Quantifying Estimates of Induced Land Use Change (ILUC) and Emissions from Sustainable Aviation Fuels

Project 13-C-AJFE-PU

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AVIATION SUSTAINABILITY CENTER

Motivation

- Induced Land Use Change (ILUC) emissions will be a part of the aviation biofuel emission estimates for the ICAO/CAEP/AFTF process, so we need the best possible estimated values available.
- ILUC emissions are commonly estimated using computable general equilibrium models such as GTAP.
  - In recent years, a lot of work has been done improving the way GTAP works on the **extensive margin**.
  - However, little work has been don on the **intensive margin** (double cropping, irrigation, or other productivity investments). This research will take advantage of newly available data to better calibrate changes on the **intensive margin**.

Objectives

- Our work under ASCENT covers stochastic TEA and induced land use change emissions for aviation biofuels.
- Today, I am reporting only on the ILUC work.
- Our long term objectives will concentrate on producing ILUC estimates for different types of aviation biofuels produced in different region of the world.
- Our near term objectives are to begin testing the new model with test simulations for aviation biofuels in four world regions.

History of GTAP-BIO Model

GTAP-E (2002), first model of the energy-economy-environment-trade linkages.
GTAP-AEZ (2005), land use model designed based on 18 Agro-Ecological Zones for agricultural production including crops, livestock, and forestry.
Initial GTAP-BIO (2008), combing GTAP-E and GTAP-AEZ, highlighting interactions among biofuel, livestock, and forestry, ignoring by-products
Improved GTAP-BIO-ADV (2010), ILUC emissions due to first-generation biofuels, considering biofuel by-products and crop yield response (YDEL), variation in global extensive margin (ETA), and cropland pasture.
GTAP-BIO-ADVFUEL (2011), modelling ILUC emissions due to second-generation biofuels, i.e. switchgrass-gasoline, miscanthus-gasoline etc.
Latest GTAP-BIO, improvements on the intensive margin (double cropping).

Major Data Base Changes 2004-11

- Biofuels production increased substantially in many regions, but particularly in the EU, Brazil, and the US. This means that any simulations starting from the 2011 data already have considerable biofuels in the base data.
- Land availability has changed, particularly the category called cropland pasture, has changed substantially. Cropland pasture was only included in Brazil and the US in the 2004 data. It has been added for Canada in 2011. In the US, cropland pasture fell from about 25 million hectares in 2004 to about 5 million in 2011. In prior simulations cropland pasture had been an important source of land to meet land needs for biofuels.
- Significant crop intensification occurred in some regions.

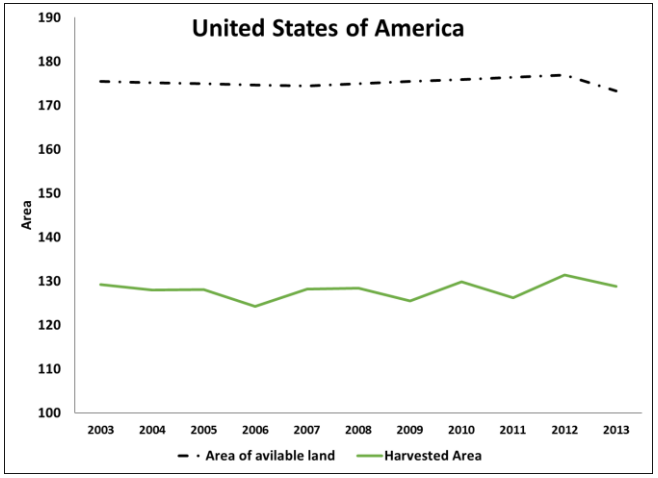
Major Data Base Changes 2004-11

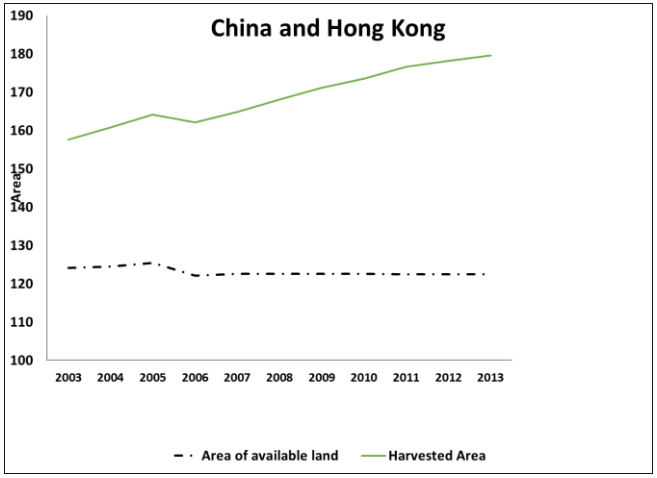
- Trade patterns and shares changed for some commodities, and that can ultimately impact land use change and emissions.
- Crop yields were different in 2004 and 2011.
- The impacts of many shocks in GTAP are driven by shares of affected resources or commodities. For example, the capital share of ethanol production cost was much higher in 2004 than in 2011. An ethanol shock in 2011 requires less reduction in capital elsewhere and less flexibility in other sectors to adapt, leading to higher need for more cropland.
- Many commodity prices are different. Corn price, for example, was three times in 2011 the price in 2004.

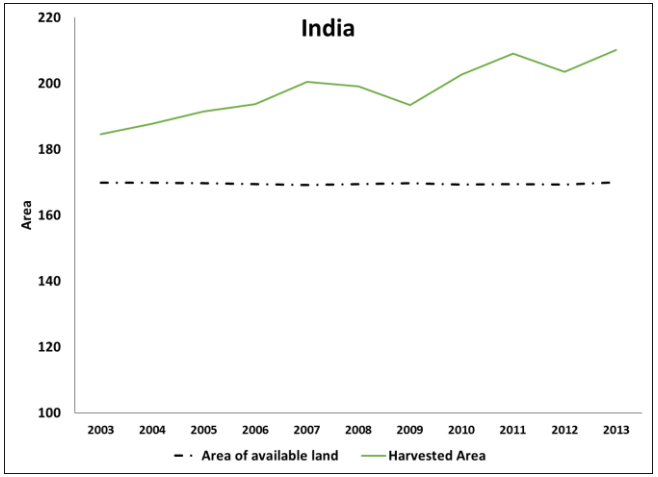
Induced Land Use Change Impacts

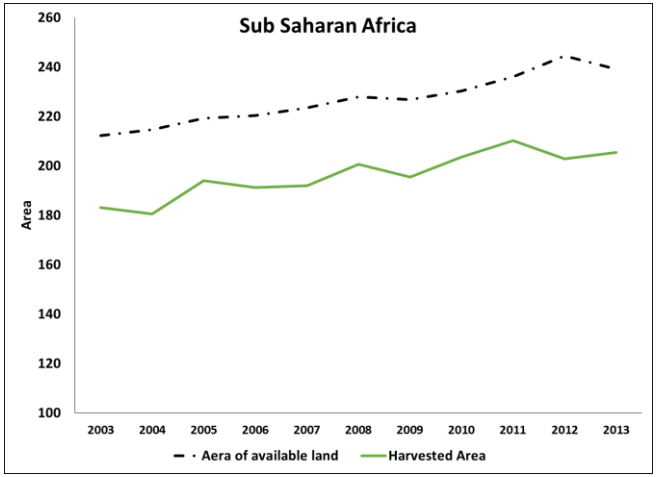
- Reduced consumption of the feedstock in non-biofuel uses.
- Switching among crops to produce more of the biofuel commodity.
- Changes at the extensive margin to convert pasture and forest to cropland.
- Changes at the intensive margin to increase crop yield, engage in more double cropping, and increased cultivation of unused land.
- Shifts in global production and trade.

Historic Changes in Land Cover and Harvested Area









Current Status of GTAP-BIO

- From FAO data of available cropland and harvested area for the period 2003-2013, we found that there has been more intensification (e.g., double cropping) and less extensification (changes in available cropland) in recent years.
- We have now created a new version of the GTAP model that better reflects the relative degrees of extensification and intensification by region that have actually occurred over the past decade.
- Simulations with this new model generally show lower induced land use change globally for any give biofuel shock, and also lower associated GHG emissions.

GTAP Modifications to Better Handle Intensification

- There is a parameter in GTAP, YDEL, which is known as the yield price elasticity. We calibrated the YDEL value to the historic yield changes across regions with parameter values ranging between 0.175 and 0.325.
- The previous assumption in GTAP was that changes in cropland cover (L) equal changes in harvested area (H). A more general relationship could be expressed as L = H + B, where L is the area of cropland, H is harvested area, and B is the difference between the two. Using the data described above we could estimate the historic changes in L and H and determine the sign and magnitude of B. B could represent double cropping or bringing into production unused agricultural land.
- We added a new parameter, γ, which enables us to tune the degree of intensification by global region. We call this the "new model."

ILUC Emissions – Model Comparison (preliminary)

Biofuel Pathway	Old model	New model (2004)	Reduction (2004)	New model (2011)	Reduction (2011)
	g CO_2e/MJ	g CO_2e/MJ		g CO_2e/MJ	
Corn ethanol	13.4	8.7	-35.1%	9.7	-27.6%
Brazil ethanol	5.7	4.7	-17.5%	0.1	-98.2%
US Soy	21.6	16.7	-22.7%	8.3	-61.2%
EU Rape	26.6	15.6	-41.4%	7.2	-72.9%

New Results Compared with Current CARB Values (preliminary)

Biofuel Pathway	Current CARB Values	New model (2004)	Reduction (2004)	New model (2011)	Reduction (2011)
	g CO_2e/MJ	g CO_2e/MJ		g CO_2e/MJ	
Corn ethanol	19.8	8.7	-56%	9.7	-51%
Soy biodiesel	29.1	16.7	-43%	8.3	-71%
Brazilian sugarcane ethanol	11.8	4.7	-60%	0.1	-99%

CARB values are the average of 30 GTAP simulations covering a range of parameter values.

Schedule and Status

- We have updated the GTAP data base and model from 2004 to 2011.
- We have recalibrated the regional values for YDEL – the yield price elasticity based on historic evidence.
- We have introduced an intensification parameter also calibrated with historic data. This parameter helps determine the extent of changes at the intensive versus extensive margins.
- Aviation biofuels have been introduced into the new model.
- We are beginning test simulations with the new model for aviation biofuels.

Interfaces and Communications

External

- Presentation to the DOE aviation biofuels workshop, Sept, 2016
- Recent Publications

- Taheripour, Farzad, and Tyner, Wallace E. "Incorporating Recent Land Use Change Data into Simulations of Biofuels Land Use Change." *Applied Sciences* 3 (2013) 14-38.
- Suttles, Shellye A., Wallace E. Tyner, Gerald Shively, Ronald D. Sands, and Brent Sohngren. "Economic effects of bioenergy policy in the United States and Europe: A general equilibrium approach focusing on forest biomass." *Renewable Energy*, 69 (2014), pp. 428-436.
- Taheripour, Farzad, and Wallace E. Tyner. "Corn oil biofuel land use change emission impacts: Sharing emission savings between ethanol and biodiesel Biofuels," *Biofuels* 5(4), 2014, pp. 353-364.
- Bittner, Amanda, Xin Zhao, and Wallace E. Tyner. Field to Flight: A Techno-Economic Analysis of Corn Stover to Aviation Biofuels Supply Chain." *Biofuels, Bioproducts & Biorefining* 9, 201-210, 2015
- Mueller, Steffen, Stefan Unnasch, Wallace E. Tyner, Jennifer Pont, and Jane M-F Johnson. "Handling of co-products in life cycle analysis in an evolving co-product market: A case study with corn stover removal." *Advances in Applied Agricultural Science* 3(5) 2015, pp. 8-21.
- Zhao Xin, Yao Guolin, Tyner Wallace E. "Quantifying breakeven price distributions in stochastic techno-economic analysis." *Applied Energy*. 2016;183:318-26.

Within ASCENT

- Collaboration with Robert Malina and his group at MIT

Summary

- Summary statement
  - Land use change is a market mediated response to an increased demand for agricultural commodities. We need to provide the best possible estimates of the induced land use changes and the GHG emissions associated with these changes. That is the overarching objective of this sub-project.
- Next steps?
  - After getting feedback from AFTF on the test simulations, we will begin exploring a structure of the actual simulations to be used for the analysis.
- Key challenges/barriers
  - Each of the major changes in GTAP requires a lot of time and it must be documented in the literature. That process takes longer than desired, but is important.

Contributors

- Farzad Taheripour, Research Associate Professor, Purdue University
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- David Cui, post doc, Purdue University

Thanks

Questions and Comments