Why Energy Prices will be a Key Driver of Global Land use in the 21st Century

Jevgenijs Steinbuks
Center for Global Trade Analysis
Purdue University
(co-authored with T.W. Hertel)

Prepared for 15th Annual Conference on Global Economic Analysis, Geneva, Switzerland, June 2012
With support from the NSF Center for Decision Making Under Uncertainty, University of Chicago

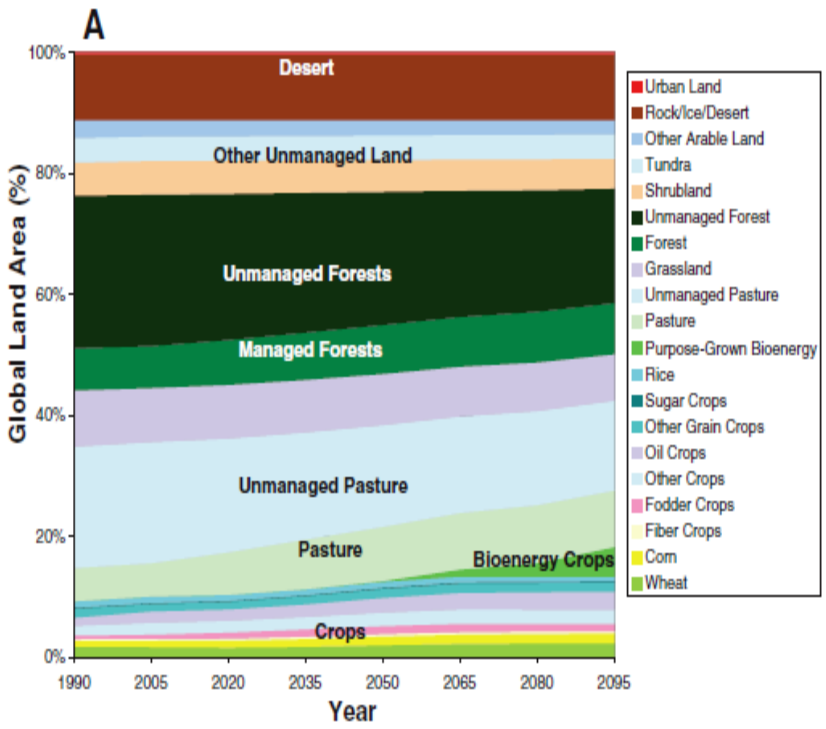
Outline of the Talk

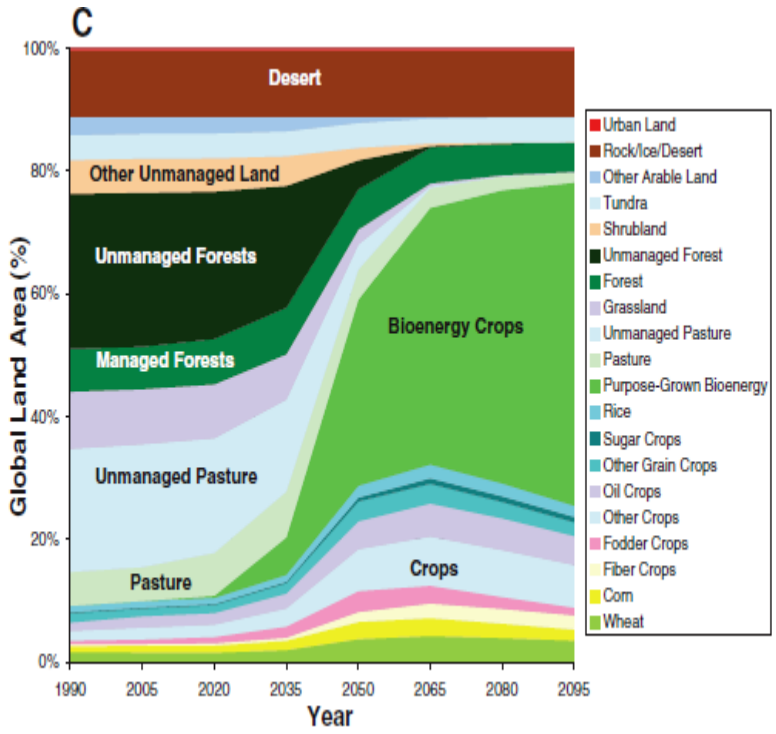
- Background / Motivation / Objectives
- Model Features
- Baseline Construction
- Key Uncertainties
  - Climate Impacts
  - Climate Policies
  - Energy Prices
- Conclusions

Outline of the Talk

- **Background / Motivation / Objectives**
- Model Features
- Baseline Construction
- Key Uncertainties
  - Climate Impacts
  - Climate Policies
  - Energy Prices
- Conclusions

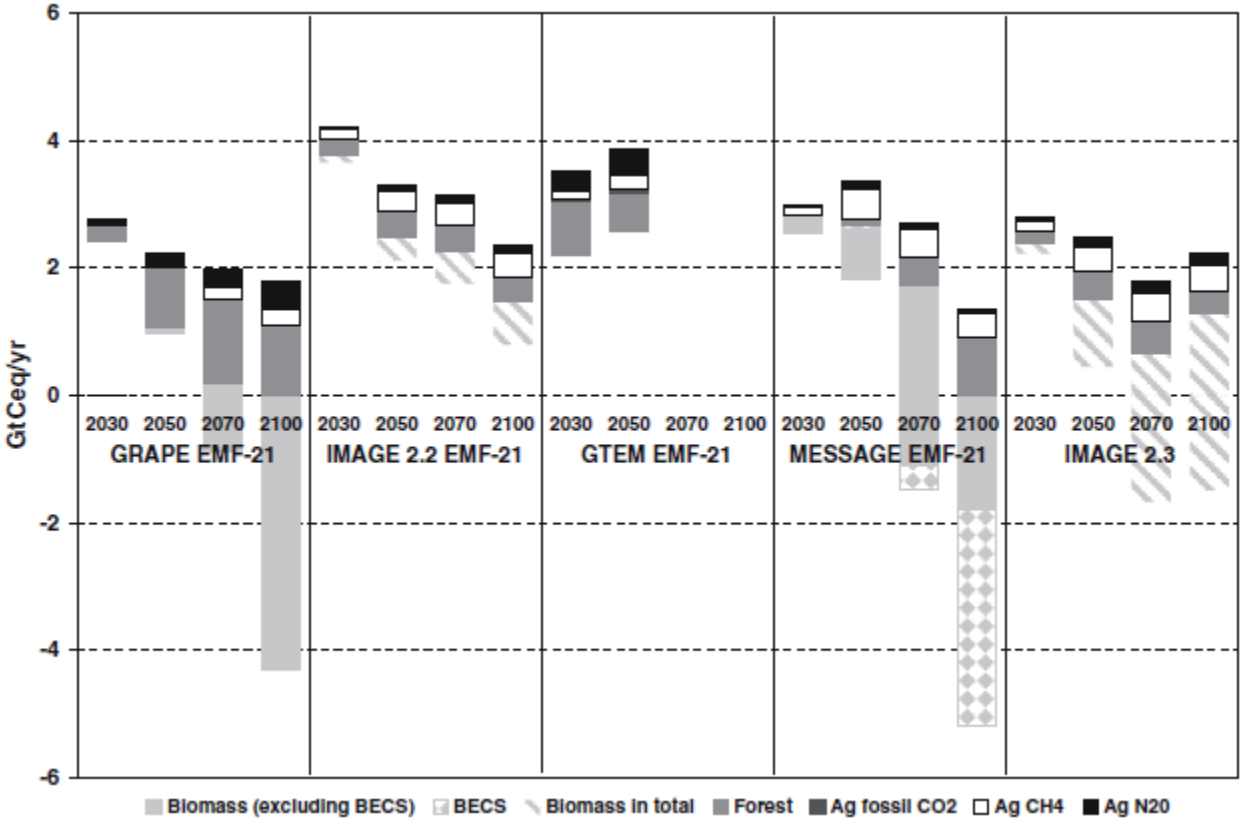
What pattern of land use will we see in 2100?





Source Wise et. al (2009)

How much abatement from land do we expect in 2100?



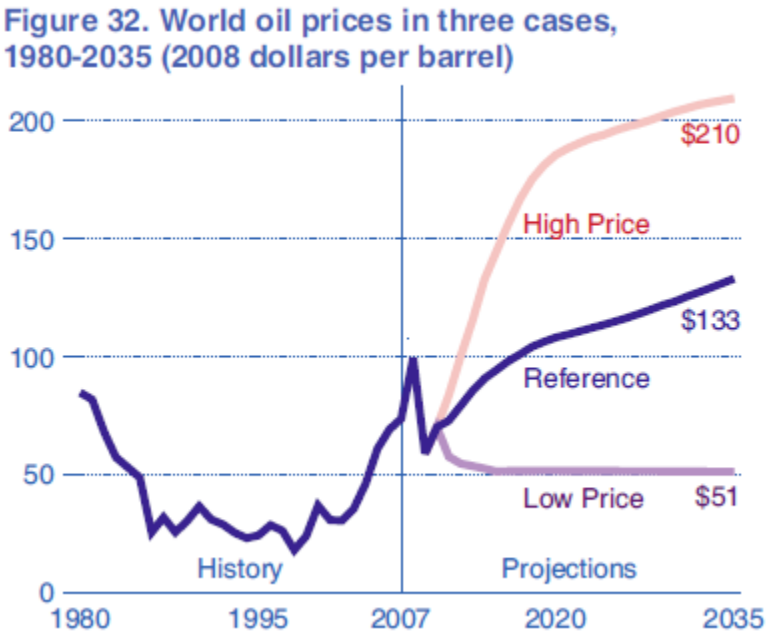
Source Rose et. al (2011)

Key Drivers of iLUC Uncertainty

- Climate Impacts / Crop Yields
- Regulatory / Climate Policies
- Technological Progress in Crops / Biofuels
- Energy / Fossil Fuel Prices

Why Energy Prices Matter?

- **Key Driver for Biofuel Demand**
- **Strong Impact on Fertilizer Costs which affect the incentive to boost yields**
- **Global Consumption / Indirect Demand Effect**
- **Highly Uncertain**



Source: EIA 2010

Research Objectives

- **Analyze interplay between competing land uses within a comprehensive framework, which combines 5 separate literatures and modeling traditions**
- **Develop baseline results for 100 years, using projections for population, climate, income, productivity, and energy prices**
- **Capture different sources of emissions/sequestration, including:**
  - **Petroleum and biofuels combustion**
  - **Fertilizer production and use**
  - **Land use change**
  - **Forest harvesting and sequestration**
- **Investigate land-use sensitivity to uncertainties in energy prices, climate impacts and climate policies**

Outline of the Talk

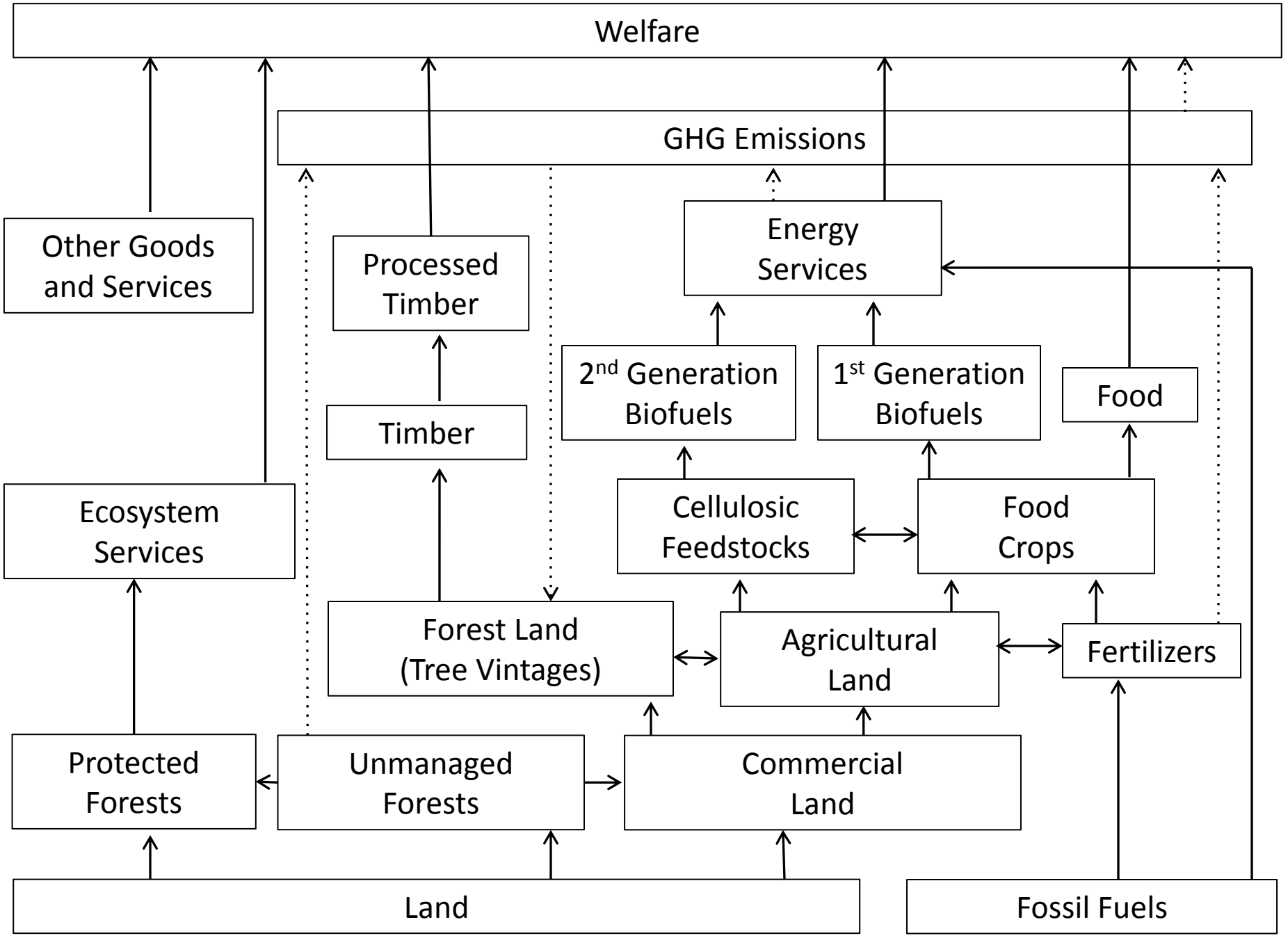
- Background / Motivation / Objectives
- **Model Features**
- Baseline Construction
- Key Uncertainties
  - Climate Impacts
  - Climate Policies
  - Energy Prices
- Conclusions

Model Features

- **Perfect Foresight, Dynamic, Partial Equilibrium**
- **Eight Sectors / Commodities**
- **Annual Forest Vintages**
  - Older Trees Yield More Timber
  - Younger Trees Sequester More GHG
  - Inertia in Land-Use
- **Intensification: Fertilizer-Land Substitution**
- **Renewable Energy: Petroleum vs. Biofuels**
  - 1g Biofuels: established technology, blend with petroleum
  - 2g Biofuels: emerging technology, drop-in alternative

Model Features

- **Efficient Use of Resources**
  - Services not Quantities
- **Irreversibility of Ecosystem Services**
  - Deforestation vs. Ecosystem Services
- **Land Access and Management Costs**
  - Rising Natural Land Access Costs
  - Commercial Land Conversion Costs
  - Short Term Adjustment Costs
- **Non-Homothetic AIDADS Preferences**
  - estimated econometrically based on GTAP data
  - favor ecosystem services in long run
  - food demand grows less rapidly


Welfare
GHG Emissions
Other Goods and Services
Processed Timber
Energy Services
2nd Generation Biofuels
1st Generation Biofuels
Food
Timber
Ecosystem Services
Cellulosic Feedstocks
Food Crops
Forest Land (Tree Vintages)
Agricultural Land
Fertilizers
Protected Forests
Unmanaged Forests
Commercial Land
Land
Fossil Fuels

Outline of the Talk

- Background / Motivation / Objectives
- Model Features
- **Baseline Construction**
- Key Uncertainties
  - Climate Impacts
  - Climate Policies
  - Energy Prices
- Conclusions

Baseline Construction

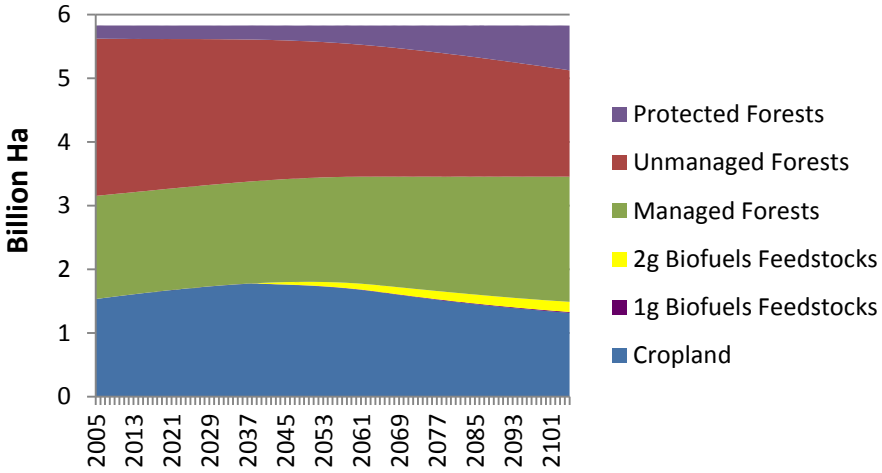
- Starting point: World in 2004
  - Calibrated based on GTAP 7 / GTM, FAOSTAT
  - Growth projections from IEA, IPCC, UN, USDA
- Food
  - total crop output
  - yields based on 3 main crops (maize, wheat, rice)
- Energy
  - petroleum
  - corn-based ethanol
  - cellulosic biomass-to-liquid diesel (Fischer-Tropsch)

Baseline Construction

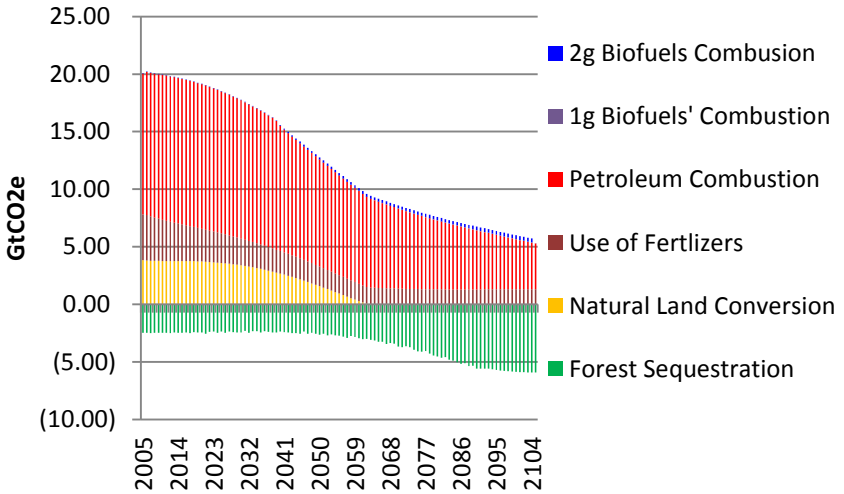
- Fertilizers
  - nitrogen based fertilizers (EPA Report)
  - sensitive to energy prices
- Timber
  - 100 vintage densities
  - yields based on GTM (Sohngen & Mendelsohn)
- Ecosystem services
  - gleaned from GTAP 7 database following MIT-EPPA
- Other Goods & Services
  - TFP projections from Jorgenson et al. 2010

Model Baseline

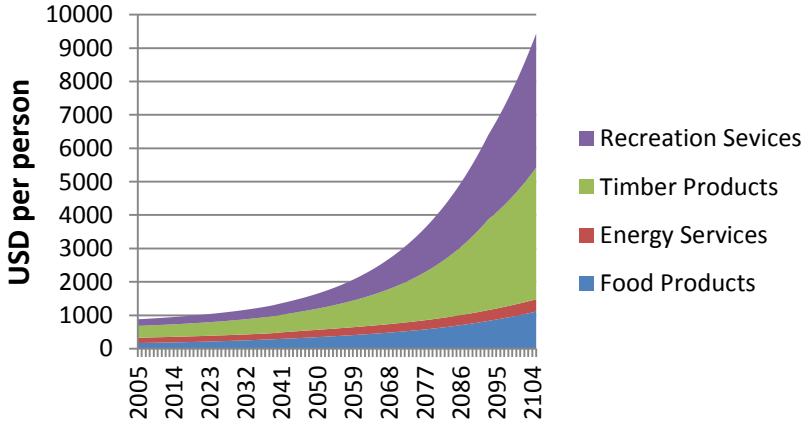
Allocation of Land



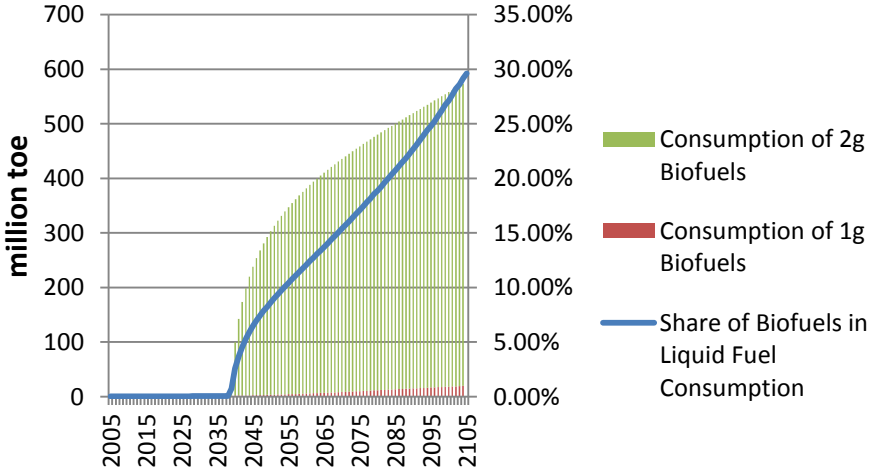
GHG Emissions



Consumption of Goods and Services



Consumption of Biofuels



Outline of the Talk

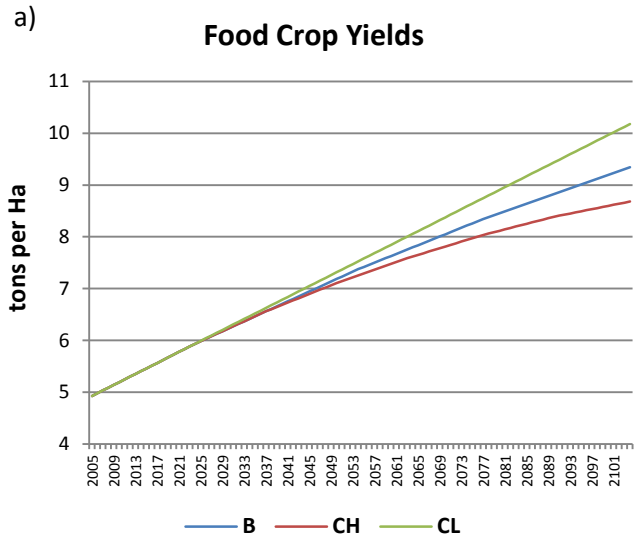
- Background / Motivation / Objectives
- Model Features
- Baseline Construction
- **Key Uncertainties**
  - Climate Impacts
  - Climate Policies
  - Energy Prices
- Conclusions

Key Sensitivities

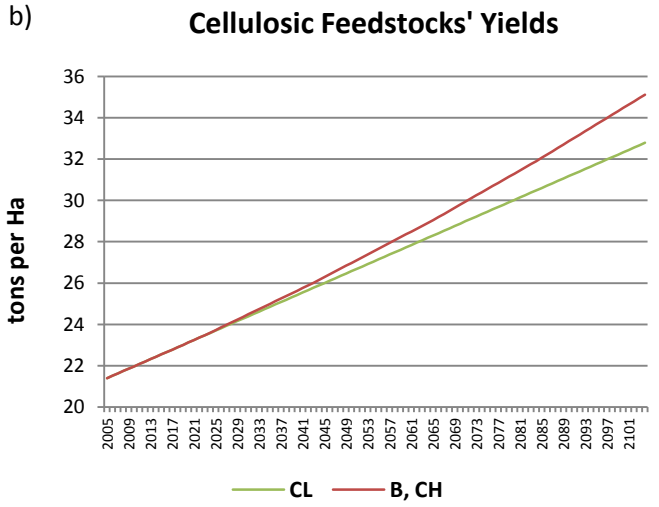
Yields (CL, CH):

- IPCC SRES B1 vs. A1FI
- Higher temperatures hurt staple crops (Lobell et al. 2011)
- Higher Temperatures benefit cellulosic feedstocks (Brown et al. 2000)
- CO_2 Fertilization Effect

a)



b)

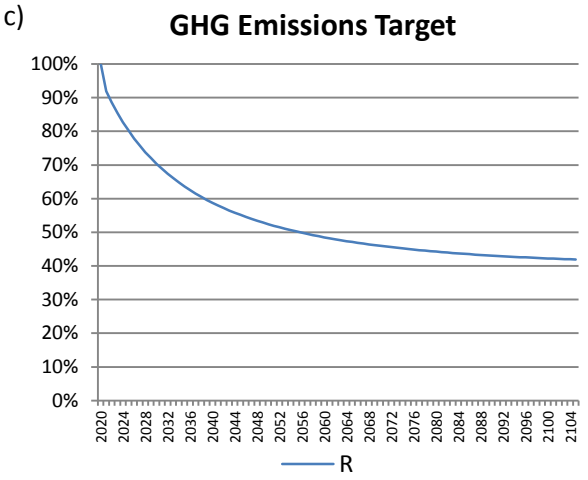


Key Sensitivities

GHG Emissions Target (R):

- IPCC 4AR CO_2 stabilization at 400 – 450ppm
- 60% reduction in *land-based* GHG by 2100

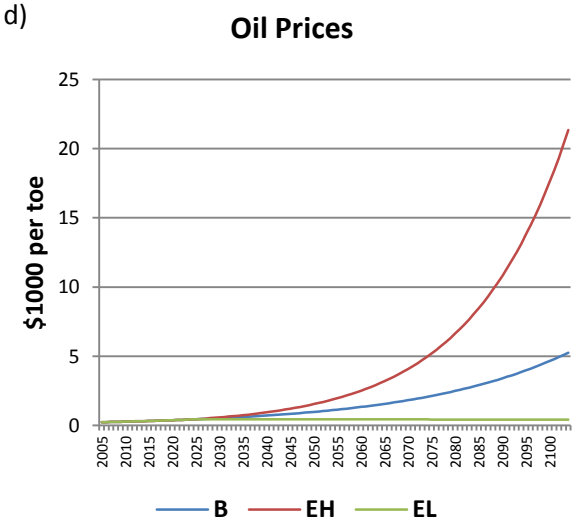
c)



Energy Prices (EL, EH)

- Extrapolate EIA (2010) medium-term projections.

d)

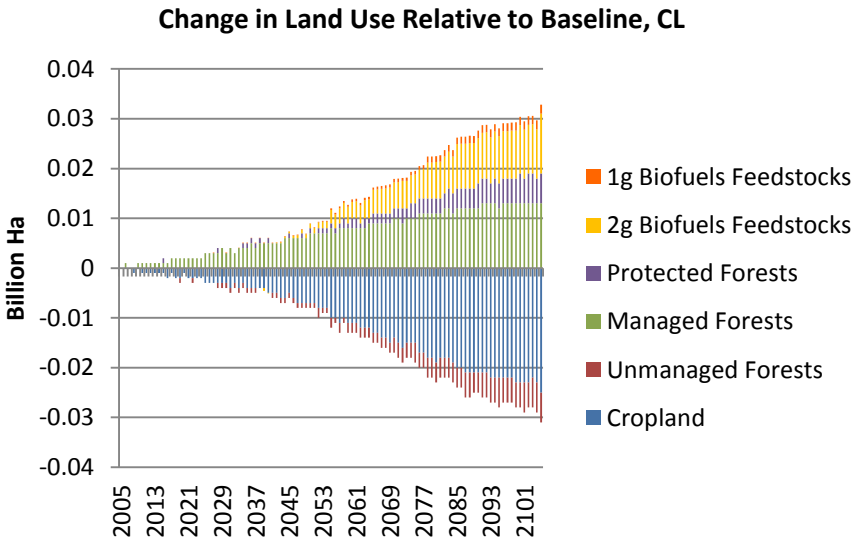


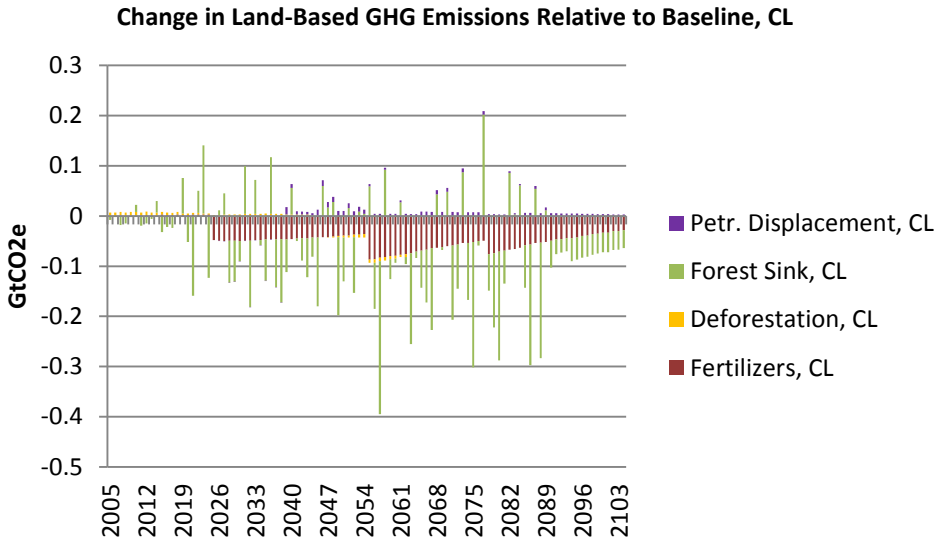
Outline of the Talk

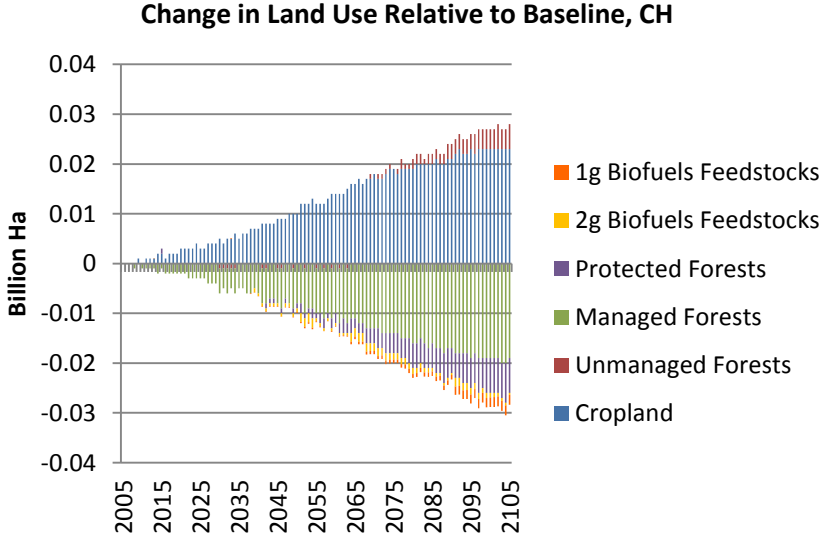
- Background / Motivation / Objectives
- Model Features
- Baseline Construction
- **Key Uncertainties**
  - **Climate Impacts**
  - Climate Policies
  - Energy Prices
- Conclusions

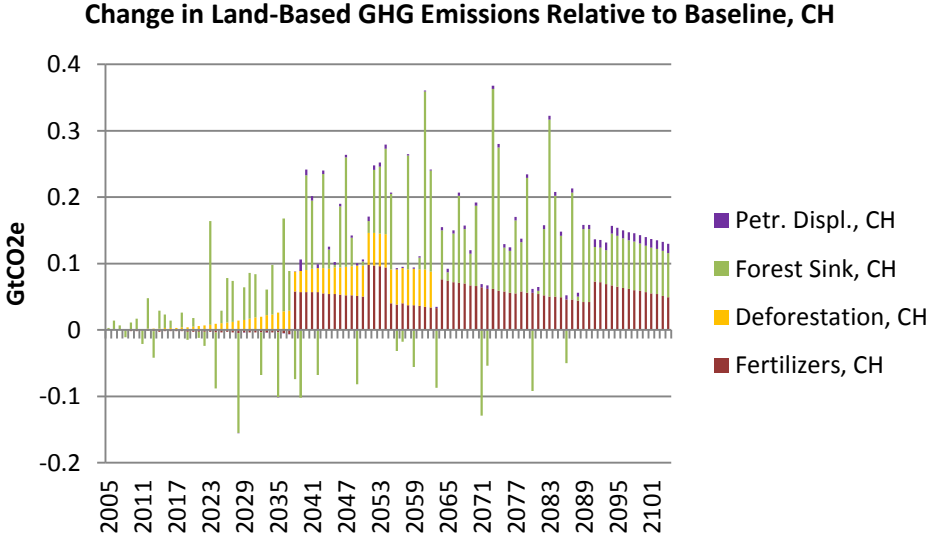
Uncertainty in Agricultural Yields:

CL = low impact, best case, CH = high impact, worst case)





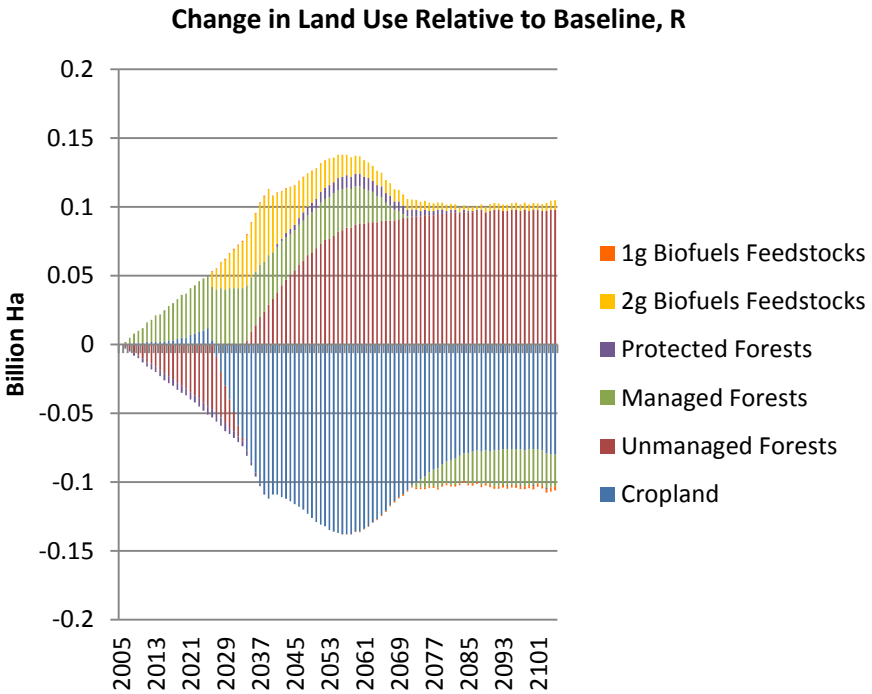


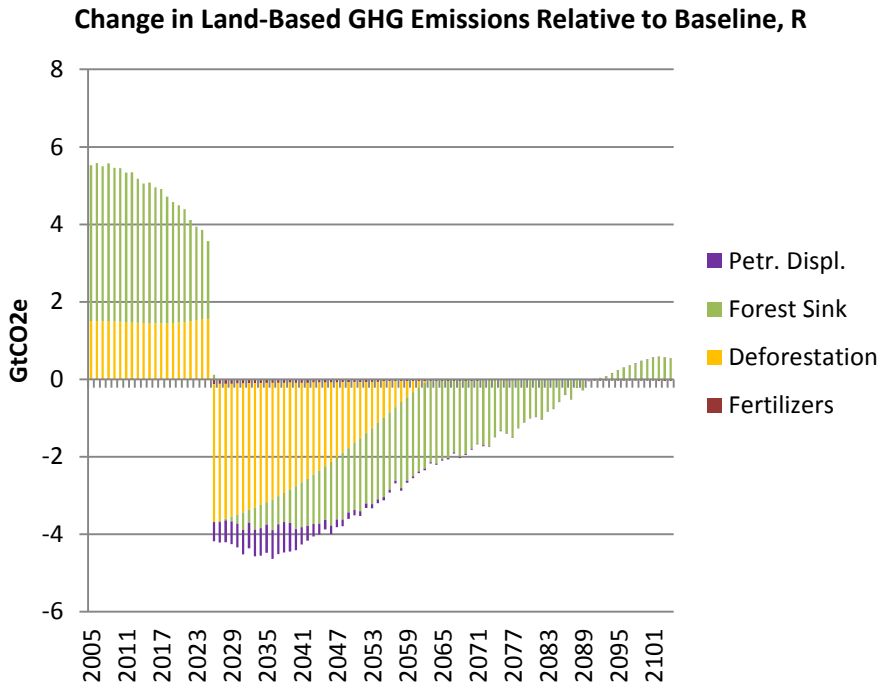


Outline of the Talk

- Background / Motivation / Objectives
- Model Features
- Baseline Construction
- **Key Uncertainties**
  - Climate Impacts
  - **Climate Policies**
  - Energy Prices
- Conclusions

Uncertainty in Climate Policies



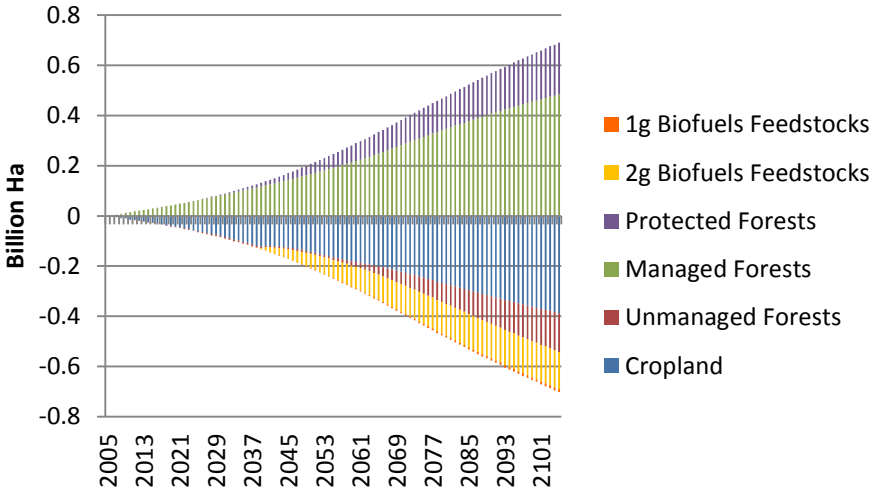


Outline of the Talk

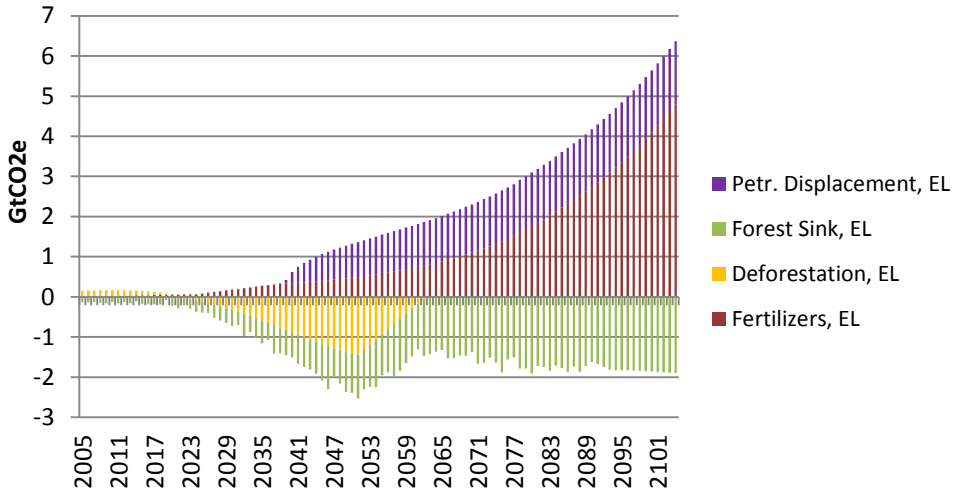
- Background / Motivation / Objectives
- Model Features
- Baseline Construction
- **Key Uncertainties**
  - Climate Impacts
  - Climate Policies
  - **Energy Prices**
- Conclusions

Uncertainty in Energy Prices:
EL= Low price path; EH = High price path

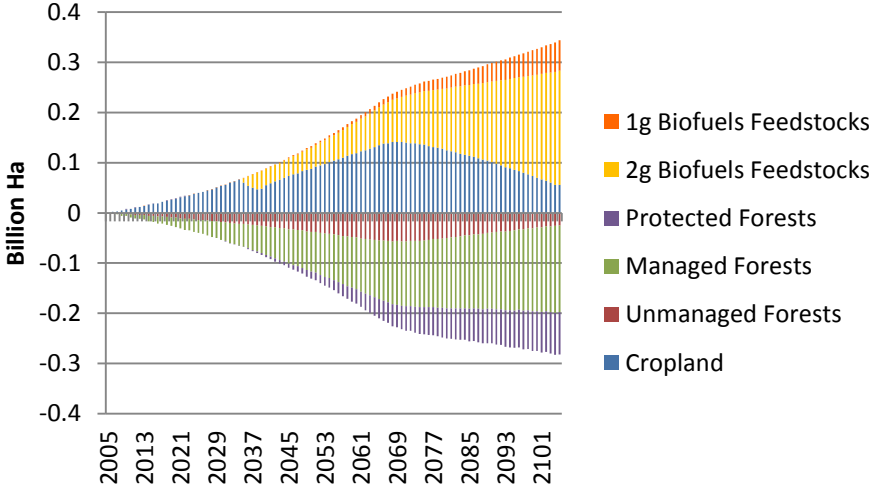
Change in Land Use Relative to Baseline, EL



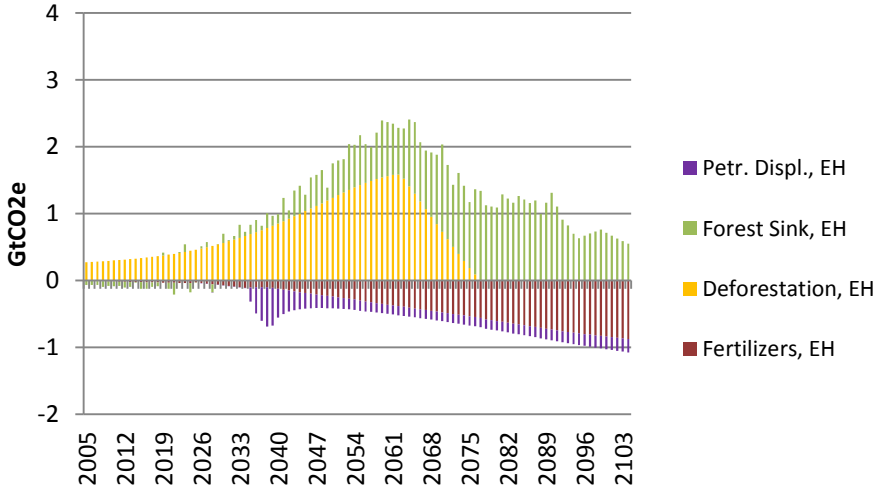
Change in Land-Based GHG Emissions Relative to Baseline, EL



Change in Land Use Relative to Baseline, EH



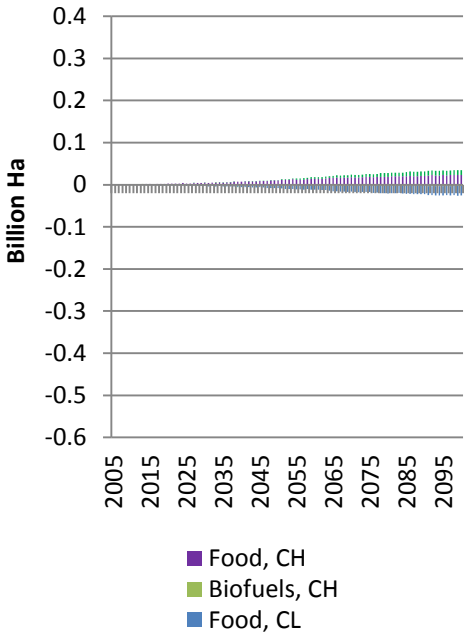
Change in Land-Based GHG Emissions Relative to Baseline, EH



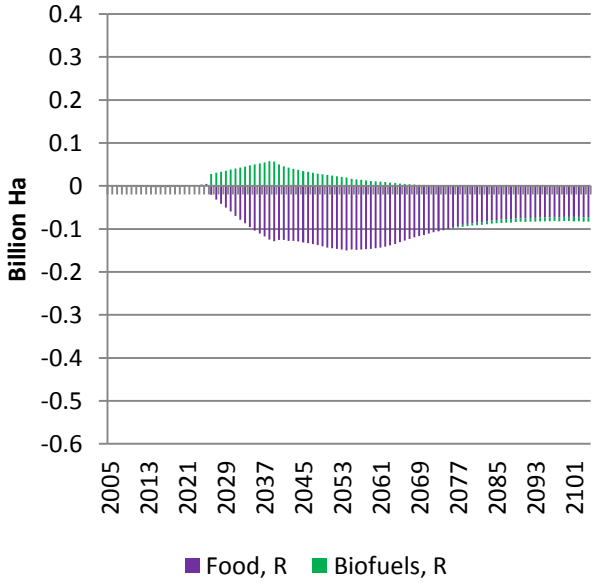
Outline of the Talk

- Background / Motivation / Objectives
- Model Features
- Baseline Construction
- Key Uncertainties
  - Climate Impacts
  - Climate Policies
  - Energy Prices
- **Conclusions**

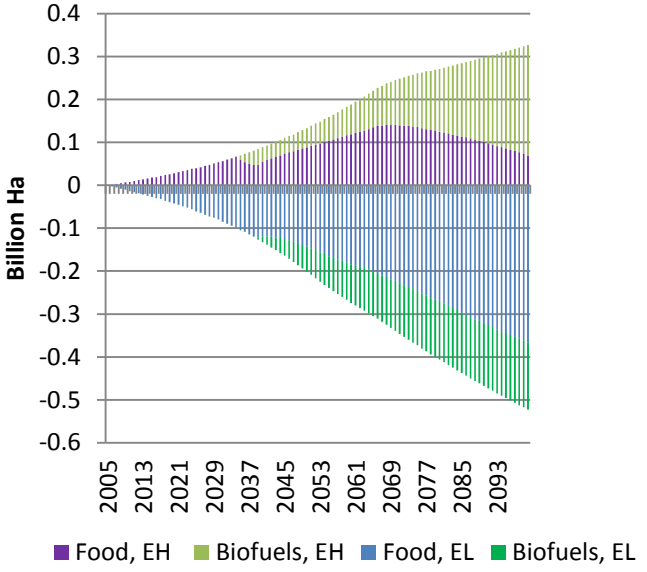
Putting Everything on the Same Scale: Change in Global Land Use Relative to Baseline



Uncertainty in Climate Impacts



Uncertainty in Climate Policies



Uncertainty in Energy Prices

Conclusions

- The linkages between energy, land, environment and GHGs are complex
- Energy prices and policies will be an increasingly important driver of agricultural land use
- What happens with oil prices may be more important than climate impacts for agriculture or land-based climate abatement policies