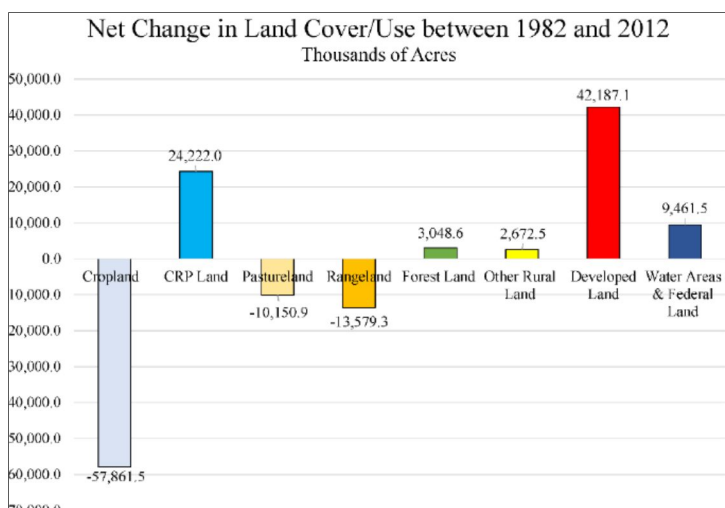
use of tile drainage was most effective for reducing nitrate and total nitrogen (TN). Use of cover crops was most effective for overall water quality improvement. From this work, Wu concluded that watershed-scale hydrologic modeling and analysis can provide knowledge and insights at fine resolution to support strategies that achieve increased biofuel feedstock production while limiting water quality degradation.

Keith Kline [Oak Ridge National Laboratory (ORNL)], “Science and Land Use Change – Can Better Data and Analysis Address Priority Development Needs?” Kline presented a review of LUC issues, including definitions, observations, assessments, predictions, and causal factor analysis. He pointed out that ILUC estimates are not based on direct monitoring or consistent measurements, and thus cannot be tested by normal scientific methods. Nevertheless, quantitative measures can be made for land cover, crop productivity, land management, and other important variables. These data are essential to perform science-based LCA. When conducting such studies, it is important to define clearly and consistently what is meant by terms such as land-use change, land management, negative emissions, waste, LUC accounting, and others. It is also essential to indicate the basis of comparison when changes are being reported.

Kline described the use of Index Decomposition Analysis (IDA) to estimate the contributions of different factors in meeting U.S. corn demand for ethanol production. IDA is a statistical analysis, not an analysis of causation. Nevertheless, it is useful in examining market-mediated ILUC linkages and in assessing specific contributions based on empirical data. Results were shared from a published IDA study covering the 2001-2009 time period (Oladosu et al. 2011), along with an updated IDA study to cover the 2001-2017 period. The updated study reinforced the earlier results showing that most of the change in corn used for ethanol production can be attributed to changes in the distribution of domestic uses of corn among feed and other industrial uses. Increased corn production over the 2001-17 period is responsible for 26% of the change in corn used for ethanol production, with most of this attributable to per-acre yield increases.

In assessing whether U.S. biofuel policies alter U.S. land use trends, Kline cautioned about selecting proper time frames for comparison. For example, he pointed out that the period of most rapid ethanol growth was 2001-2010, noting that several recent published studies that focus on the 2008-2012 period may not be representative of the effects of expanding ethanol output. Interestingly, during the period of 2001-2010, total cropland area in the U.S. declined by about 1%.

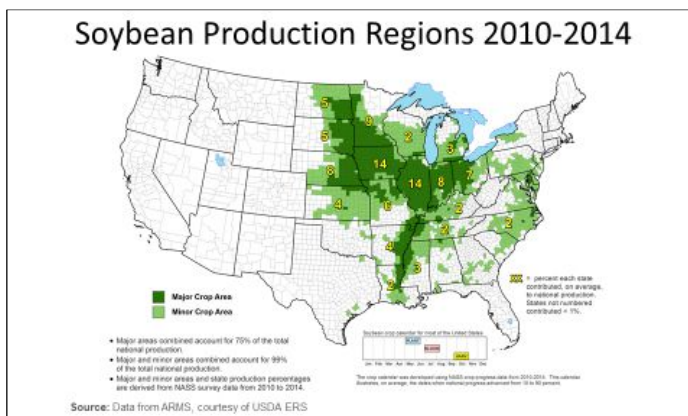
Kline also presented LUC information regarding energy crops from the U.S. DOE’s 2016 Billion Ton report (BT16), pointing out that the LUC estimates depend upon model specifications and assumptions. The amount of land allocation predicted by BT16 for energy crops in 2040 is consistent with historical land trends reported by USDA and shown in the figure. These trends indicate reductions in cropland, pasture land and range land; but increases in developed land and forest.



With respect to global food security and the growing demand for food, Kline pointed out that about 40% of all produced food is wasted today – with a higher percentage for fruits, vegetables, and seafood; and a lower percentage for meat and dairy. He stated that future food security is not limited by the amount of global land available, but by inadequate land management and extreme weather (including drought). While deforestation remains a concern, it can only be addressed by targeting the actual causal factors locally. These local causes of deforestation are unlikely to include global market demand for biofuels.

Bill Hohenstein (USDA), “Conservation and Production Trends and Implications for the GHG Profile of Biofuels.” Hohenstein began by emphasizing several reasons why GHG emissions (and their reduction) are important to the agricultural and biofuels industries. He pointed out that the GHG profiles of biofuels are not static, and are improving with time as efficiency gains and other developments are occurring. USDA believes that EPA and CARB have not fully accounted for such improvements in their determination of life-cycle carbon intensity (CI) values for biofuels. For example, EPA’s current estimates for corn ethanol indicate a 21% reduction of GHG emissions compared to gasoline (by 2022), whereas more recent work supported by USDA suggests a 40% reduction. A major reason for this difference is recently improved understanding of LUC. In particular, deforestation has been less extensive than originally anticipated, while crop intensification (especially through multi-cropping) has been more extensive.

More relevant to the GHG profile of biodiesel has been the growing conservation trends in soybean production. The map shown here illustrates the areas where soybeans are grown in the U.S. Fertilizer inputs (which are significant GHG drivers for biofuels – especially corn ethanol) have remained nearly constant for soybeans from 2006 to 2012, at 17 lbs. nitrogen/acre-year. However, yield per acres has risen substantially, so pounds of nitrogen used per bushel harvested has gone down. The GPS-driven navigation system known as Auto-Steer, has increased significantly over this period. Auto-steer, combined with Variable Rate Technology (VRT), has significantly improved the efficiency of soybean agriculture. While application of no-till agriculture is no longer growing, use of cover crops is, resulting in improved sustainability. Hohenstein concluded that with these numerous improvements in soybean production, an update to previous LCA studies would likely determine lower CI values for soy biodiesel than the values currently defined by EPA and CARB.



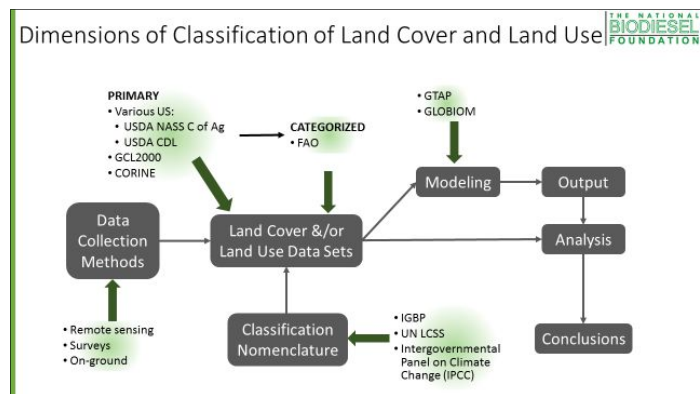
Sharon Bard (Centrec Consulting Group), “Reader Beware! Land Use Classification Nomenclature Issues.” Many stakeholders within the biofuels industry employ modeling and research efforts utilizing data sources that define land use (LU) and land use change (LUC). However, it is recognized that there are many uncertainties and inconsistencies among the datasets, along with variations in how different researchers utilize the data. These problems have implications with respect to modeling efforts, analysis outcomes and conclusions that are drawn from biofuels studies – including derivation of CI values from ILUC. The figure shown below was presented by Bard to explain the overall process by which LU/LUC information is utilized in biofuels analysis studies. Specific areas of inconsistency and errors were

pointed out with respect to LU/LUC classifications. Some of the key classification issues addressed include the following:

- Handling of missing data points
- Accuracy of the data
- Proper accounting for double cropping
- Delineating land cover vs. land use vs. land management
- Aggregation of land cover types
- Land use change methodology
- Omission of specific land categories
- Definition of marginal land

Bard discussed a specific land classification change within the USDA’s Census of Agriculture (CoA) datasets. Between 2002 and 2007, total U.S. cropland decreased by 34 million acres, with a 26-million acre decline in cropland pasture (CP) contributing a large share of this. However, much of the CP decline can be attributed to a methodological change in the CoA that was hypothesized to cause the respondents to reclassify some CP to permanent pasture (PP). If analysts are unaware of this classification change, they could draw erroneous conclusions about LU/LUC over this period.

Bard also provided examples of how different organizations and data sources utilize inconsistent nomenclature and categorization of LU information. For example, the USDA’s CoA utilizes highly aggregated classification nomenclature for cropland. This is unlike USDA’s Cropland Data Layer (CDL) analysis tool that uses a detailed and disaggregated categorization scheme for different cropland uses. Other organizations such as the IPCC and International Geosphere-Biosphere



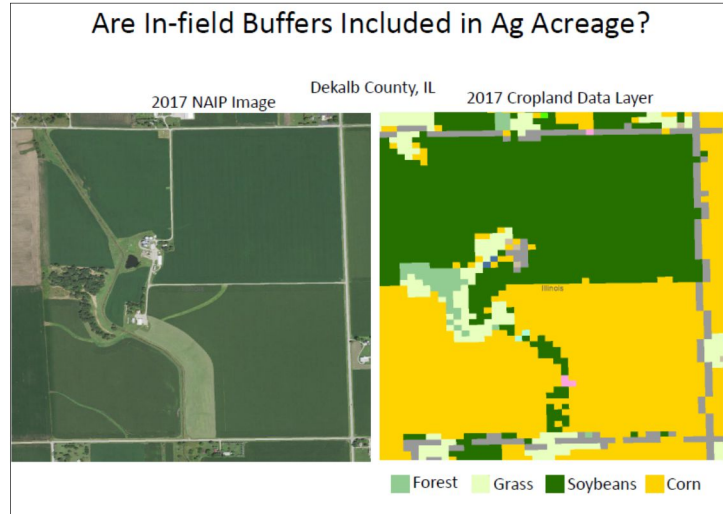
Programme (IGBP), employ classification nomenclature that is less aggregated than the CoA but more aggregated than the CDL analysis tool. Bard concluded by discussing how the errors in LU/LUC can be minimized. Suggestions include the following:

- Increase accuracy of land cover classification
- Apply standardized classification nomenclature for land cover across different data sets
- Apply standardized methodology for defining LUC
- Be aware of limitations in the data and methods, and account for this in research projects and their conclusions

Ken Copenhaver (CropGrower, LLC), “Using Remote Sensing for Direct Land Use Change Detection Related to Biofuels Production.” Copenhaver began by discussing different methods for assessing LUC, and the errors inherent in these methods. Satellite-based, multi-spectral analyses provide rapid monitoring of vast land areas, but sometimes suffer from poor accuracy in identifying specific land uses and changes in land use. Generally, LUC only occurs on a small fraction of total land surface in a given

region. Using Brazil as an example, Copenhaver showed that the identification of land use is less accurate in areas where the greatest amount of LUC occurs.

Many analysts utilize USDA's Cropland Data Layer (CDL) which is a satellite-based analysis tool used to identify agriculture types and locations at a 30-m spatial resolution. Raw CDL data tends to overestimate the amounts of land undergoing change from one time to another. In part, this is due to "fuzziness" of the analyses, leading to mis-identification of specific land areas, particularly around the fringes of agricultural fields. An example of this is shown in the figure, where an in-field buffer apparent in the visual image on the left is mis-identified as a crop by CDL.



Copenhaver described ways in which raw CDL data can be modified to create more accurate assessments of LUC. These include elimination of unlikely LUC scenarios (such as back and forth conversions of cropland and forests) and corrections for roadways and other buffers. Even with these modifications, CDL analysis methods may overestimate actual LUC as assessed by aerial photography as part of USDA's National Agriculture Imagery Program (NAIP), or by ground truthing.

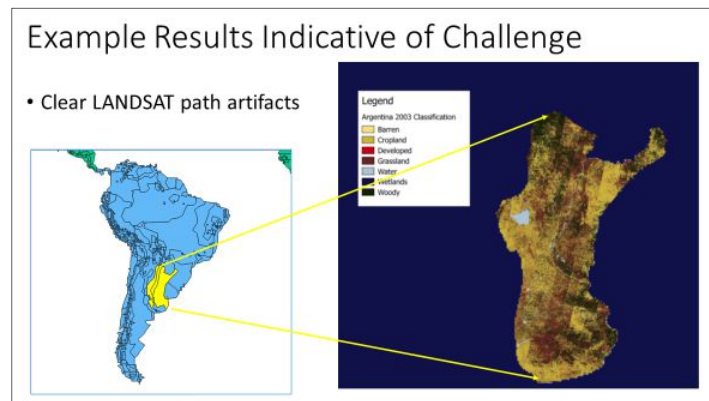
Copenhaver also described a research study now underway, utilizing remotely sensed imagery to determine land use conversion associated with operation of specific corn ethanol plants in 14 states. LUC assessment will be made by examining (and correcting) CDL data from 2006/2007 and from 2017/2018. Several approaches will be used to assess and reduce errors in the LUC determinations, and to examine the establishment of field buffers, double cropping, use of CRP lands, and other significant land use modifications.

Charles Linville (Ploughman Analytics), "Digital Imagery for Identifying Land Classifications."

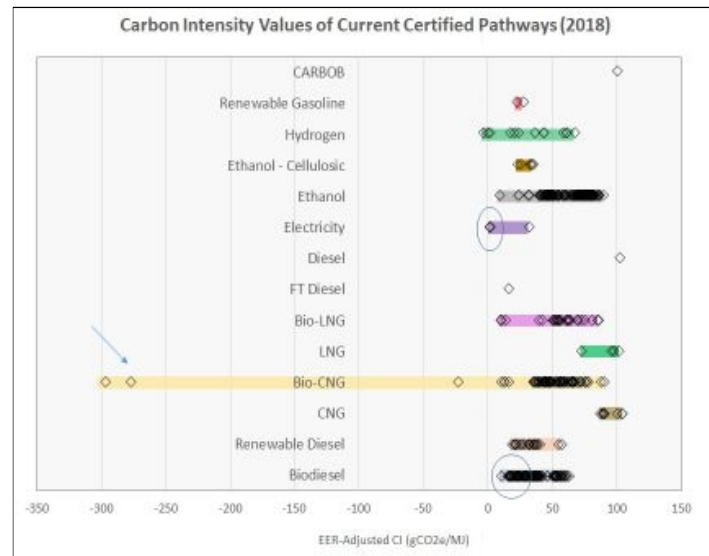
Linville discussed work being done to improve land classification through use of various digitized imaging techniques. Prior work utilized a MODIS satellite imaging product to define land cover types at a fairly coarse resolution of 500-m, but this method gave significantly different results than those from other data sources such as the Food and Agriculture Organization (FAO) and GTAP. In this reclassification study, researchers focused on selected areas in Brazil and Argentina, which are relevant to the issues of LUC associated with biofuels.

Undergraduate students were employed to inspect high resolution satellite images (sub-meter scale) and make determinations of land cover in selected locations and times. This detailed determination was then used to perform "supervised classification" of all times and locations within the study area using LANDSAT data. (The LANDSAT resolution of 30-m is coarser than the initial sub-meter data, but much finer than MODIS data.) This supervised classification approach utilized 48 6-day composite images to represent an entire year.

Various aspects of image selection, image screening, and image rendering were investigated to quantify and improve the reliability of this land classification methodology. Challenges included lack of familiarity with the geography, cloud cover, the various stages of crop growth when images were taken, and others. Problems with nomenclature were also uncovered, leading to difficulties in delineating land cover vs. land use vs. land management. It also proved difficult to distinguish idle land, fallow land, and failed crops. Despite preparation and use of a 76-page student training guide, it was difficult to obtain repeatable and reliable classifications. An example of one challenge in dealing with LANDSAT images is shown in the figure here, where artifacts can clearly be seen resulting from merging of data from different satellite paths. The research team is now exploring ways to solve this problem. They are also considering options for further improvement of the supervised classification methodology, including use of a more recent study period and application of machine learning techniques.



Stephen Kaffka (U.C. Davis), “Can Biofuel Feedstock Production have a Role in California’s Changing Agricultural and Policy Landscapes?” Kaffka began with an overview of biomass, bioenergy, and transportation policies in California. The Low Carbon Fuel Standard (LCFS) is just one of many policies meant to address social and environmental goals, including GHG reduction, air quality improvement, rural employment, social justice, and others. California’s Renewable Portfolio Standard (RPS) of 33% renewably-generated electricity by 2020 is already being met, and the State is making progress towards meeting the goal of 50% renewable energy by 2030. As shown in the figure, California has now certified dozens of renewable fuel pathways under the LCFS Program, including many for biodiesel and renewable diesel fuels.



Kaffka also discussed the concept of “dematerialization of agriculture.” In recent decades, total agricultural productivity has increased dramatically, and real agricultural prices have fallen, even as world population growth has accelerated. While still of concern, the global problems of malnourishment and food insecurity are declining, at the same time some coproducts from food crops are increasingly used for bioenergy. It is possible that with the current trend of producing more crops on less land, we have already passed the point of “peak cropland,” and are now releasing increasing amounts of land to other purposes. This “land sparing” could be reduced if more land begins to be used for non-food crops, such as bioenergy. The GHG implications of these trends are complex.

Over the past decade, tree nut plantings in California have increased dramatically, contributing to a “hardening” of water demand within the state, and resulting in reduced water supplies for other crops. This trend has altered the state’s agricultural economy and landscape in significant ways, including expansion of idled farmland. Kaffka pointed out that from the standpoint of GHG emissions, it makes no sense to idle land within one of the world’s most productive agroecosystems. One potential solution to this problem is adoption of winter annual oilseed crops, such as canola and camelina, which would require less irrigation and would provide an additional source of rural revenue. The economic and environmental effects of such landscape intensification options were explored using the Bioenergy Crop Adoption Model (BCAM). Results from LCA analysis of biodiesel production from canola gave CI values of 20-22 g CO_{2eq}/MJ, which compares very favorably with biodiesel from other feedstocks.

Finally, Kaffka discussed the topic of co-benefits arising from biomass use and LUC in California. One example involves the co-benefits of fire risk reduction and forest health improvement by utilizing forest residuals as feedstocks for biofuel production. Using the Geospatial Biorefinery Siting Model (GBSM), both cellulosic ethanol and gasification/Fischer-Tropsch hydrocarbon fuel scenarios from forest residual feedstocks were explored. With both residue-based biofuels, a subsidy of roughly \$1.25/gasoline gallon equivalent (GGE) would be necessary for economic operation. However, a subsidy of this level could already be provided by a combination of California LCFS credits and Renewable Information Numbers (RINs) under the Federal RFS Program.

Another example of co-benefits is production of renewable natural gas (RNG) by capturing and upgrading methane emissions from various sources – including landfill gas, wastewater treatment plants, municipal solid waste (MSW), and animal manure digesters. Integrated biorefinery concepts are now beginning to emerge in California, whereby conventional ethanol and biodiesel production facilities are being expanded to accommodate production of non-conventional biofuels. A problem mentioned by Kaffka is the inability of standard, regulatory LCA approaches to properly account for biofuel co-benefits such as healthy forests, methane reduction from dairies, reduced open burning of agricultural waste, and others.

Don O’Connor (S&T Squared Consultants), “Changes to CARB’s LCA Methodology.” In 2019, CARB will begin using an updated LCA model, CA GREET3.0, and a simplified calculator for determining a fuel’s CI value. This updated California model is based on the Argonne National Laboratory’s GREET-2016 model, whereas the previous CARB model was based on GREET-2013. Some of the most significant changes in the updated model are reduced GHG emissions associated with fertilizer production, higher N₂O emissions from soybean agriculture, and reduced energy (and hence reduced GHG emissions) for soybean crushing. In addition, carbon emissions associated with feedstock transportation have changed – reduced for heavy-duty trucking and barge transport; increased for medium-duty trucking.

The simplified calculator will allow biofuel plants to enter operational data to determine and track the CI of their fuels on a monthly basis. The oil extraction emission values built into this calculator have been revised, as shown in the table. The reduced values for soy oil and corn oil will contribute to lower CI values for biodiesel fuels produced from these feedstocks. Provisions for user-defined oil extraction values introduce opportunities for further CI reductions. In particular, the extremely

	CA GREET 2.0	CA GREET 3.0
Soy Oil	4.10	3.54
Canola Oil	2.68	3.33
Corn Oil	4.81	2.84
UCO	5.00	5.41
Tallow	17.82	18.78

high default emissions for oil extraction from tallow could be reduced by incorporating user-defined data. O'Connor suggested that it may be worthwhile to develop a simplified calculator for oil extraction using energy data from current operators and emissions data from the existing biodiesel/renewable diesel calculator. He further suggested that the biodiesel industry should undertake this effort themselves, rather than wait for CARB to do so.

Don Scott (National Biodiesel Board), "Attributional + Consequential Lifecycle Analysis." Scott discussed how attributional and consequential LCA studies are used to "attribute" or "allocate" causality between biofuel production and GHG emissions. An important point with respect to soy biodiesel is that the main driver for soybean production is demand for protein used in the food/feed industry, not demand for biodiesel. This raises questions about the appropriateness of attributing farming emissions to biodiesel, if the land would have been farmed for soybeans anyway, regardless of any biofuel demand. Compositionally, soybeans contain approximately 80% meal and 20% oil. When more soybeans are produced to satisfy the need for protein (part of the meal), additional oil becomes available for use as biodiesel.

Attributional LCA (ALCA) uses engineering data to estimate the "direct" emissions that occur during each process that comprises a biofuel's entire life cycle. Scott cited eight different ALCA studies of biodiesel in the U.S., which estimated direct GHG emissions reductions (compared to conventional petroleum diesel) in the range of 66-89%. Introduction of ILUC concepts has complicated this situation, and led to use of consequential LCA (CLCA) approaches to estimate GHG emissions associated with ILUC. CLCA uses econometric models to predict what will happen with respect to LUC as a consequence of policy changes, and then attributes GHG emissions to this LUC. The final CI value assigned to a particular biofuel (by CARB) combines the direct emissions (from ALCA) and the indirect emissions (from CLCA) to derive the total emissions. Scott questioned whether this approach is optimal, or even valid. These are open questions that require additional study. Scott asserted that when traditional ALCA is employed, the emissions of farming and crushing soybeans are allocated between the oil and the meal. Even though these beans would be grown anyway for protein demand, a portion of those emissions are levied onto the biodiesel feedstock. CLAC is employed to determine what changes in agriculture resulting from biofuels policy. Scott questioned whether assessing the consequential increase in oilseed production and allocating emissions from existing production is equivalent to double-counting the emissions of farming and oilseed crushing contributing to biodiesel production. He concluded with the statement, "When we grow protein to feed the world, we get more carbohydrates and fat than we can eat."

D. Priorities and Next Steps

The following is a list of information gaps and additional research that were identified by participants of this workshop. They are not listed in priority order, nor is this list all-inclusive.

1. Determine if GTAP-BIO responds appropriately with changes in meat demand with higher feed prices. Do higher feed prices result in simply less animals being raised, or is it more likely to switch the type of animal being raised to that which can consume cheaper feed or lower total cost of production?

2. Directly consider this increased demand for protein meal by adding a second meal shock to the oil shock. Then, it could be that meal would get more of the allocated emissions. In other words, in addition to the argument that oil is a marginal byproduct, another approach might be to test what happens when we explicitly add the increased meal demand to the model shock.
3. How are consumer choices based on economics, health attributes or subjective tastes impacting the intensification of livestock production, and how does that impact markets for feed ingredients and crops or land fluxing from grazing pasture? How can understanding of these factors better inform modeling for biofuels?
4. Update GTAP-BIO to the 2014 or 2017 database.
5. Data suggests that emission factors associated with palm expansion were overestimated in GLOBIOM and the CARB AEZ model. These have since been updated in GLOBIOM and some versions of the AEZ-emission factor model used by Purdue with GTAP-BIO. More research or publications in this area may be required to update all models in use by researchers and regulators.
6. Analyze and document relationships between crude oil prices and the price of soybean oil and other vegetable oil prices.
7. Review EPA's 2018 report on environmental impacts of the RFS and prepare analyses to document and fill key gaps and prepare for reset provisions EPA will likely employ for the future of the RFS.
8. Continue to seek better understanding of the drivers for palm oil production and how those drivers may be related to biofuels or changing markets for feedstocks used in food manufacturing and other industries.
9. Work with the National Corn Growers, the Renewable Fuels Association, USDA, DOE, National Labs and universities to establish "historical US agricultural scenarios" and corresponding data sets. These data sets will facilitate the analysis of the impacts of the RFS by providing a clearly defined and consistent set of historical data, as well as a common basis for comparison: a well-documented hypothetical counterfactual scenario (e.g., business-as-usual based on trends prior to the ethanol boom).
10. Conduct consequential analysis of biofuel policy on land management practices in the US including the TFP-intensification elasticity response to policy-driven market growth.
11. Review and submit paper to *Science* to test alternative hypotheses for the drivers of forest cover change (in part to correct the estimate in Sept 14 issue of *Science* stating that 27% is from ag products). Separate what is "ag-driven deforestation" from "deforestation for land speculation, followed by agricultural practices designed to hold or reinforce ownership claims"
12. Translate ILUC uncertainties into more useful forms for policy makers.
13. Document drivers of deforestation over the past decade to improve attribution among causes and to distinguish among policies that can serve as buffers versus those that serve as catalysts.

14. Establish better definitions for land management and seek standardization of definitions for modeling and general discourse.
15. Explore the potential of satellite imagery and other data technology that can help better document and quantify land management and land use change.
16. Organize all the information on these issues collected over the years in to a single, accessible place. Perhaps produce a book or other documentation covering the entire history such as the tome produced for the International Civil Aviation Organization and their Alternative Fuel Task Force.

APPENDIX I

Glossary of Terms Used During the Workshop

AEZ	Agricultural Ecological Zone
AEZ-EF	Agricultural Ecological Zone – Emission Factor (model)
ALCA	Attributional Life Cycle Assessment
ANL	Argonne National Laboratory
ARMS	Agricultural Resource Management Survey
BCAM	Bioenergy Crop Adoption Model
BD	Biodiesel
Bg/y	Billion gallons per year
BT16	DOE Billion Ton Study for 2016
CARB	California Air Resources Board
CDL	Cropland Data Layer
CES	Constant Elasticity of Substitution
CGE	Computable General-Equilibrium (model)
CHF	Crop Harvest Frequency
CI	Carbon Intensity (also Compression Ignition)
CLCA	Consequential Life Cycle Assessment
CO ₂	Carbon Dioxide
CO _{2,eq}	Mass of a specified GHG expressed as a mass of CO ₂ having equivalent GWP
CoA	(USDA) Census of Agriculture
CP	Cropland-Pasture
CRP	Conservation Reserve Program
DOE	(US) Department of Energy
EBB	European Biodiesel Board
EC	European Commission
EF	Emission Factor
EIA	Energy Information Administration
EPA	(US) Environmental Protection Agency
EU	European Union
FAO	(UN) Food and Agricultural Organization
FAPRI	Food and Agricultural Policy Research Institute
FASOM	Forest and Agricultural Sector Optimization Model
FCAF	Forest Carbon Accounting Framework
FDA	(US) Food and Drug Administration
F-T	Fischer-Tropsch
g CO _{2,eq} MJ ⁻¹	grams of CO ₂ , equivalents per MJ of fuel
GBSM	Geospatial Biorefinery Siting Model
GDP	Gross Domestic Product
GGE	Gasoline Gallon Equivalent
GHG	Greenhouse Gas
GLOBIOM	Global Biomass Optimization Model
GPS	Global Positioning Satellite
REET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model

GTAP	Global Trade and Analysis Project (economic model and database)
GTAP-BIO	Latest version of GTAP, which considers biofuels
GWP	Global Warming Potential
Ha	Hectare
HEFA	Hydro-processed Esters and Fatty Acids
IDA	Index Decomposition Analysis
IEA	International Energy Agency IGBP
IGBP	International Geosphere-Biosphere Programme
IIASA	International Institute for Applied Systems Analysis
ILUC	Indirect (or Induced) Land Use Change
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCFS	Low Carbon Fuel Standard (California regulation)
LMC	Land Management Change
LMRB	Lower Mississippi River Basin
LU	Land Use
LUC	Land Use Change
MMT	Million Metric Ton
MODIS	Moderate Imaging Spectroradiometer (satellite)
MRB	Mississippi River Basin
MSW	Municipal Solid Waste
N ₂ O	Nitrous Oxide
NAIP	National Agriculture Imagery Program
NBB	National Biodiesel Board
NBF	National Biodiesel Foundation
NG	Natural Gas
NREL	National Renewable Energy Laboratory
ORNL	Oak Ridge National Laboratory
PHO	Partially Hydrogenated Oil
RD	Renewable Diesel
RED	Renewable Energy Directive
RFS	Renewable Fuels Standard
RNG	Renewable Natural Gas
RPS	Renewable Portfolio Standard
SLCP	Short-Lived Climate Pollution
SS	Suspended Sediment
SWAT	Soil Water Assessment Tool
TFP	Total Factor Productivity
UMRB	Upper Mississippi River Basin
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VRT	Variable Rate Technology (fertilizer application)