Global Analysis of Biofuel Indirect Effects & Feedstock Potential

Analysis Platform Review
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Goals and Objectives

- Provide analytical support to the DOE Office of Biomass Programs towards meeting EISA-RFS2 goals through:
  - "improvement and development of analytical tools to facilitate the analysis of life-cycle energy and greenhouse gas emissions… attributable to all potential biofuel feedstocks and production processes"
  - "systematic evaluation of the impact of expanded biofuel production on…the food supply for humans and animals"
- Develop capabilities and tools for analyses of:
  - domestic and global land-use effects of U.S. biofuel policies
  - potential global bioenergy feedstock supplies taking into account land-use capacity and other competitive uses of land
  - other global concerns (such as food-versus-fuel), economic trade-offs, and regulatory proposals

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Overview

- FY2009
  - Review of existing modeling efforts, specifically GTAP* simulations with Purdue University and Argonne National Laboratory
  - Communication and interaction with the scientific community on biofuels and indirect effects
- FY2010
  - Modeling to demonstrate effects of issues highlighted during the review process and recommended changes on estimates of indirect land-use-change (iLUC)
  - Empirical modeling on corn use for ethanol production and feedstock potential
  - Review efforts and collaboration continued with participation in several national and global initiatives

*GTAP – Global Trade Analysis Project

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Approach

- Review and evaluation of current models for estimating iLUC to identify:
  - Strengths, weaknesses, gaps
  - Source data (resolution, classifications, uncertainty); scales (temporal, spatial);
  - Underlying assumptions and sensitivities

- Development of an in-house GTAP modeling capability to:
  - Evaluate the impacts of several critical factors in modeling indirect land-use-change
  - Incorporate more complete land-use-change sub-model
  - Incorporate cellulosic feedstock projections from the billion-ton study update
  - Incorporate model dynamics for evaluation of biofuel policy over future scenarios

- Other modeling to analyze global biofuel issues and feedstock potential:
  - Application of econometric and other empirical methods

- Support DOE collaboration and cooperation efforts:
  - Participate in dialogue process

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Approach (cont'd)

- Background on Global Trade Analysis Project (GTAP)
  - GTAP is a combined computable general equilibrium (CGE) database and modeling framework developed since 1992 at the Purdue University Center for Global Trade Analysis
  - CGE models are a class of models for economy-wide analyses
  - The database is often used in the development of other global economic models.
- Biofuel Analyses with the GTAP Model
  - The GTAP Model has recently been adapted for the evaluation of biofuel policies
  - Its advantage is in the ability to capture complex trade and other economic adjustment mechanisms critical to estimates of the global land-use-change implications of biofuels
  - ORNL and others participated in reviewing the modeling approach, data and simulation results

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Accomplishments: Review Process pointed to a number of crucial factors in estimating iLUC effects of biofuels

- Baseline and calibration issues:
  - iLUC estimates depend on baseline economic conditions and model calibration
- Land use and supply specification:
  - Land use is subject to biophysical, political, demographic and market forces, whereas economic models tend to focus on price effects.
  - Land-use-change is expressly local, but available data are inconsistent in quality and spatial/temporal resolution
- Yield change modeling
  - Accurate estimates of yield change are important to current and future LUC effects of biofuels. It affects the difference between LUC with and without ethanol, not just the latter.
  - Given that price changes can induce crop yield changes and biofuels can affect prices, yield estimates cannot be assumed to be a baseline (without-ethanol) variable
- Policy specification
  - Current biofuel policies differ significantly from previous ones and have distinct land use and economic/welfare effects
  - Model simulations need to match policy closely in order to measure its indirect effects
- Other issues: model parameters, aggregation issues, dynamics, etc.

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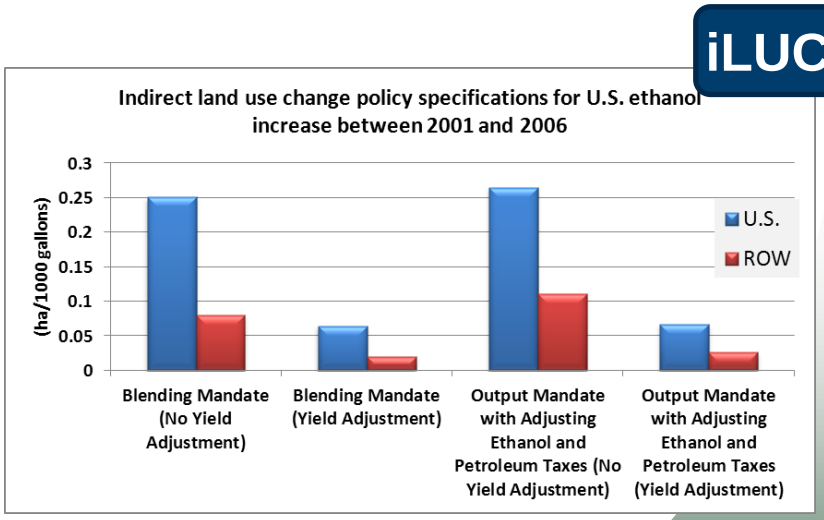
Accomplishments: Simulations of static GTAP-ORNL demonstrated impacts of several factors on estimates of iLUC

- Constructed an in-house version of the static GTAP model
- Main additions to the biofuel model
  - Incorporated a land supply sub-model
  - Corn ethanol modeling closely follows the nature of RFS2 mandates

- **Example**: Effects of policy specification and yield change

- Ethanol use change between 2001 and 2006
- Two biofuel policy specifications
  - Consumption mandate as in the RFS2
  - Production mandate using a combination of price and subsidies as instruments
- Without and with yield adjustments
- iLUC results for the two policies are similar in this particular case

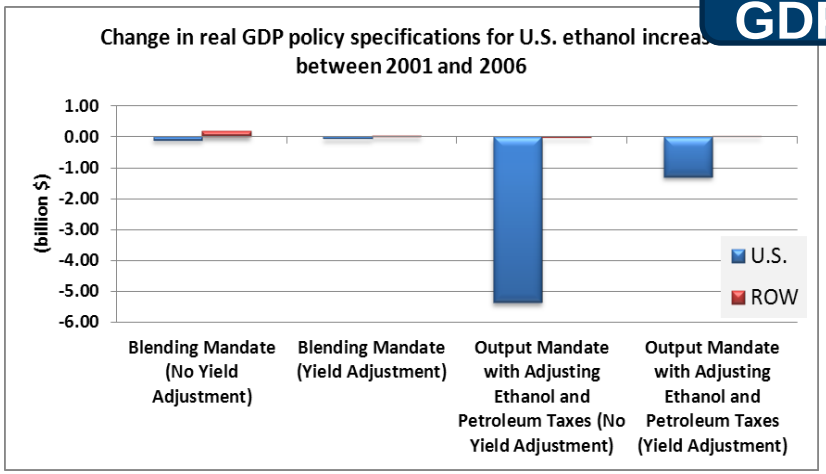


Accomplishments: Simulations of static GTAP-ORNL demonstrated impacts of several factors on estimates of iLUC

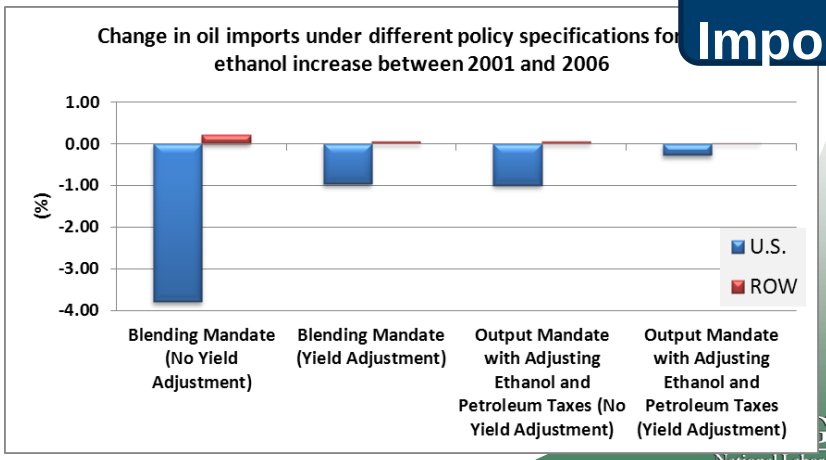
- **Example**: Effects of policy specification and yield change

- Results for other measures differ significantly for the two policies
- U.S. GDP effect
  - Blending Mandate: about -$0.1 billion
  - Output mandate: -$5 to -$1.2 billion
- Rest of the world (ROW) GDP effect
  - Blending Mandate: Small positive
  - Output Mandate: Negligible
- Oil import effects
  - Also differ substantially

Real GDP



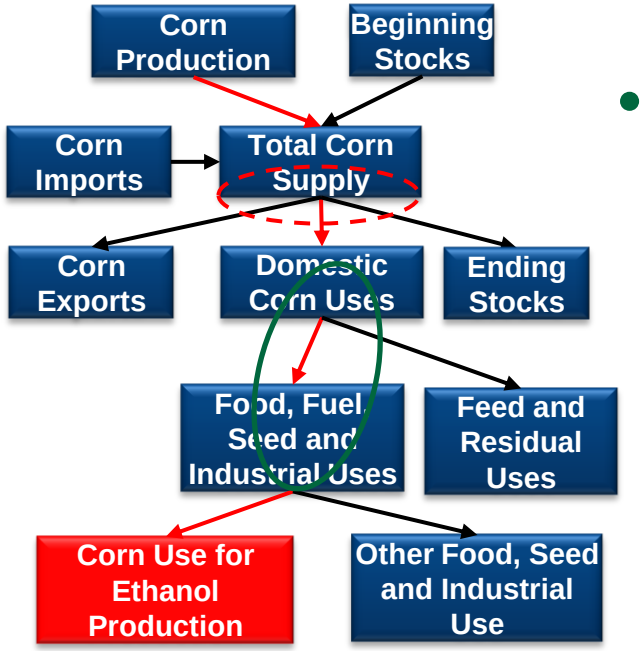
Oil Import



Accomplishments: Empirical analysis of corn use data lends little support to usual iLUC assumptions

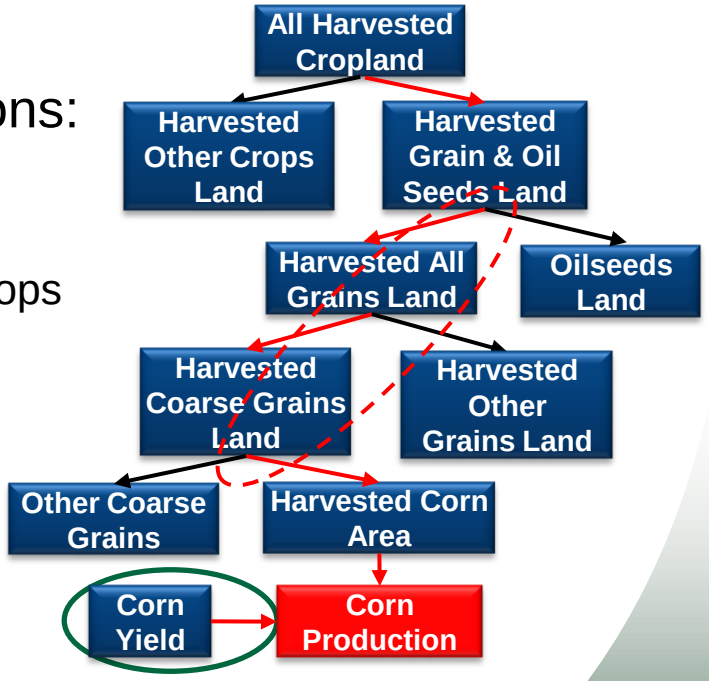
- Index decomposition analysis (IDA*) was used to test crucial assumptions in estimating iLUC using empirical data (2001-2009)

Hierarchical Description of Corn Supply and Allocation



- Main iLUC assumptions:
  - Diversion of corn exports
  - Displacement of land previously under other crops

Hierarchical Description of Corn Land Use

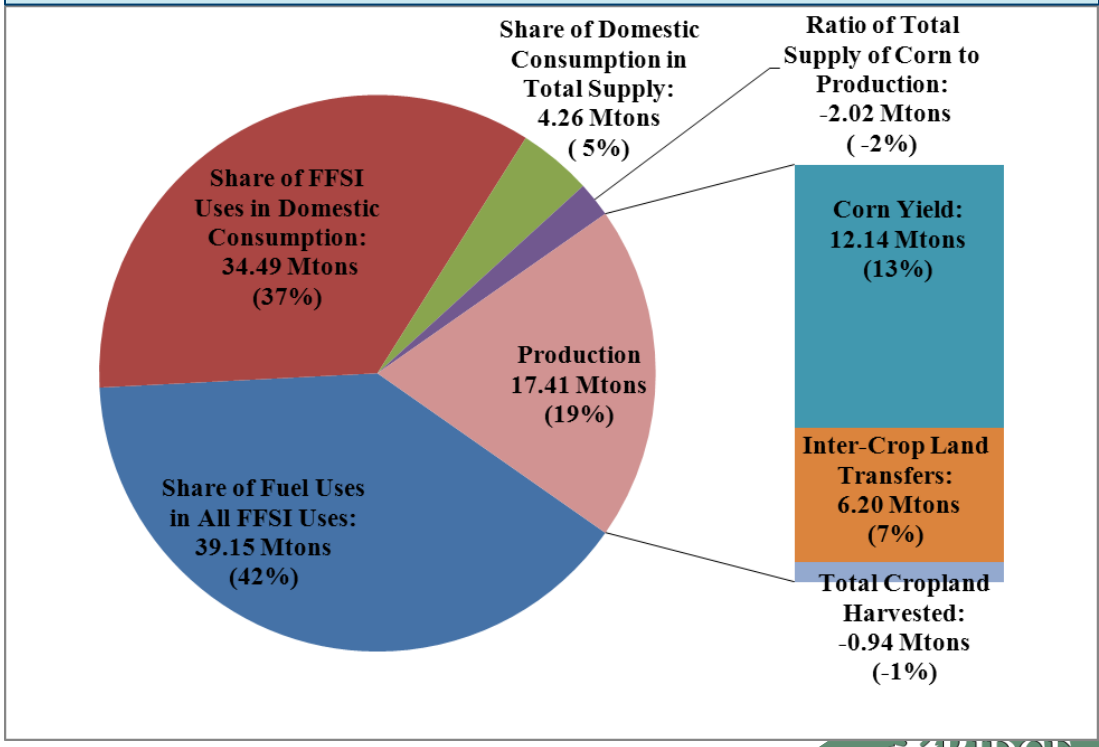


*IDA: Allocates the change in a given variable (y) to each contributing factor *ceteris paribus i.e.* other factors held constant to isolate the effects of each factor

Accomplishments: Empirical analysis of corn use data lends little support to usual ILUC assumptions

- Empirical decomposition analysis showed that recent corn use for ethanol production were largely due to:
- Reallocation of domestic consumption in favor of ethanol
- Increases in domestic production of corn
- Yield change accounted for about two-thirds of the production contribution between 2001-2009

IDA Estimates of Factor Contributions to Corn Used for Ethanol Production from 2001 to 2009

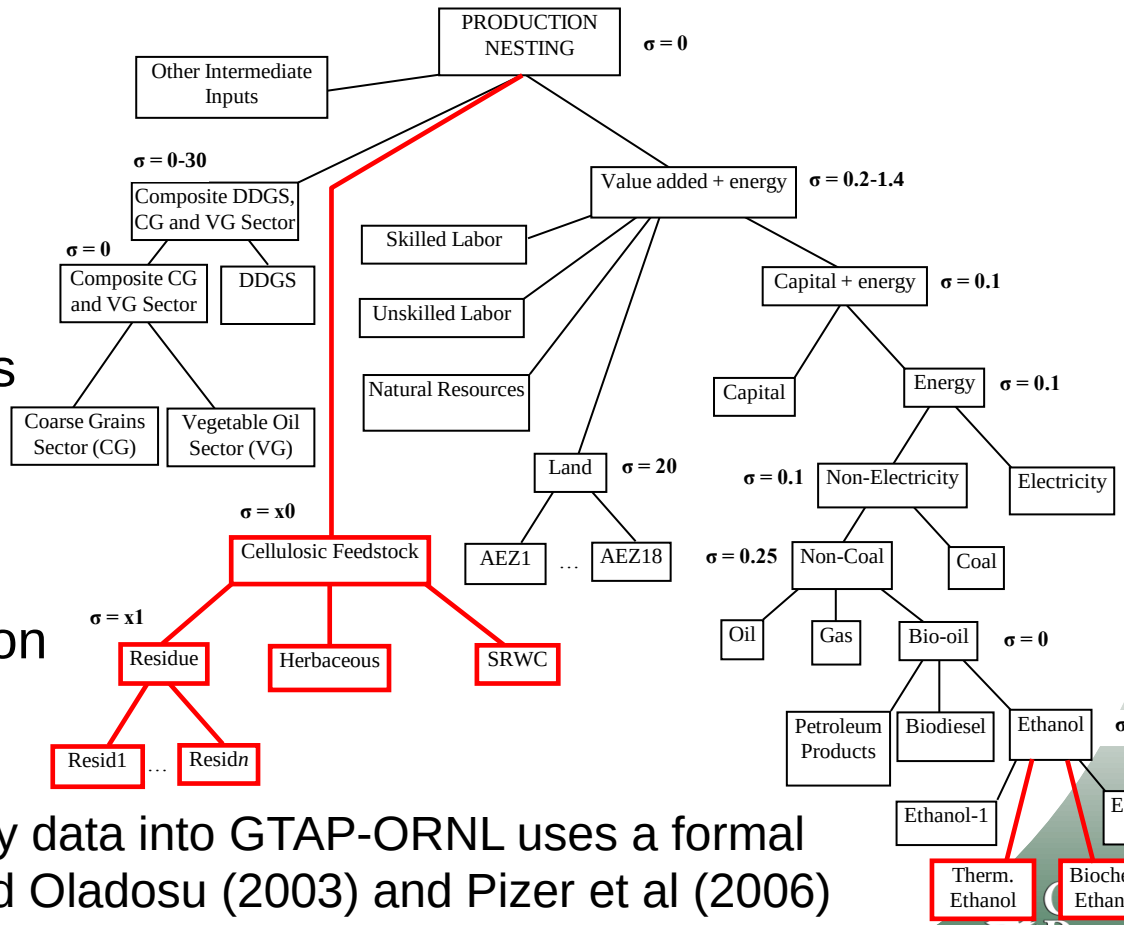


Implication: Domestic market for corn adjusted flexibly to ethanol production with minimal land use change

In-Process: Enhanced GTAP-ORNL model to incorporate new feedstock data and model dynamics

- Cellulosic feedstock data from the billion-ton study update
- Recursive dynamic equations based on the GTAP-Dyn model

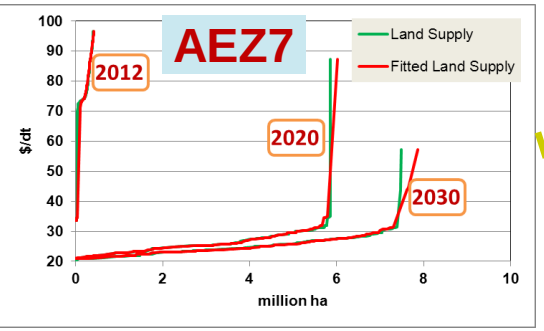
- Feedstocks: Residues, Herbaceous and Short Rotation Forestry
- Billion-ton study data transformed from counties to agro-ecological zones (AEZ)
- Biochemical and thermochemical conversion



- Integration of billion-ton study data into GTAP-ORNL uses a formal approach similar to Rose and Oladosu (2003) and Pizer et al (2006)

In-Process: Enhanced GTAP-ORNL model to incorporate new feedstock data and model dynamics

- **Illustrative Scenario: Ethanol blending mandate up till 2010**

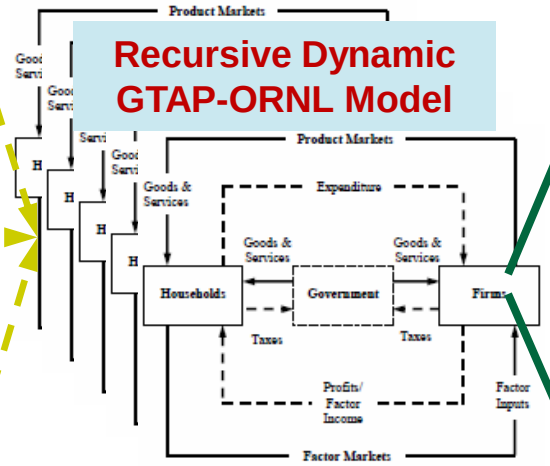


Herbaceous Energy Crops

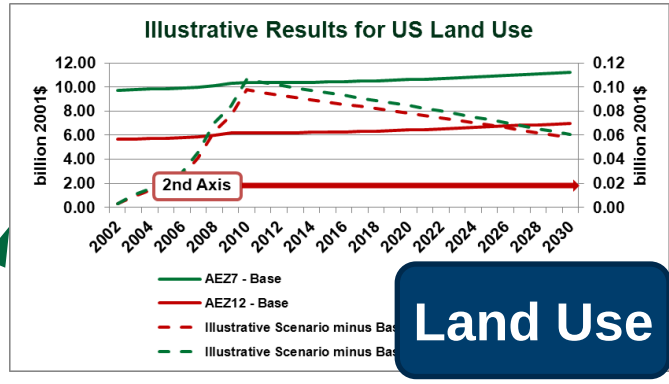
Other Inputs

Population Growth
Labor Supply
Productivity change
Dynamic parameters

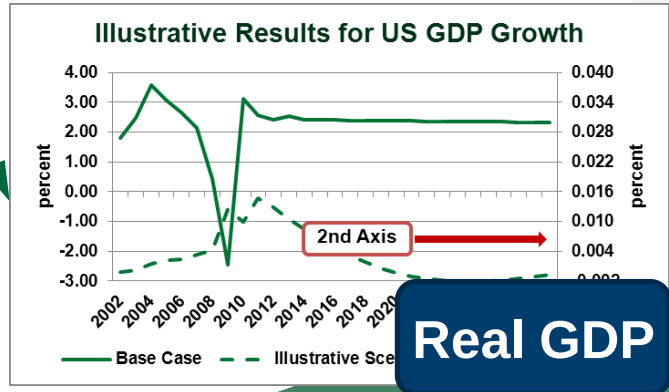
- Billion-ton study data provides information on the evolution of cellulosic feedstock availability, cost, land requirement and location



- Recursive CGE model allows dynamic estimation of indirect effects, and evaluation of different future policy and technology scenarios



- Illustrative Results:
  - Baseline (Solid lines)
  - Difference (Dashed lines – 2nd Axis)



Accomplishments: Contributions to CARB* working groups on Low Carbon Fuel Standards

- Contributed to analysis and recommendations of CARB working groups related to:
  - Modeling uncertainty
  - Time accounting
  - Land availability
  - Effects of other fuels, food-fuel interactions, emission factors and others
- Key contributions include presentations and discussion notes on:
  - Empirical analysis to underscore uncertainty in key modeling assumptions
  - Conceptual differences in modeling first-time LUC (principle concern) versus influences on management of occupied lands
  - Alternative modeling approaches to illustrate a wider range of potential effects of bioenergy policy
- Based on reports of the working groups CARB staff recommended previously proposed iLUC estimates be modified.

*CARB – California Air Resources Board

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Relevance

- The RFS2 goals require accurate estimates of indirect land-use-change for the calculation of associated emissions.
- Social concerns over biofuels imply a need to demonstrate overall benefits and minimal global impacts
- Activities under the project have contributed significantly to the discussion and evaluation of the indirect land-use-change effects of conventional biofuels
- Ongoing analytical tool development will further enhance DOE capabilities to conduct LCA of biofuels, and assess other socio-economic implications

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Benefits and Expected Outcomes

- Several changes recommended from this project's review and simulation efforts are reflected in latest simulations of iLUC by Purdue for the GREET LCA model

- Ex-post analysis of U.S. corn market data showed that crucial assumptions behind iLUC played a small role in supplying the corn used for ethanol production.

- Enhanced GTAP-ORNL Model would allow evaluation of other strategic goals:
  - Oil import reduction; food vs. fuel issues; trade effects; welfare effects; alternative policy and technology scenarios

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Summary

- Relevance
  - Project provides analytical support to evaluate the indirect effects of U.S. biofuel policy, particularly indirect land-use-change, which is a constraining requirement in meeting EISA RFS2 targets

- Approach
  - Development of enhanced modeling capabilities to evaluate the indirect effects of biofuels, and to estimate global biofuel feedstock potentials.
  - Review and collaboration to help highlight state of the art, strengths, weaknesses and gaps in current modeling.

- Technical Accomplishments
  - Developed a version of the GTAP model (GTAP-ORNL) focused on LUC and used simulations to demonstrate the impacts of several critical factors and recommended changes on estimates of iLUC
  - Empirical analysis was used to show that several crucial assumptions behind iLUC find little support in the data for the recent period of boom in U.S. corn ethanol production.
  - Incorporated cellulosic data from the billion-ton study update and model dynamics into the GTAP-ORNL model.

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Summary (cont'd)

- Success Factors
  - Indirect emissions remain the deciding component in meeting RFS2 requirements
  - There is a strong global interest in the socio-economic implications of biofuels
  - Need to demonstrate the overall benefits of biofuels versus fossil fuels or alternative uses of biomass
- Challenges
  - Indirect effects involve complex processes
  - Existing models were not designed for this purpose and must be properly re-worked
  - Models to incorporate detailed land data and explicit causal factors for LUC analysis are still in development

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Future Work

- Conduct analysis of indirect effects of EISA with enhanced GTAP-ORNL model - iLUC; trade effects, oil import reduction, welfare impacts, food vs. fuel implications
- Incorporate more detailed model of land use currently in development into the GTAP-ORNL for improved representation of land-use-change
- Evaluate paths to meeting EISA goals and the impacts of policy, technological development and other changes, and their global indirect effects
- Evaluate the impacts of alternative biomass uses (e.g. bio-power) on RFS goals, and the indirect effects
- Incorporate potential cellulosic feedstock data for other world regions
- Update model with data from future revisions of the billion-ton study
- More direct linkages to detailed energy and agricultural models

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Additional Slides

Publications and Presentations

- G. Oladosu, K. Kline, R. Uria-Martinez and L. Eaton (2011) "Sources of corn for ethanol production in the United States: A Decomposition analysis of the empirical data" (*Accepted for Publication in the Biofuels, Bioproducts & Biorefining Journal*)
- K. Kline and G. Oladosu, 2010 "Myths, Facts and Uncertainties for Bioenergy", Presentation at Center for Bioenergy Sustainability Forum, Oak Ridge National Laboratory, Aug. 20 2009
- Oladosu GA and Kline KL 2010 "The Role Of Modeling Assumptions And Policy Instruments in Evaluating The Global Implications Of U.S. Biofuel Policies." Proceedings of the 33rd International Association of Energy Economics International Conference "The Future of Energy: Global Challenges, Diverse Solutions" Rio de Janeiro, Brazil, June 6-9, 2010
- Kline, KL and Colman, MD. 2010. Woody Energy Crops in the Southeastern United States: Two Centuries of Practitioner Experience. Biomass & Bioenergy (first published on-line 21 August, 2010) http://dx.doi.org/10.1016/j.biombioe.2010.05.005
- K. Kline, V. Dale and G. Oladosu (2010) "Models, Science, and the Precautionary Principle applied to bioenergy and land-use change", Presentation at the US Chapter of the International Association of Land Ecology Conference, Athens GA , April 7 2010
- Carolyn Sarls and G Oladosu (2010) "A Comparison of Empirical and Theoretically Estimated Eucalyptus Yield in Brazil", Poster Presentation, Oak Ridge National Laboratory
- G. Oladosu (2010) "Global Indirect Land Use Implications of U.S. Biofuel Policies: A Review of the Evidence", University of Tennessee Department of Agricultural Economics Fall Seminar Series, Sept. 2010
- Oladosu GA and Kline KL "Empirical Analysis of the Sources of Corn Used for Ethanol Production in the United States: 2001-2009", Presentation at the National Corn Growers Association (NCGA) AgEnergy Symposium, Nov. 4 2010, Washington, D.C.
- Oladosu, GA, and Kline KL "Revisiting Simulations of the Indirect Land-Use Impacts of U.S. Biofuels Policy" Report Oak Ridge National Laboratory
- Oladosu, GA, and Kline KL "Land Use Impacts of Corn Ethanol: Reconciling Models, Empirical Data and Policy" at the National Corn Growers Association Conference on Land Use and Carbon Impacts of Corn-Based Ethanol, St. Louis, Missouri August 26 2009
- K. Kline, G. Oladosu and V. Dale (2009) "Uncertainty in Measuring Land-Use Change for Biofuels", Conference on Measuring Land-Use Change for Biofuels by the National Science Foundation, Boston MA, September 28 2009

A Summary of the Index Decomposition Analysis Method

- Used extensively for energy decomposition analysis but has been applied to agricultural and other non-energy issues(see references)
- Allocates the change in a given variable (y) to each contributing factor *ceteris paribus i.e.* if all other factors were held constant
  - Addresses the need to isolate the role of individual factors
- Decomposition analysis is based on the total differential of a general function of the following form:
  - $y = x_1.x_2....x_n$
- Derived from index number theory
- The log. mean divisia index (LMDI I) formulation used in current study is more recent, but has gained popularity due to its advantages

$$\Delta y^D = \sum_{i=1}^{n}\left(\frac{(y_{t1}-y_{t0})}{ln\left(\frac{y_{t1}}{y_{t0}}\right)}\right) ln\left(\frac{x_{i,t1}}{x_{i,t0}}\right) = \sum_{i=1}^{n} \Delta y \frac{g_{xi}}{g_y}$$

Factor Contributions

References on the Index Decomposition Analysis Method

- Albrecht J, Francois D and Schoors K *A Shapley decomposition of carbon emissions without residuals*, Energy Policy **30**:727-736 (2002)
- Lenzen M *Decomposition analysis and the mean-rate-of-change index*, Applied Energy **83**:185-198 (2006)
- Chunbo M and Stern DI *China's changing energy intensity trend: A decomposition analysis*, Energy Economics **30**:1037-1053(2008)
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