Dynamics of the Indirect Land Use Change (ILUC) Effects of Biofuel Policy

Gbadebo Oladosu

Keith Kline

Coordinating Research Council Workshop on Life Cycle Analysis of Transportation Fuels

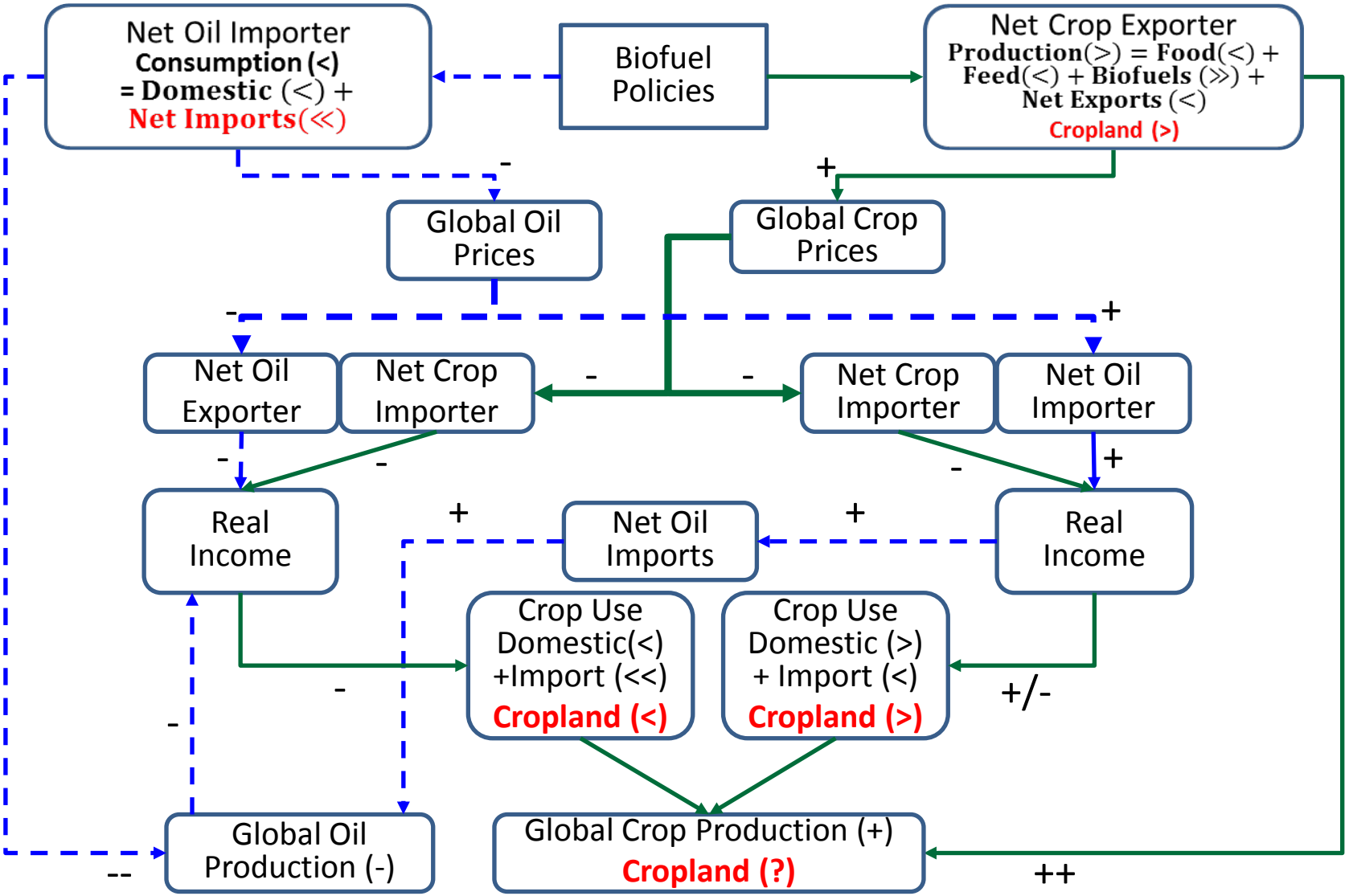
Argonne National Laboratory
October 16, 2013

Outline

- **Estimating the land use change effects of biofuel policy**
- **Overview of the modeling framework**
- **Simulation scenarios and results**
- **Ongoing land use/supply modeling changes**
- **Conclusions**

Estimating the land use change effects of biofuels

LUC impacts of biofuel policy have many dimensions



- **Net global LUC depends on the relative strengths of these effects**

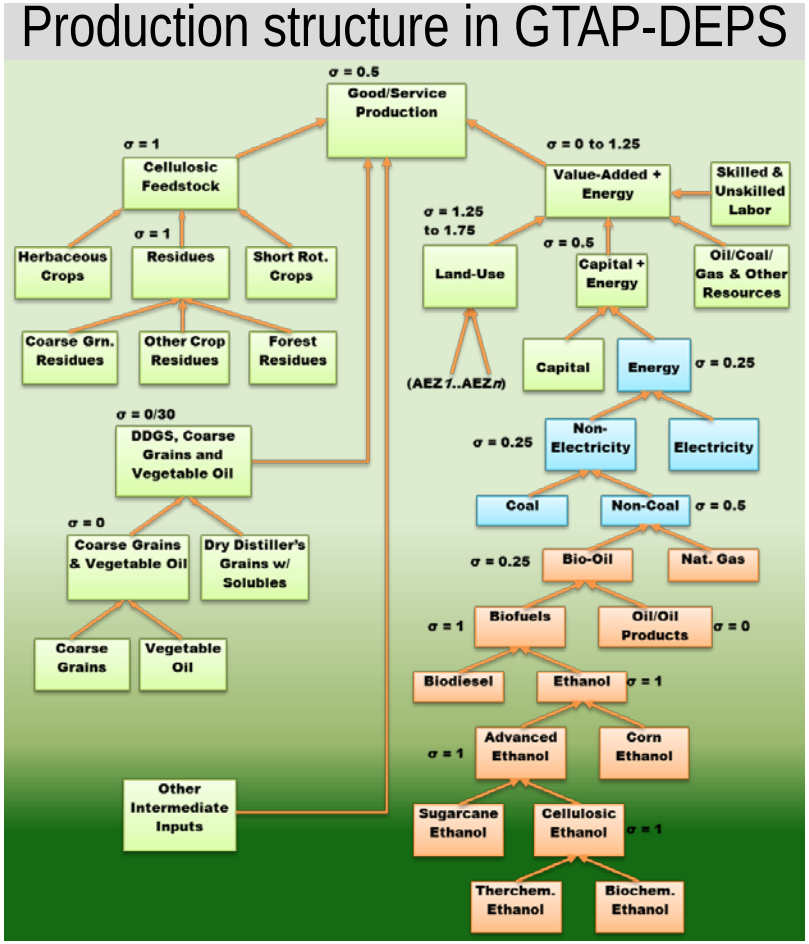
Oil market effects

Crop market effects

Overview of the modeling framework

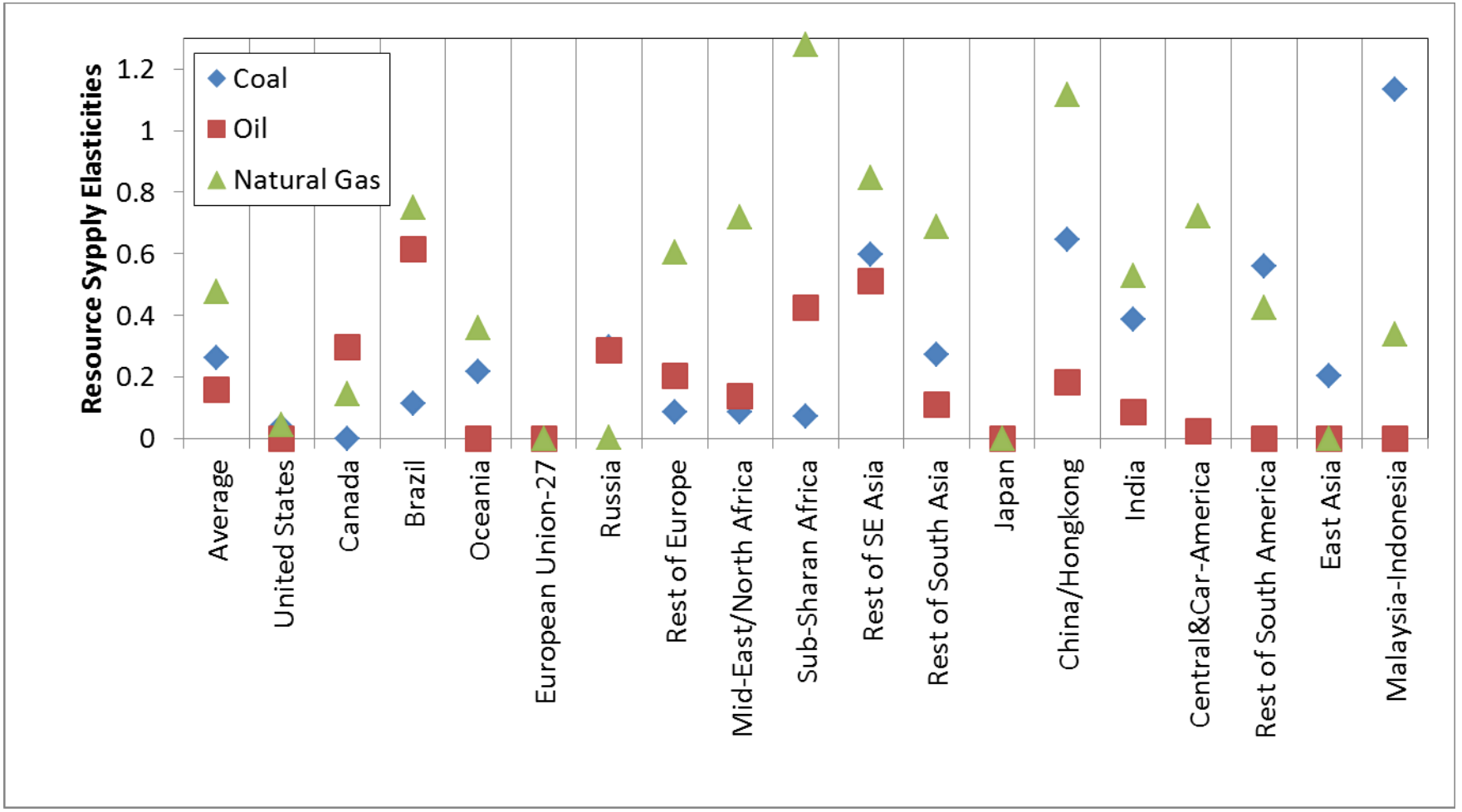
Overview of the modeling framework

- GTAP-DEPS* is a version of the GTAP general equilibrium framework
- Model dimensions:
  - 33 Sectors; 18 Regions; 2001-2030
- Major enhancements
  - Land supply/demand sub-models with 3 sources of yield change
  - Oil, gas and coal supply curves
  - Explicit dynamics: 2001-2030
- Modeling of biofuel policy reflects its implementation as a mandate – without new taxes or subsidies



*GTAP-DEPS:GTAP for Dynamic Energy Policy Simulations (see Oladosu, 2012; Oladosu et al, 2012). The standard GTAP (Global Trade Analysis Program) model is described in Hertel et al., 1997)

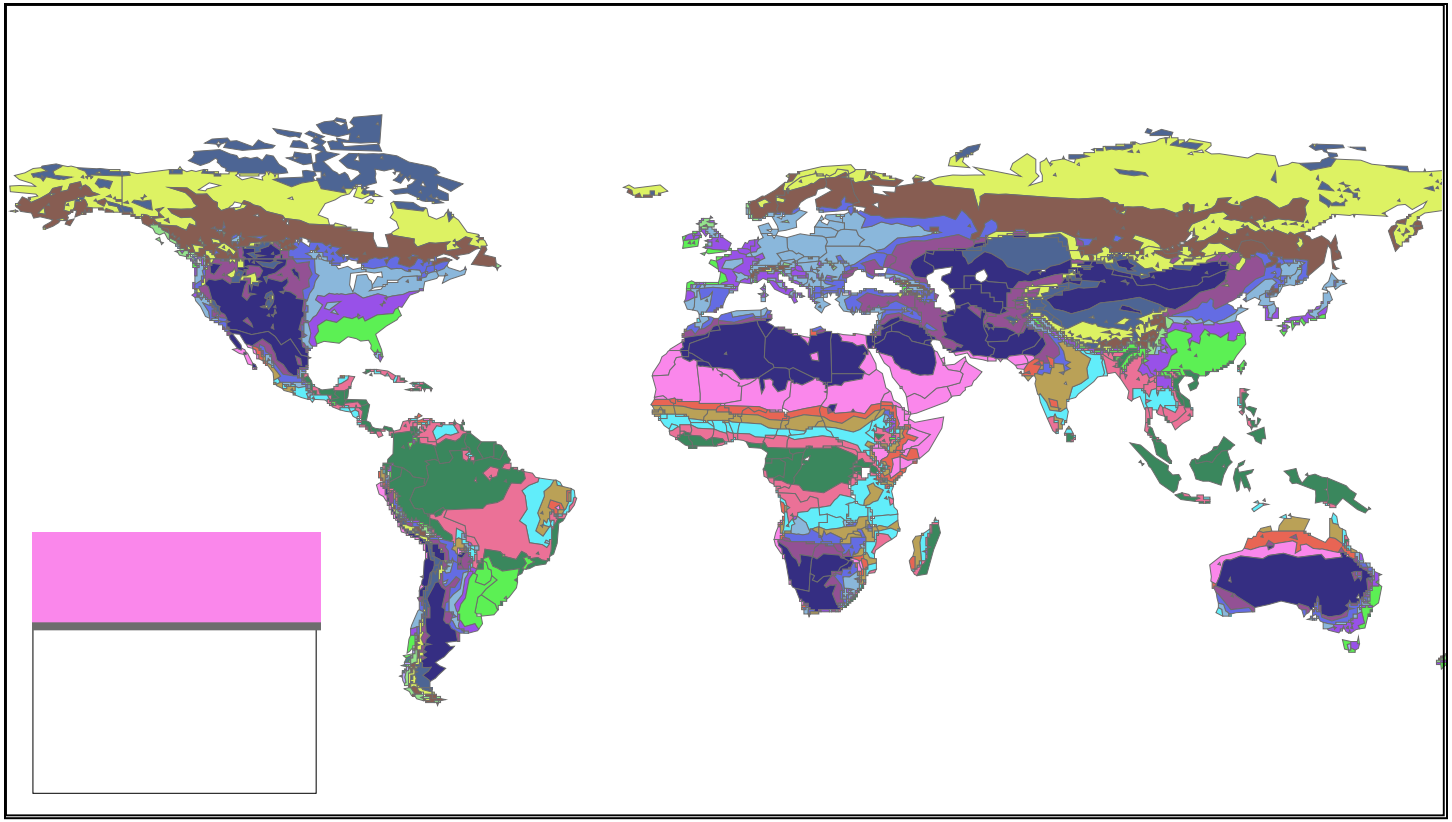
Supply elasticities for energy resources estimated from the empirical data



- Average global supply elasticities:
  - **Oil: 0.16 / Coal: 0.48 / Natural Gas: 0.26**

Agricultural Ecological Zones (AEZ)

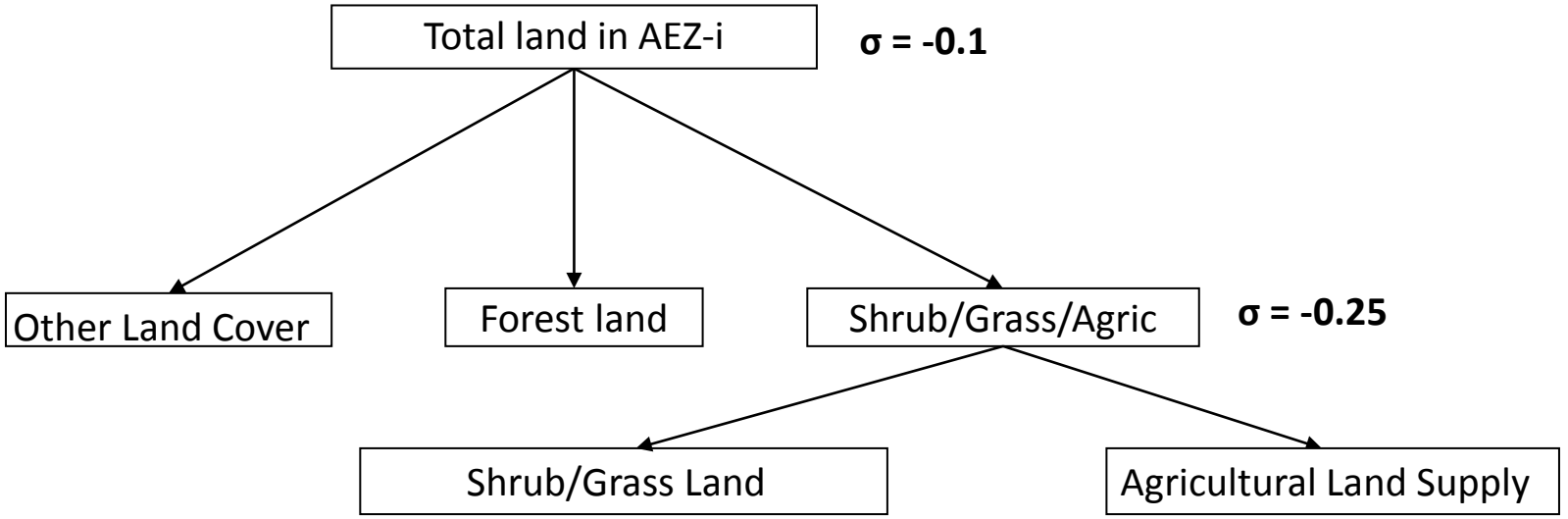
- Classifies the global land base into 18 categories
- Sub-regions for land-use modeling with the GTAP database



- **Land use change potentially occurs in 384 different sub-regions**
  - i.e. 18 AEZ x 18 economic regions

Land supply sub-model implies a price-driven transition matrix for each AEZ

- Changes in land demand induce changes in land prices & supply



United States – AEZ10

	Forest	Otherland	Shrub/grass	Agric
Forest	0.056	-0.003	-0.010	-0.043
Otherland	-0.044	0.097	-0.010	-0.043
Shrub/grass	-0.044	-0.003	0.211	-0.164
Agric	-0.044	-0.003	-0.039	0.086

Brazil – AEZ5

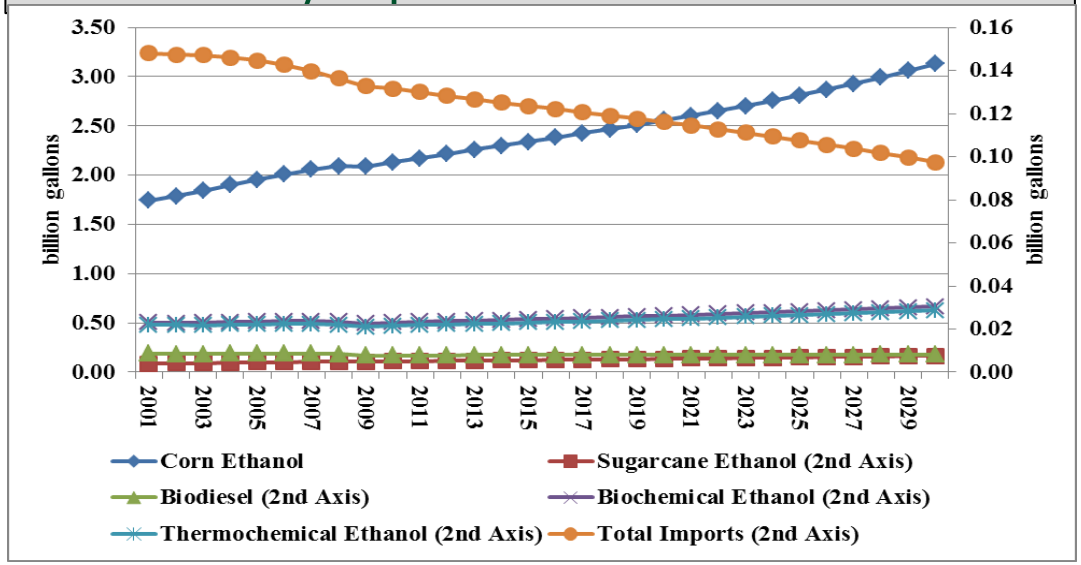
	Forest	Otherland	Shrub/grass	Agric
Forest	0.060	0.000	-0.020	-0.039
Otherland	-0.040	0.100	-0.020	-0.039
Shrub/grass	-0.040	0.000	0.179	-0.138
Agric	-0.040	0.000	-0.071	0.112

Examples of implied price elasticities of land supply

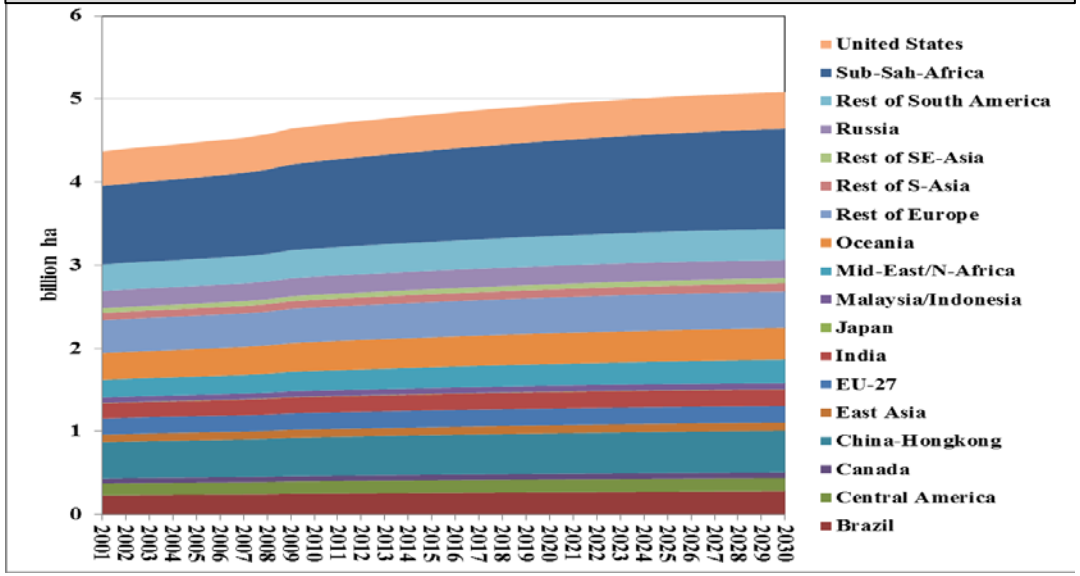
Simulation scenarios and results

Baseline simulation: biofuels/land use

Production/imports of biofuels in the USA



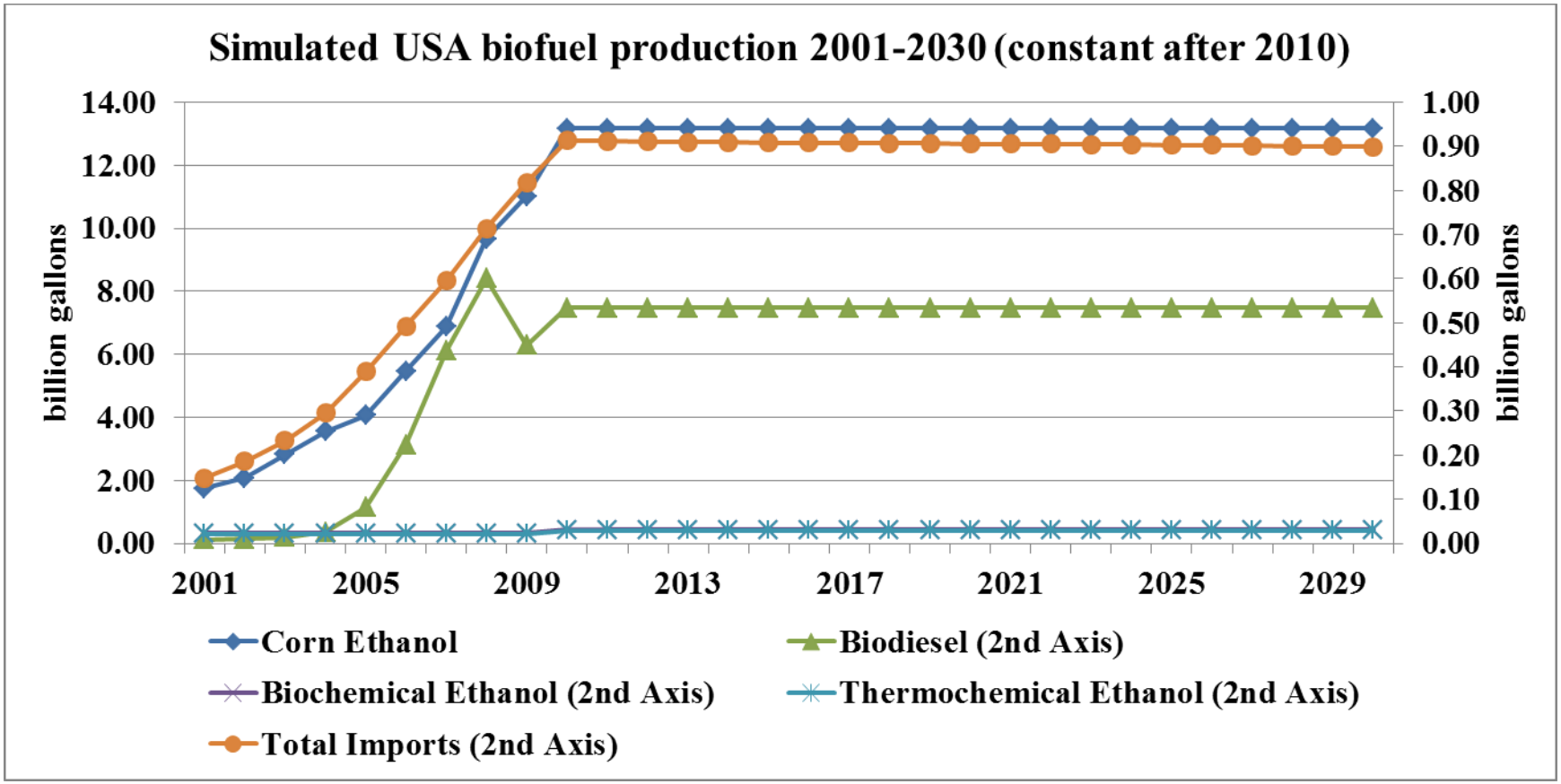
Regional agricultural land use



- Baseline ethanol production in the USA doubles between 2001 and 2030 without biofuel policy

Scenario: USA biofuel under RFS2 to 2010

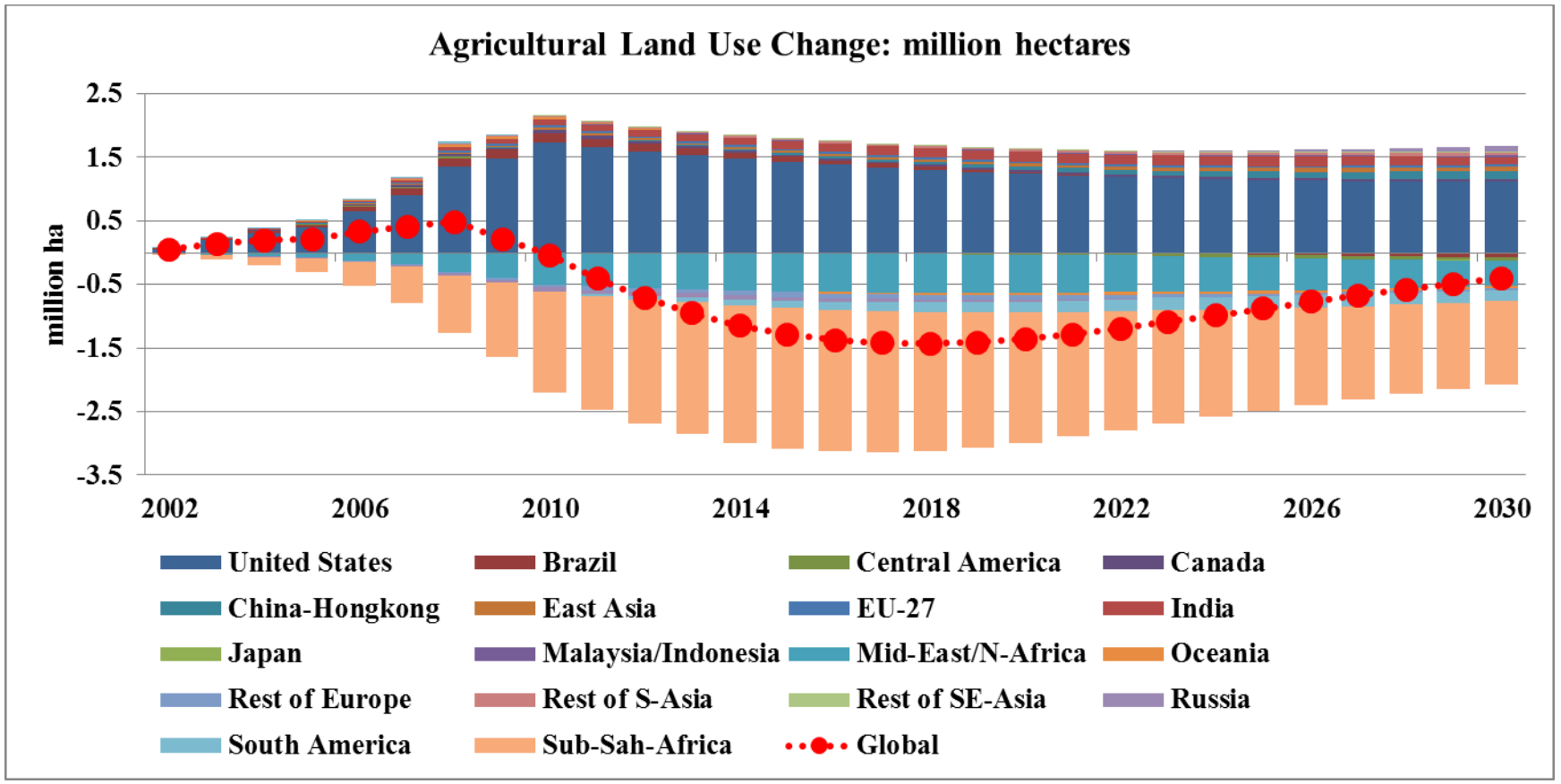
- Simulation of policy targets: RFS2 targets in 2010 reflect six-fold growth in ethanol production in USA between 2001 and 2010



- Differences between the results for baseline and RFS2 simulations are the effects of policy

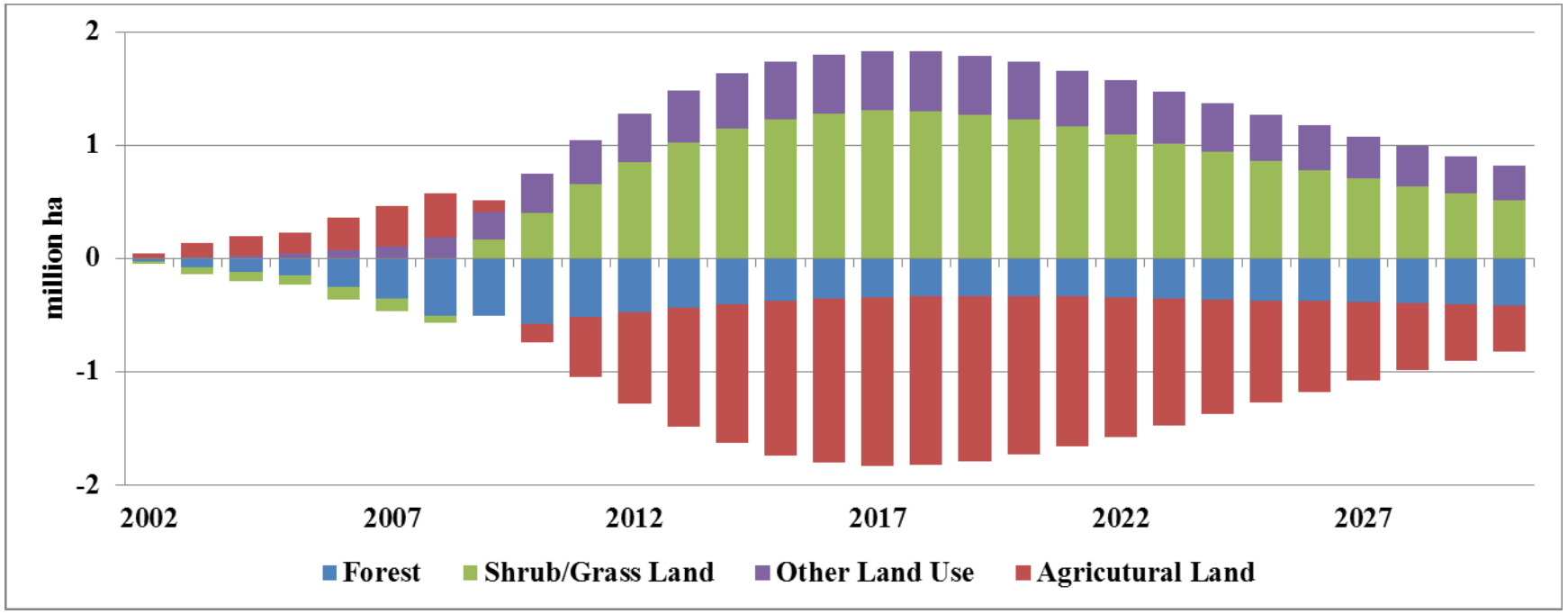
Net land use change effects vary over time

- Most of the increase in agric. land use occur in the USA (dark blue bars)
- Net global agric. LUC (red dots) reflect initial expansion followed by a contraction of total agric. area (net negative LUC)



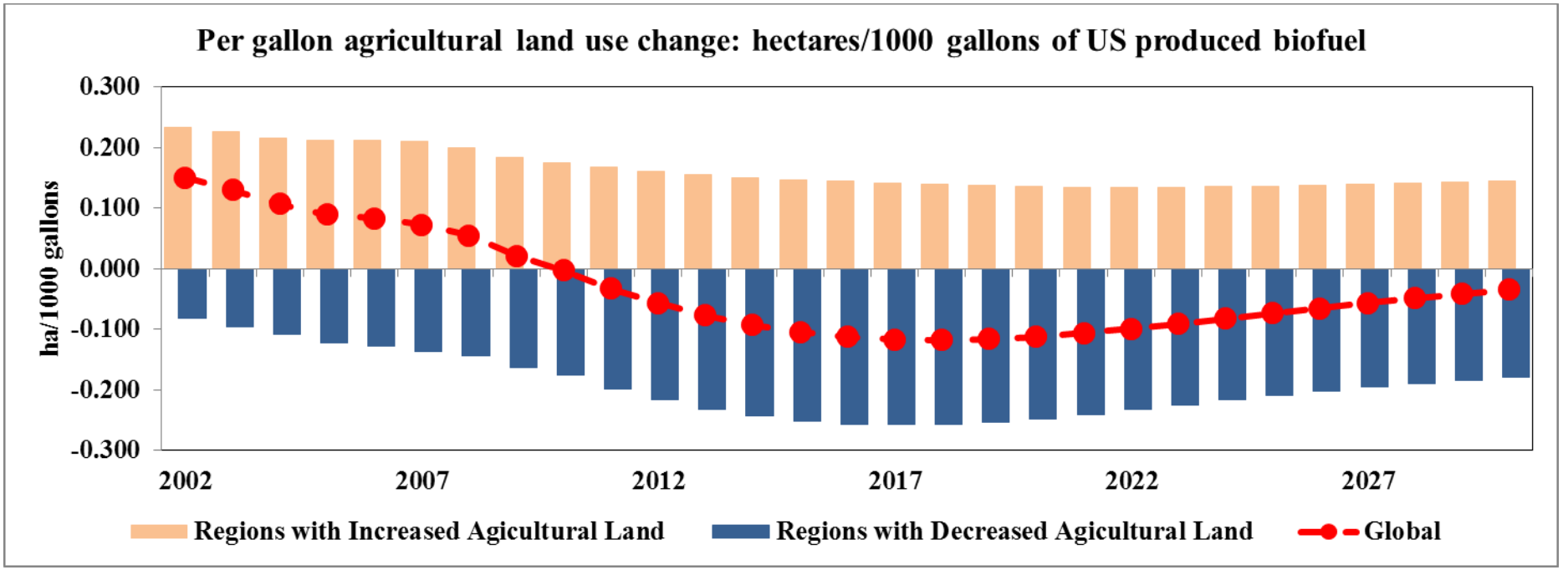
Shrubland cover responds most to agricultural LUC

- Shrubland (green bars) responds most to changes in agricultural land use
- Forest land contraction (blue bars) is mainly in the USA (prior slide)
- Longer-term land transitions are not captured in these simulations



- Note: **These results represent annual changes in other land cover types that match the changes in agricultural land use**

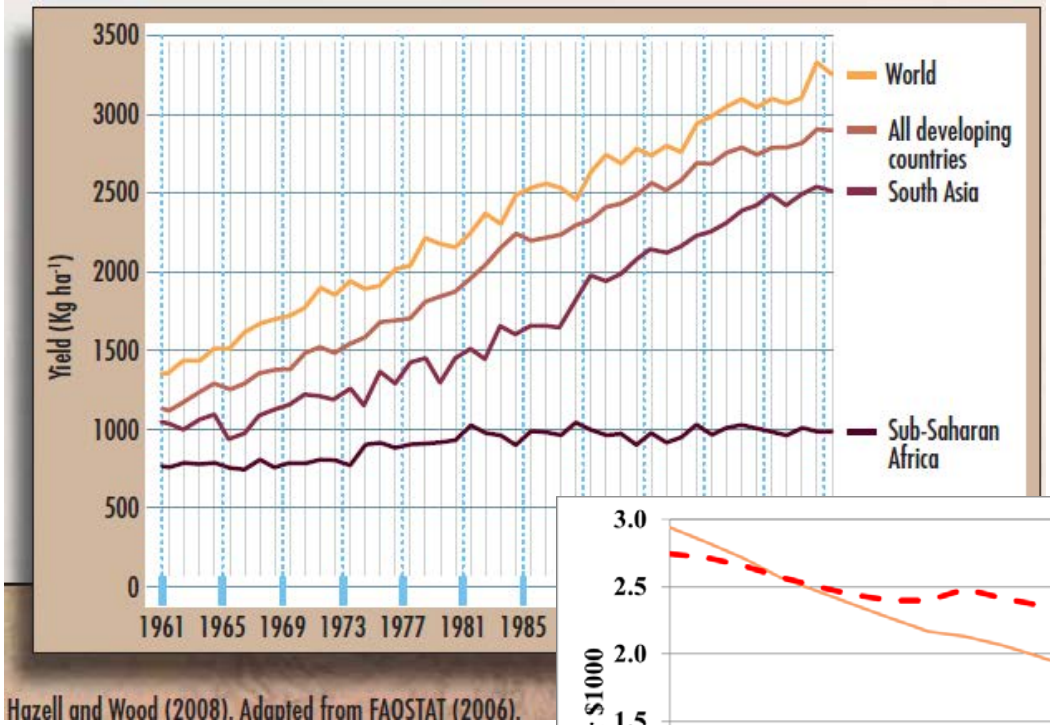
Per gallon ILUC estimates also vary over time



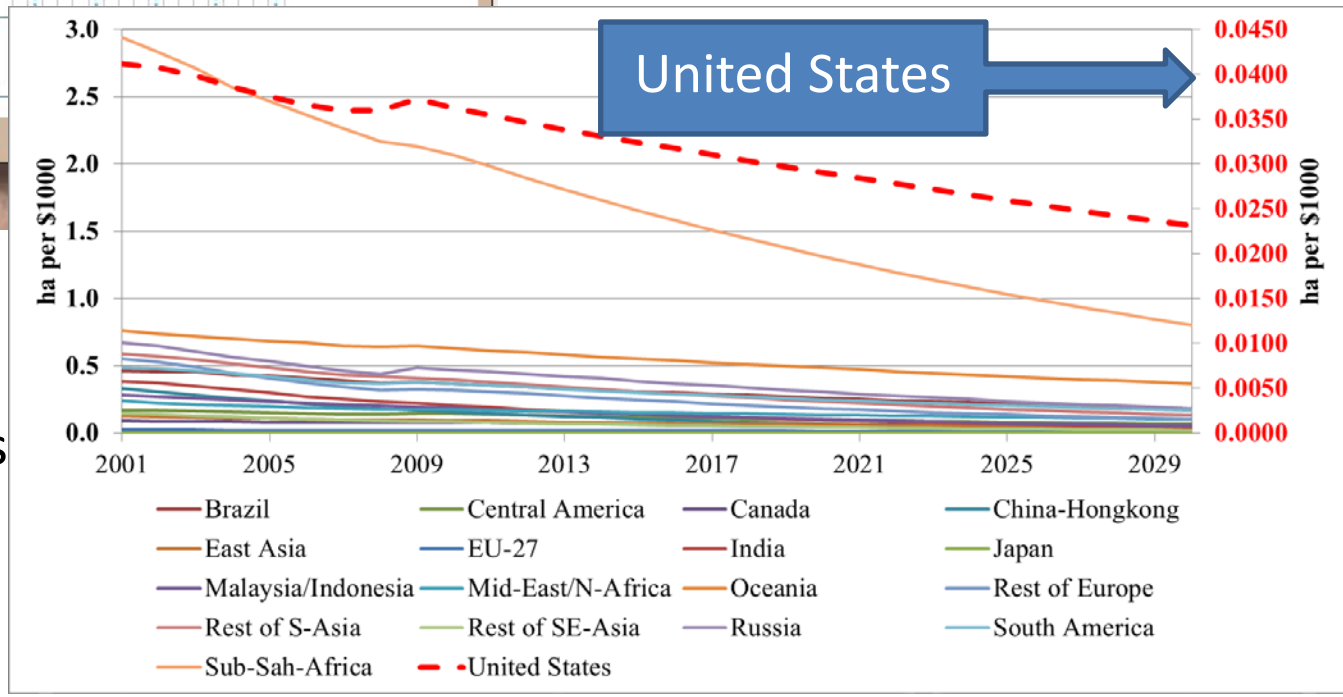
- Annual agricultural LUC range from a net expansion of 0.17 ha per 1000 gallons produced (in 2002) to a net contraction of -0.13 ha per 1000 gallons (in 2018)

- **Initial net global increase in agricultural land use is consistent with those from previous simulations with static variants of our model and other recent static versions of the GTAP model.**

Efficiency of agricultural land use is a major factor in estimates of the regional LUC impacts of biofuels



- Yield gaps across the world are substantial
- Similar gaps are reflected when calculated as land use per $1000 of GDP



- Model baseline is quite optimistic about yield changes across the world over time

Influence of land use efficiency on estimates of ILUC

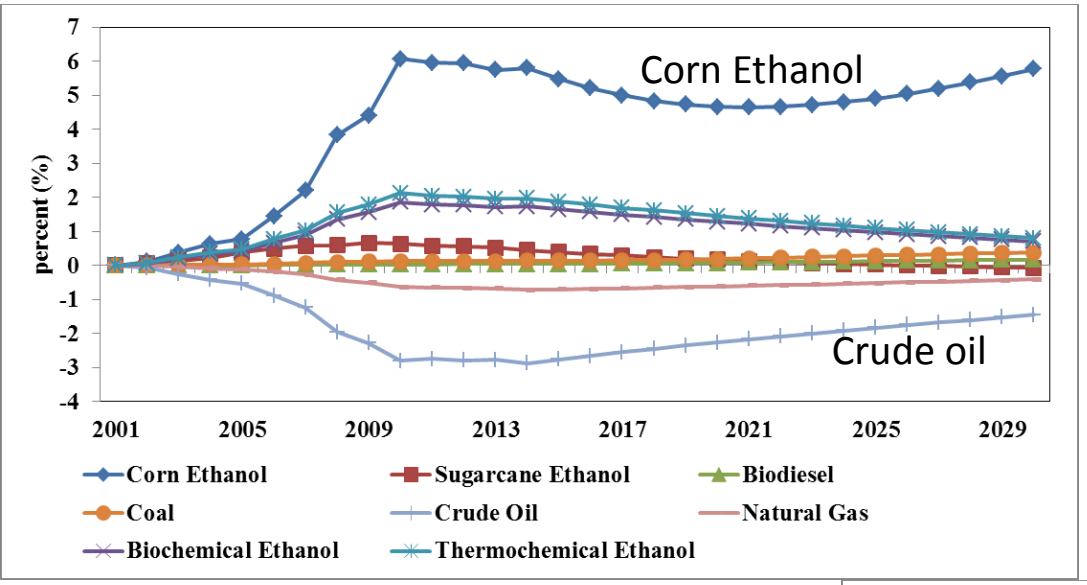
- Mid-East/Africa agric. land impact at own efficiency (2017)
  - Baseline agricultural land area: 1.37 **billion** hectares
  - Change in agricultural land area: -2.74 **million** hectares

- Mid-East/Africa agric. land area impact at US efficiency (2017)
  - Baseline agricultural land area: 74 **million** hectares
  - Change in agricultural land area: -149 **thousand** hectares

- Land use change still negative in these regions

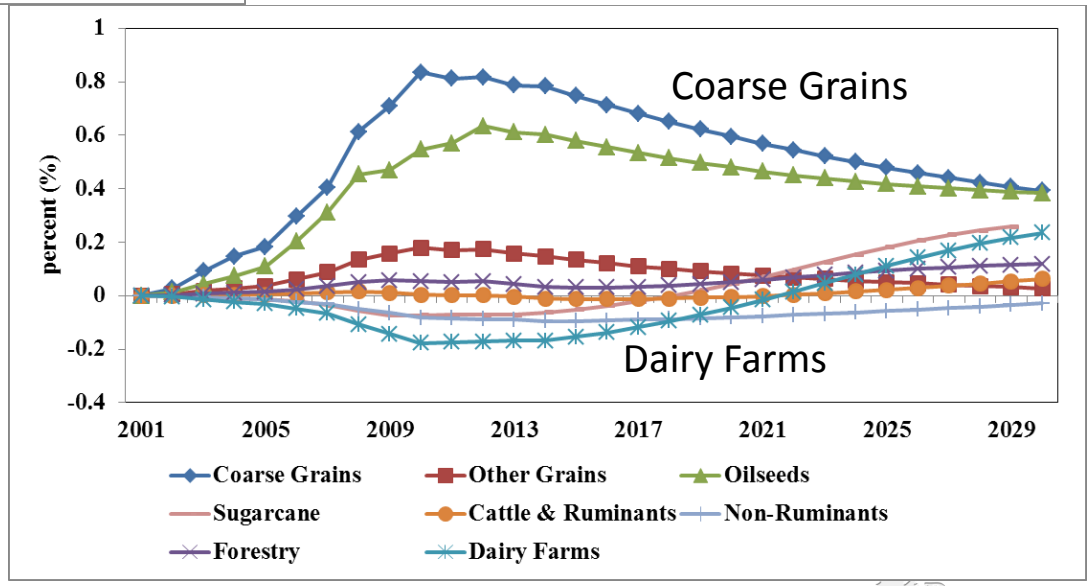
- Aggregation issues imply need for local-level modeling of land-use

Global price changes are generally as expected



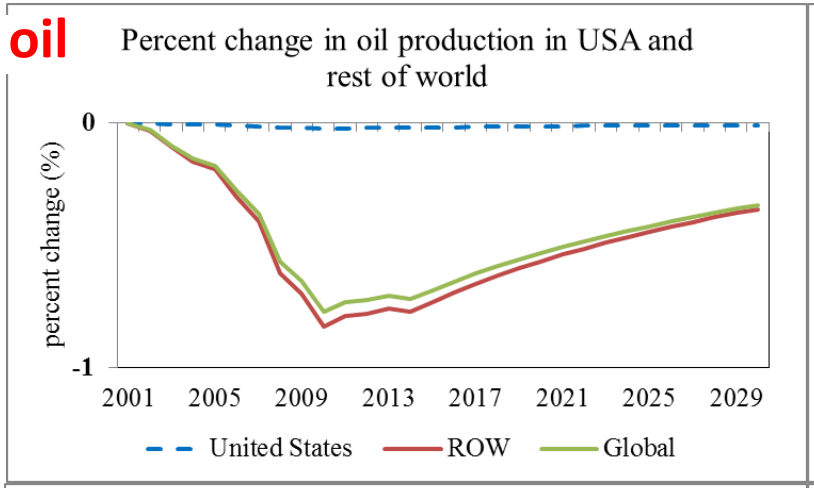
- Biofuel cost increases
- Crude oil price declines

- Most crop prices increase
  …but by less than 1%
- Livestock prices decline
  …factors include demand changes and DDGS

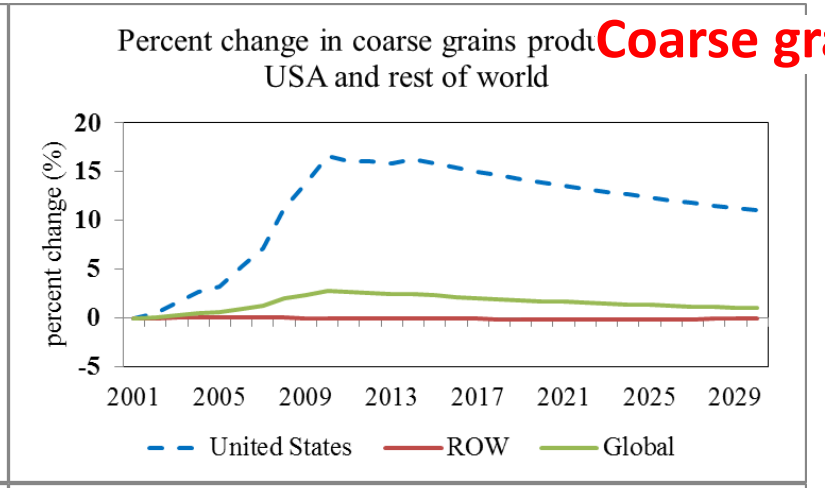


Production changes also match expectations

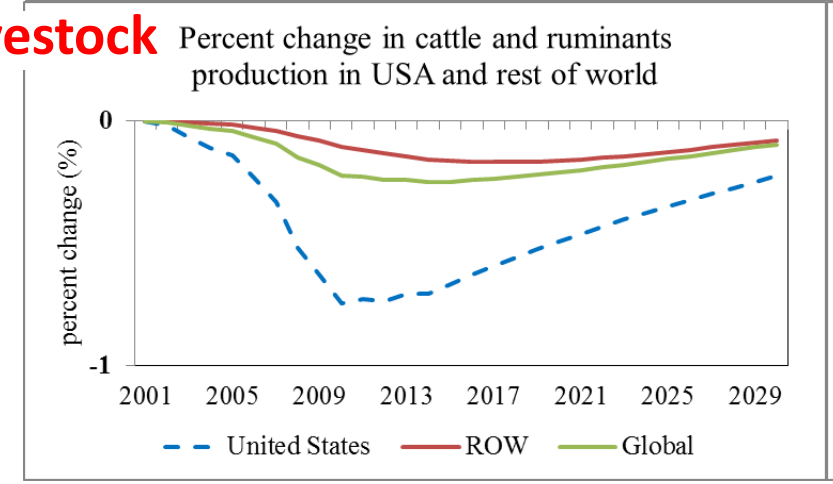
Crude oil



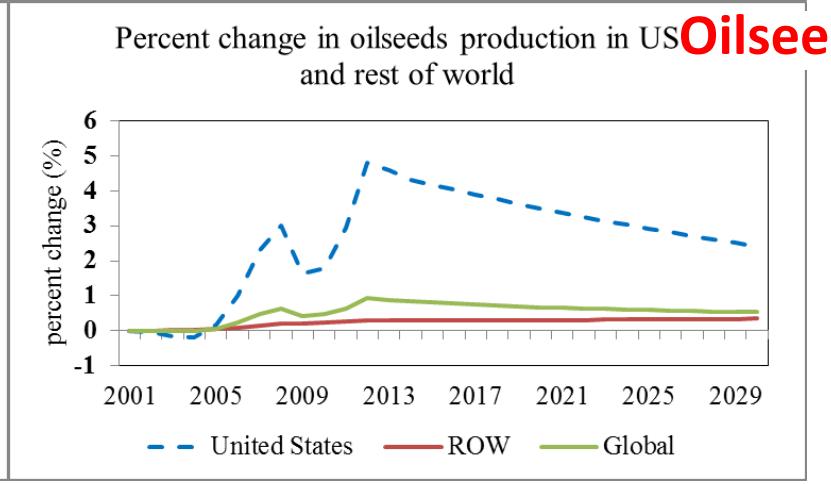
Coarse grains



Livestock

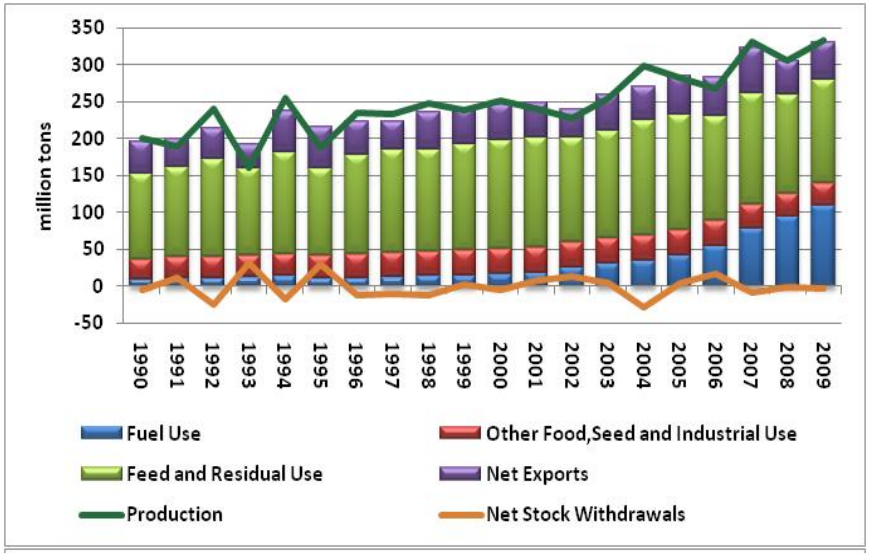


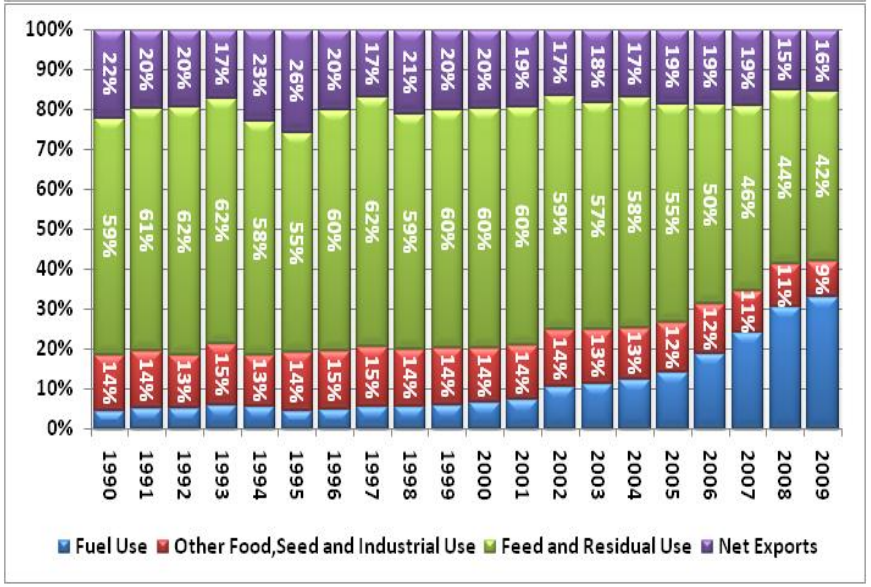
Oilseeds



- Global oil production decreases – almost all in the rest of world
- Coarse grains and oilseeds expand globally - most in the USA
- Livestock production/demand decrease – most in the USA

Empirical US corn data match these model results

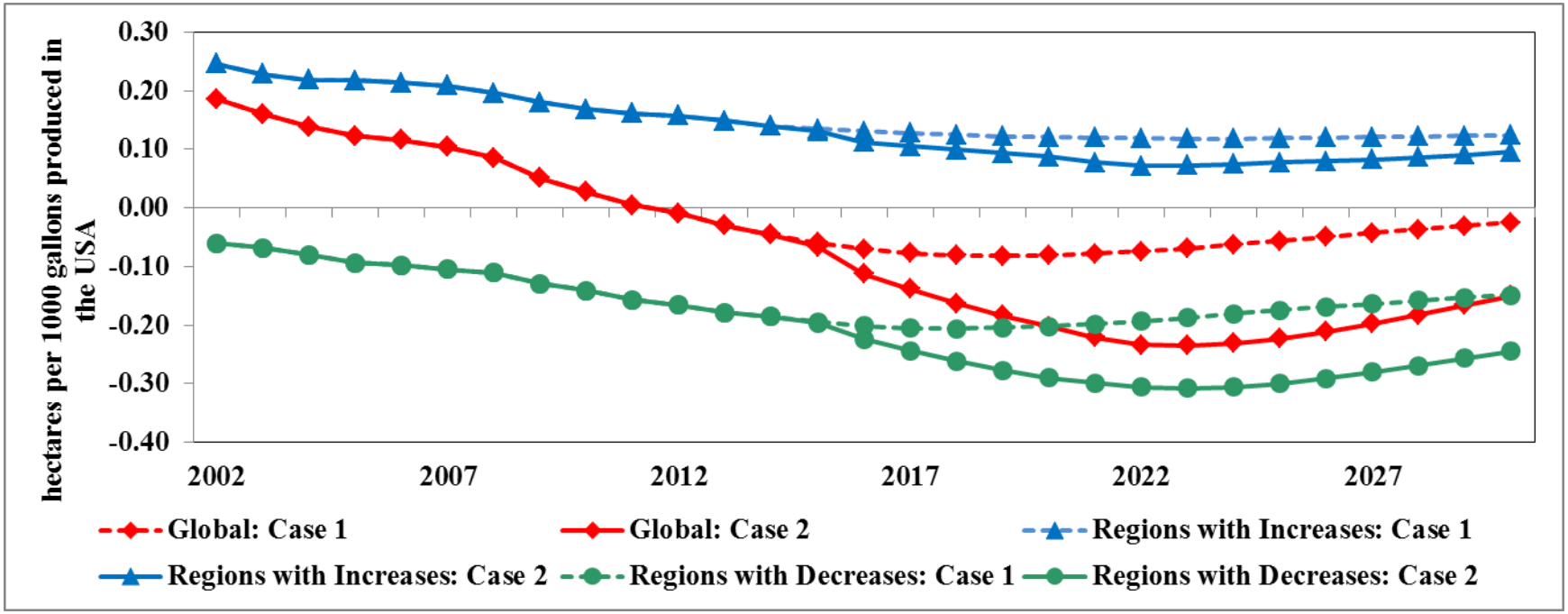




- Large increase in domestic production
- Ethanol use share: +26%
- Export share stable from 2001- 2007
- **Other domestic uses share: -23%**
- 38 million tons of DDGS in 2009
  - 8 million tons exported

Estimates of ILUC with advanced biofuels production

- Case 1 (dotted lines) : RFS2 to 2014
- Case 2 (solid lines): RFS2 to 2022 (Full RFS2 implementation)

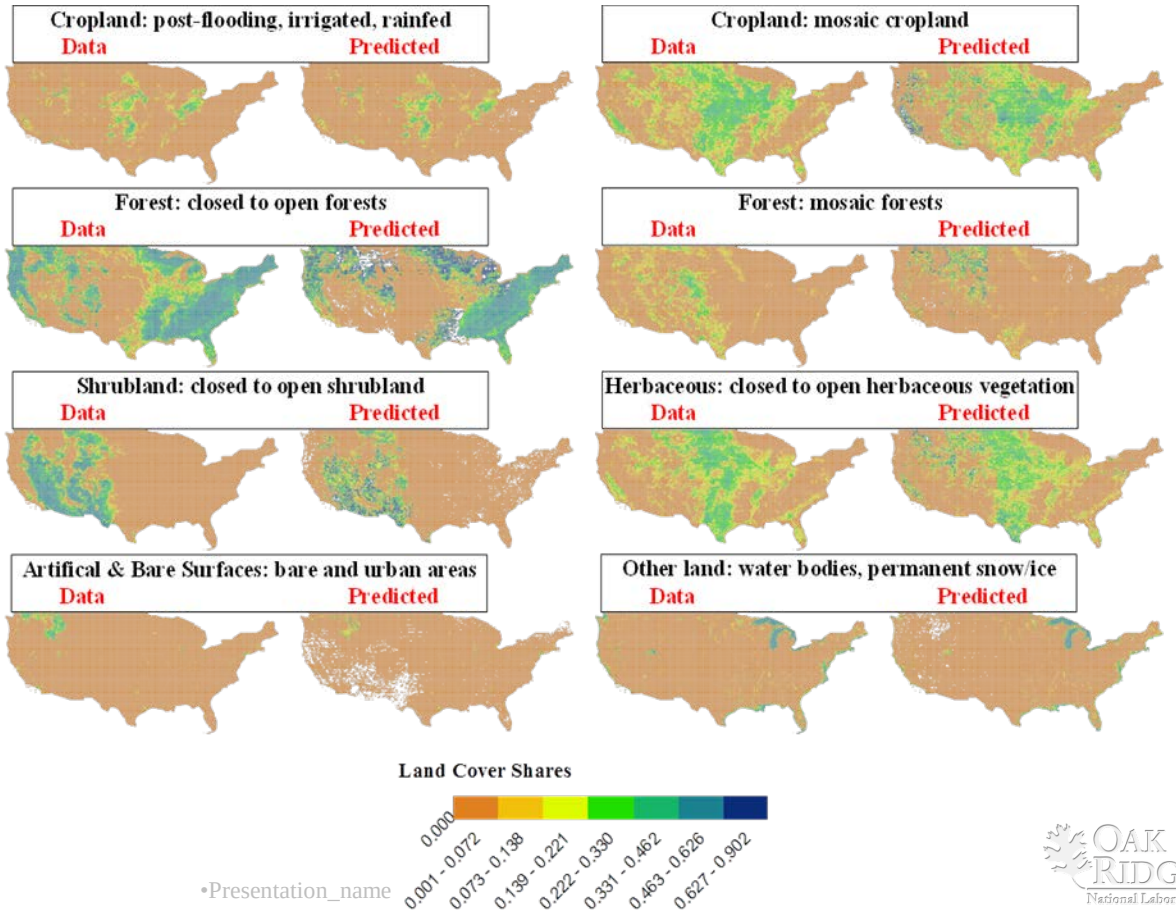


- ILUC impacts of RFS2 to 2014 similar to those discussed above
- ILUC impacts of RFS2 to 2022 are substantially different
  - Most of the advanced biofuels are produced from residues
  - Main source of ILUC is the income effects of fossil fuel displacement

Ongoing land use/supply modeling improvements

- Match land-cover categories to the ANL soil carbon emissions model
  - Perform single-feedstock simulations of biofuel production
- Land allocation sub-model for detail in land-cover changes

- Land allocation sub-model currently estimated for the United States
- Estimation is based on globally available data to facilitate extension to other regions



Conclusions

- Dynamic modeling of energy markets identifies important dimensions of the effects of bioenergy policies on land
- Estimated effects of US biofuel policy show an initial net expansion in agricultural land use, primarily in the USA
  - These initial land expansion results are consistent with those generated by previous static simulations that do not consider the cumulative effects of biofuels on oil prices and the income effects
- Estimated effects of US biofuel policy show net global reductions in agricultural land use over time
  - The net reductions in agricultural land use reflects income effects of policy and land use efficiency in specific regions
- Future work includes:
  - More detailed modeling of land allocation to address aggregation issues in the estimates
  - Investigate the role of future energy market conditions on land use

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Acknowledgements

This research was supported by the US Department of Energy (DoE)

under the

Bioenergy Technologies Office (BETO).