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

Wallace E. Tyner
Farzad Taheripour
Xin Zhao
Hao Cui
Purdue University

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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

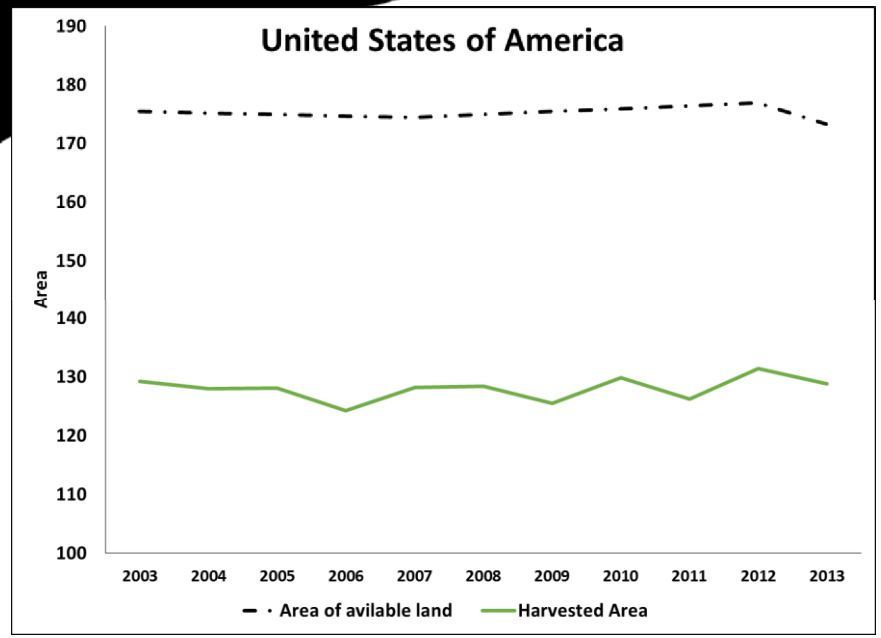
- Biofuels production increased substantially in many regions, but particularly in the EU, Brazil, and the US. This means that any simulations starting from the 2011 data already have considerable biofuels in the base data.
- Land availability has changed, particularly the category called cropland pasture, 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.


United States of America
190
180
170
160
150
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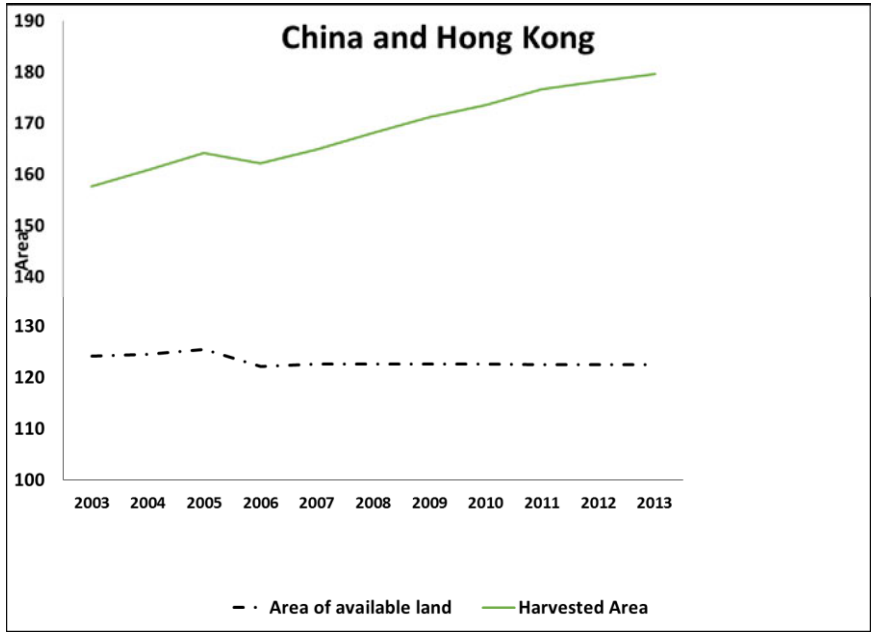
130
120
110
100
Area
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Area of avilable land
Harvested Area


China and Hong Kong
190
180
170
160
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130
120
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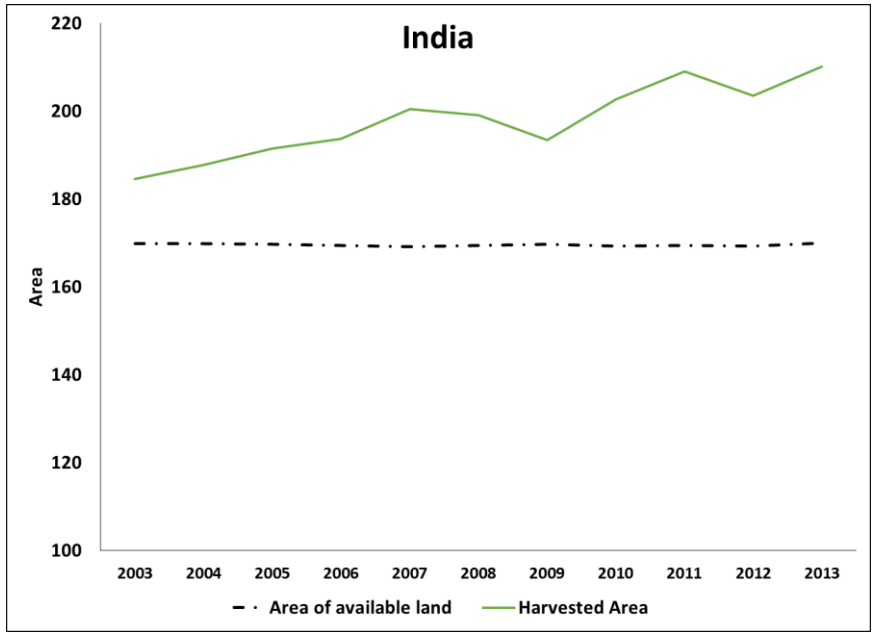
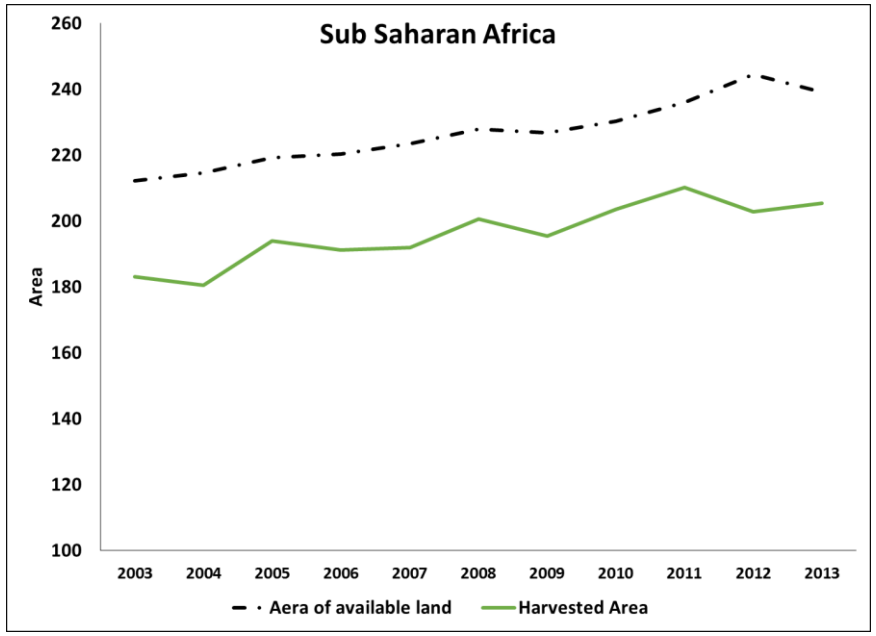
100
Area
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Area of available land
Harvested Area


India
220
200
180
160
140
120
100
Area
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Area of available land
Harvested Area


Sub Saharan Africa
260
240
220
200
180
160
140
120
100
Area
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Aera of available land
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.

Thanks

Questions and Comments