PURDUE UNIVERSITY

PURDUE AGRICULTURE

Comparison Between GTAP-BIO and GLOBIOM for Estimating Biofuels ILUC Change Emissions

Presented by Wallace E. Tyner

With collaboration from

Xin Zhao, Hugo Valin, and Farzad Taheripour

September 2018

Introduction

- Much of the content of this presentation comes from the PhD dissertation of Xin Zhao, who did a comparison of GTAP-BIO and GLOBIOM as one of his three essays.
- We also worked with Hugo Valin of IIASA in doing some of the model comparison and reconciliation work under a project on aviation biofuels.

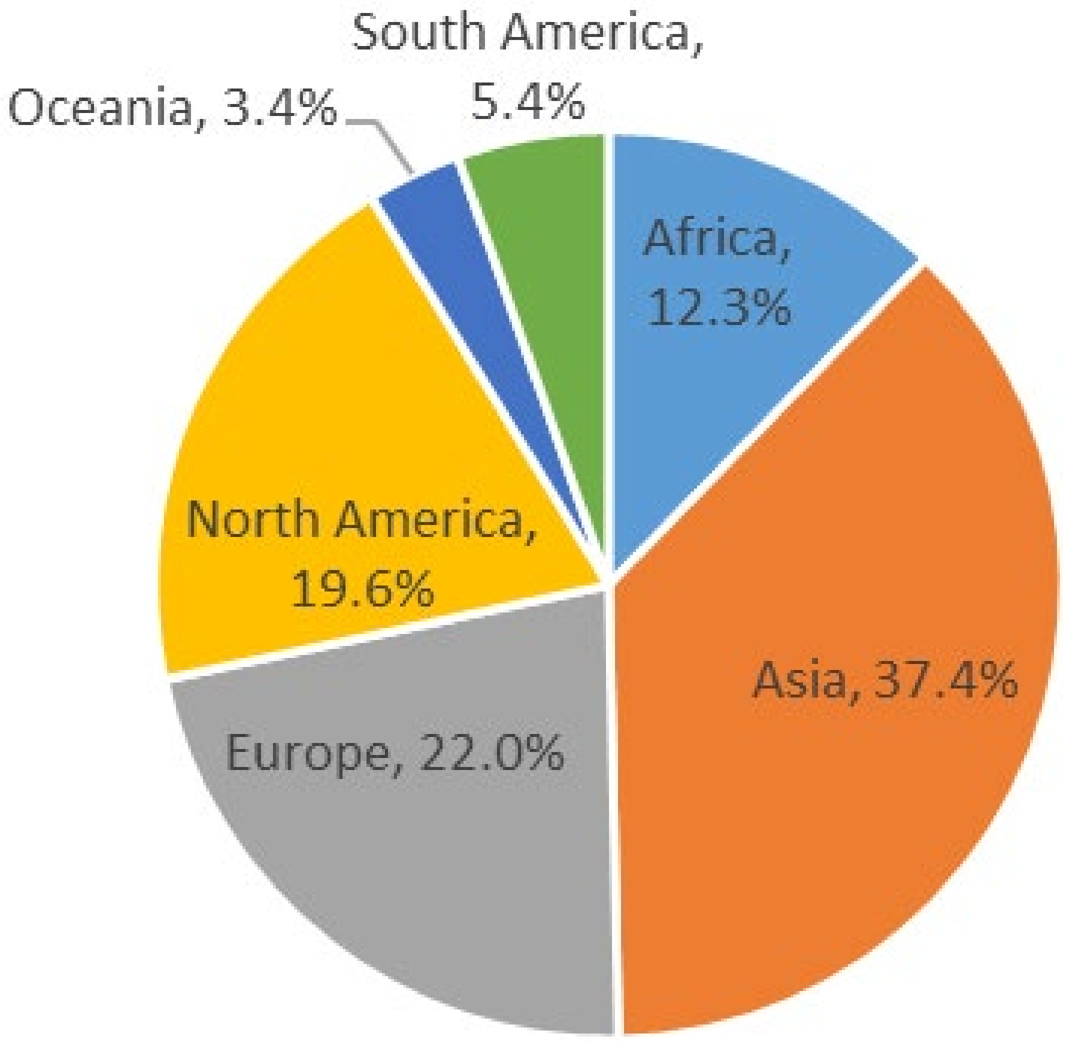
Brief History of GTAP

- In 2017 GTAP celebrated its 25th anniversary, having been founded in 1992.
- We are now using the 9th version of the data base (2011) and developing the 10th (2014).
- The data base contains 140 countries and regions and 57 economic sectors plus all the biofuel sectors
- Land is divided into 18 agro-ecological zones (AEZs)
- The GTAP model and data base are publicly available.

GTAP by the Numbers

- There are about 16,150 members of the GTAP network around the world representing 174 countries.
- There are 23,500 Google Scholar citations for ‘GTAP’
- There are 948,537 bilateral trade flows in the GTAP data base.
- 52 GTAP courses have been offered all over the world training 1,150 professionals and students.
- Many MS and Ph.D. students have used GTAP in their research.

GTAP Network Members



Consortium Membership (28)

- Asian Development Bank - Mandaluyong City, Philippines
- Centre d'Etudes Prospectives et d'Information Internationales - Paris, France
- Development Research Center of the State Council - Beijing, China
- Economic and Social Research Institute, Cabinet Office - Tokyo, Japan
- Economic Research Service of the United States Department of Agriculture - Washington DC,
- European Commission - DG Trade - Brussels, Belgium
- European Commission - Joint Research Centre - Seville, Spain
- Food and Agriculture Organization of the United Nations - Rome, Italy
- Inter-American Development Bank - Washington DC, United States
- International Food Policy Research Institute - Washington DC, United States
- International Trade Centre - Geneva, Switzerland
- KPMG Australia - Canberra, Australia
- MIT Joint Program on the Science and Policy of Global Change - Cambridge, United States
- National Graduate Institute for Policy Studies - Tokyo, Japan

Consortium Membership (cont’d)

- Organisation for Economic Co-operation and Development - Paris, France
- Productivity Commission - Melbourne, Australia
- Research Institute of Economy, Trade and Industry - Tokyo, Japan
- The World Bank - Washington DC, United States
- Thünen Institute of Market Analysis - Braunschweig, Germany
- United Nations Conference on Trade and Development - Geneva, Switzerland
- United Nations Economic and Social Commission for Western Asia - Beirut, Lebanon
- United Nations Economic Commission for Africa - Addis Ababa, Ethiopia
- University of Hohenheim - Stuttgart, Germany
- US Department of Commerce - Washington DC, United States
- US Environmental Protection Agency - Washington DC, United States
- US International Trade Commission - Washington DC, United States
- Wageningen Economic Research - The Hague, The Netherlands
- World Trade Organization - Geneva, Switzerland

Drivers of land use change

- When there is a sizeable increase in demand for a commodity due to biofuel production (e.g., maize for ethanol, rapeseed for biodiesel, etc.), that demand increase causes an increase in the price of the commodity unless the commodity supply is perfectly elastic.
- The price increase causes some combination of five main market mediated responses.

Market-mediated responses

1. Higher commodity price, consumption normally falls.
2. With higher price for this commodity, there can be switching among crops: more of this crop is produced and less of other crops.
3. With higher commodity demand, more cropland can be needed to meet increased demand, and this cropland can come from pasture or forest converted to cropland (extensive margin).
4. With higher commodity demand, existing cropland might be farmed more intensively (intensive margin e.g. double cropping, using idled land, etc.). This leads to less demand for land conversion.
5. Impacts on international trade of the commodity and of substitute commodities could also induce land use changes across the world.

CGE land use change modeling

- Computable General Equilibrium (CGE) models take into account any/all of these five responses plus many other changes.
- The resulting estimates are uncertain.
- Many of the main models that are used (EPPA, LEITAP, MIRAGE, etc.) for land use change estimation are based on the GTAP data base, but each structures the model and analysis in different ways.
- There are 18 Agricultural Ecological Zones (AEZs). The data base includes productivity data for cropland by AEZ.

GTAP-BIO and GLOBIOM

- GTAP-BIO
  - Developed at GTAP
  - Computable general equilibrium; includes all economic sectors
  - Base year: 2011
  - Comparative static
  - Runs with its coupled emission factor model, AEZ-EF
  - The GTAP models and data bases are publicly available.

- GLOBIOM
  - Developed at IIASA
  - Constrained optimization model (partial equilibrium); focus on agriculture, livestock, forestry, and biofuels sectors
  - Base year: 2000 (target 2010)
  - Dynamic model with (10-year-step, 2000-2050)
  - The emission factor model is embedded in GLOBIOM.
  - The model is not publicly available.

Comparison between GTAP-BIO and GLOBIOM

	GTAP-BIO	GLOBIOM
Model framework	A large-scale global CGE model which uses social accounting matrices by region in combination with trade and biophysical data to obtain ILUC	A grid- based global partial equilibrium model, bottom-up, starting from land and technology to markets and consumers, with embedded biophysical process models
Sector coverage	All economic sectors are represented including disaggregated sectors for crops, livestock, forestry, energy (including biofuels) industries, and services	Focus on land-based sectors: agriculture (including livestock), forestry, and bioenergy
Regional coverage	Global (aggregated into 19 regions in the version used for biofuel simulations, but these are aggregated from 140 global regions)	Global (28 EU Member states + 29 regions)
Resolution on production side	Data on land use, crop production, and harvested area are aggregated from a grid cell level to 18 agro-ecological zones (AEZs). SAM tables are at national level.	Detailed grid-cell level (>10,000 units worldwide)

	GTAP-BIO	GLOBIOM
Time Horizon	Comparative static using 2011 base year.	Dynamic model with ten-year time steps
Land data source	2011 GTAP land database, see Peña-Lévano, Taheripour, and Tyner (2015) for details.	Global Land Cover 2000 dataset with more detailed cover maps for EU (CORINE Land Cover 2000)
Market data source	2011 GTAP database (Aguiar et al., 2016; Peña-Lévano et al., 2015) developed based on official data collected by the World Bank, FAOSTAT, USITC, and several other data sources.	FAOSTAT and EUROSTAT
Modelling trade	Covers global trade in all goods and services. GTAP uses Armington assumptions to model trade relationships (imperfect substitution between domestic and imported goods and also between imports from different regions)	Bilateral trade for agricultural and wood products, with non-linear transportation costs. Products are traded in physical units as homogenous goods.
Primary factors of production	More detailed on economic resources (labor, capital, land, and natural resources), implied by social accounting matrices	No limit on labor, capital, and energy sources. More detail on non-energy natural resources (land and water).
Land use change mechanisms	Substitution of land use at regional and AEZ level. Nested CET approach is used for land transformation on the supply side of the market for land; adjustments were made for new cropland productivity.	Grid-based. Constrained mathematical optimization model. Land conversion possibilities allocated to grid-cells taking into account suitability, protected areas.

	GTAP-BIO	GLOBIOM
Representation of production technology	Production technologies are implied in the regional input-output tables from an extended GTAP database (with new sectors introduced for feedstock and biofuel industries). Constant Elasticity of substitution (CES) production function is used in all sectors.	Detailed biophysical model estimates for agriculture and forestry with several management systems Literature reviews for biofuel processing.
Crop production and yield response	Aggregated 13 crop categories represent all crops in the FAO database including silages, forages, fodders, and planted grass. Crops for biofuels production are disaggregated independently. The crop yields in base data match with the FAO database. CES production function is used for all crops. Thus, changes in the prices of primary factors of production may encourage substitution among these inputs so that crop yield may respond endogenously, according to the embedded regional yield to price elasticities.	18 crops are modeled for the world with nine additional crops for EU. Fodder and plated grasses covered through the grassland land cover. An exogenous yield growth trend is implemented in both baseline and biofuels simulation scenarios. Endogenous yield responses are modeled as farmer decisions on (1) shifts between rainfed management types and change in rotation practices; (2) investments in irrigated systems; and (3) change in allocation across spatial units with different suitability.

	GTAP-BIO	GLOBIOM
Demand side representation	Demand for each sector (good/service) has two components: 1) Final demand including household consumption, government consumption, and net trade and 2) Intermediate demand which represents consumptions of good and services by firms. One representative utility maximizing agent per region determines the final demand for goods and services based on changes in income and relative prices.	Crop and grass consumptions are explicitly modelled for different livestock management systems. Processing industry for oilseeds, woody products and bioenergy. Food and wood products are consumed directly by one representative agent per region, reacting to the price of products. No cross-price elasticities considered for final consumer except in the case of vegetable oil products.
Multiple cropping and unused land responses	Multi-cropping and unused land responses are modeled together through a calibrated parameter based on historical crop harvest frequency (CHF) trend by region and AEZ.	Multi-cropping is partly represented in the base data. Intensification response through multi-cropping was recently added at the crop level. The results reported here do not include multicropping. Unused agricultural land is currently limited to abandoned land after 2000.

Model Comparison

- Major sources of differences
  - Modeling approach
  - Theoretical background and assumptions
  - Data sources
  - Emission factors
- We evaluated and analyzed the drivers to determine the role they play in result differences, and in some cases made model changes in one or both models.
- We have evaluated pathways using oilseeds, cellulosic crops, and sugar/starch crops, and the differences are largest for oilseeds.

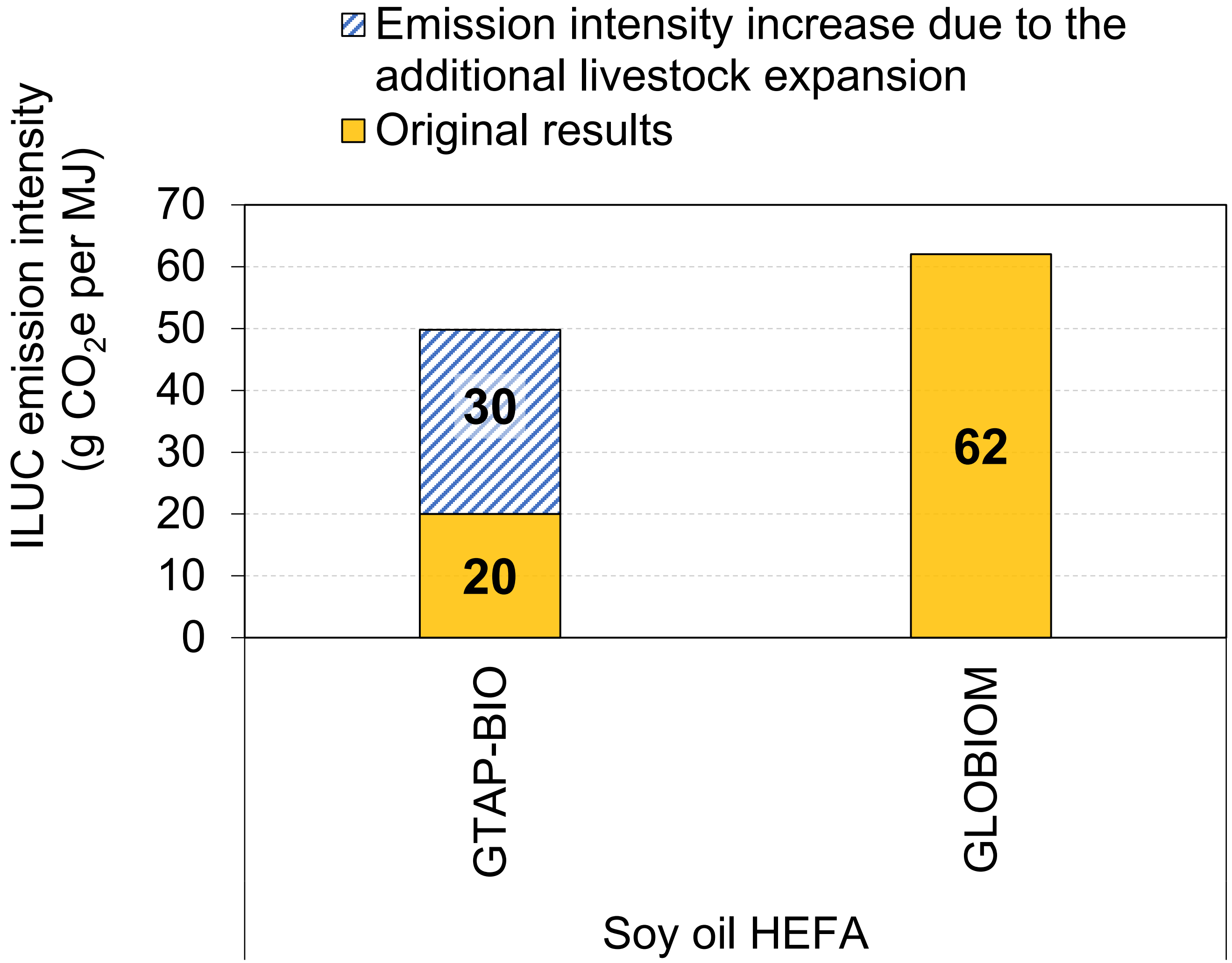
Major drivers of differences

- Livestock rebound response
- Trade modelling framework
- Palm related issues (e.g., palm oil yield and peat oxidation factor)
- Foregone sequestration on abandoned land and unused land emissions
- Cropland intensification responses through multi-cropping
- Carbon sequestration in harvested wood products
- Cellulosic crops FTJ pathways related data
- Land use change patterns in Brazil

Livestock rebound effect

- For soy oil and rapeseed oil HEFA pathways, GLOBIOM showed strong expansions in livestock sectors at the global scale (0.16%-0.43%)
  - Due to the feed ration requirements, cereal grains (energy feedstuff) are demanded to complement the coproduced proteins to supply livestock sectors.
- GTAP-BIO showed little or no expansion in livestock sectors at the global scale (-0.004%-0.012%).
  - Grain area mostly decreased while yield increased.

Test increasing livestock expansion in GTAP-BIO matching GLOBIOM for US soy HEFA



- Stronger livestock rebound effect leads to higher ILUC emissions.
- HEFA is a process that can produce a mixture of jet fuel and biodiesel and other products.

Livestock rebound effect

- Many factors may contribute to the high livestock rebound effect generated by the GLOBIOM:
  - Rigid substitution in processed feed industries (protein & energy).
  - Some feed crops are not included in the database.
  - Some types of meals are not in the database.
  - Other non-land primary inputs (labor, capital) are not constraints in GLOBIOM in livestock production and also other areas.
  - As a constrained optimization model with more limited substitution, the meal produced with veg oil gets used to grow the livestock sector.
- However, historically, biodiesel production has not been a driver for livestock industry expansion. It helps livestock to use less land

Trade modeling differences

- GLOBIOM has larger trade responses than GTAP.
  - More crops being produced in other regions with lower yield.
  - Higher international deforestation.
- GTAP
  - Armington assumptions with parameters extracted from literature.
- GLOBIOM
  - Modeled trade in physical units and exchanged as homogeneous goods.
- Much of the literature supports the Armington approach over the homogenous goods approach.

Palm expansion on peat

- New evidence shows that much of the pristine peat swamp forest in SEA has been degraded (Miettinen et al., 2016, 2017).
  - So it may be that the emission factor should be smaller than pristine peat swamp forest
- Peat oxidation emission factor
  - GLOBIOM uses 61 ton/ha/year (literature average)
  - Estimated for pristine peat swamp forest
- Palm expansion on peat land in Mala & Indo
  - GLOBIOM, 33.3% vs. GTAP, 30% (for the rape biodiesel test).
  - These numbers may decrease with the international attention on peat land conservation and government policies

Palm oxidation factor

- Mapping potential palm expansion on peat
  - Indonesia palm concession map from Global Forest Watch
  - Peatland map for Indonesia from Miettinen et al. (2016)
- EF revised based on IPCC value in Miettinen et al. (2017)

Land category	Area (Mil. ha)	t CO_2/ha/yr.
Pristine peat swamp forest (PSF)	**0.04**	55
Clearance (open area)	0.06	20
Ferns/low shrub	0.11	20
Tall shrub/secondary forest	0.26	36
Degraded PSF	0.42	45
Small-holder area (existing palm)	0.45	0
Industrial plantations (existing palm)	1.08	0
Total	2.42	**38**

Summary of results

- The ILUC emissions gap between the two models was reduced for many of the aviation biofuel pathways through the reconciliation process.
- Cellulosic pathways have low or negative emissions in both models, and the differences are mainly due to differences in SOC and the land taken for the cellulosic crops
- HEFA pathways generally have larger differences
  - Livestock rebound effect
  - Stronger market-mediated responses in GTAP-BIO
- The GTAP-BIO demand response is larger than GLOBIOM

PURDUE UNIVERSITY

PURDUE AGRICULTURE

Future Research Needs

Item	Potential Action
Crop yield responses	• Need to calibrate the biofuels induced crop yield responses to the historical data and literature estimation for both models.
Livestock rebound effect	• Explore the drivers of high rebound effects in GLOBIOM and feed substitution in GLOBIOM to determine if they are adequately handled. • The baseline assumption (2020) in GLOBIOM needs review. • Need to explore consumption declines in both models. It appears that GTAP-BIO had larger demand margin responses for vegetable oils.
Multi-cropping	• Multi-cropping practices as a response of biofuels expansion is modeled in GTAP-BIO, but was recently partially included in GLOBIOM.
International trade modelling	• GLOBIOM may have stronger trade responses than GTAP-BIO. • Need to review recent literature on trade responses and test sensitivity on parameters.
Soil organic carbon for cellulosic crops	• Different soil organic carbon (SOC) emission factors are used in the two models. • A further reconciliation of the SOC emission factors likely will help results convergence for cellulosic pathways.

Thanks

Questions and Comments