# Effects of Environmental and Energy Policies on Long Run Patterns of Land Use



**Alla Golub (golub@purdue.edu), Thomas Hertel (hertel@purdue.edu), Steven Rose (srose@epri.com)**

*Selected Paper prepared for presentation at the Agricultural and Applied Economics Association's 2012 Annual Meeting, Seattle, Washington, August 12-14, 2012*

## Motivation

- **International agricultural and forestry based greenhouse gas (GHG) mitigation**
  - **Reduce emissions abatement costs in developed countries**
  - **Provide revenue to developing countries in exchange for modifying land management for mitigation**
- **Biofuels boom driven by**
  - **Higher oil prices**
  - **Concerns about energy security**
  - **Farm income**
  - **Mitigation of climate change**
- **Changes in land-use induced by the land-based GHG mitigation policies run counter to the changes induced by biofuels**
  - **Carbon tax**
    - **Substantial GHG mitigation potential in non-US forests**
    - **Input substitution in agricultural production away from land and fertilizer**
  - **Biofuels**
    - **Deforestation and intensification in agriculture**

## Objective

- **Analyze land-use change at the global scale over the long run in the context of environmental and energy policies**

## Methodology

- **GDyn-E-AEZ: new dynamic computable general equilibrium model of global economy**
  - **Endogenous capital accumulation, adaptive expectations theory of investment, international capital mobility (Ianchovichina and McDougall, 2001)**
  - **Capital-energy and interfuel substitution (Burniaux and Troung, 2002)**
  - **Substitution between biofuels and gasoline in private consumption (Birur et al., 2008)**
  - **GHG mitigation in agriculture and forestry is calibrated to results of partial equilibrium studies (Golub et al., 2009)**
  - **Mitigation of emissions from fossil fuel combustion**
- **Integrated data base components**
  - **Foreign income receipts and payments (McDougall et al. 2012)**
  - **Biofuels and their by-products v.7 GTAP-BIO (Taheripour and Tyner, 2011)**
    - **Grain based ethanol, sugarcane ethanol, soybean biodiesel and other oilseeds biodiesel are included in this modeling**
  - **Heterogeneous land: 18 Agro-Ecological Zones (Lee et al., 2005)**
  - **Forest carbon stock data by species, vintage and AEZ (Sohngen *et al.*, 2009)**
  - **Non-$CO_2$ emissions data for all sectors of the economy (Rose and Lee, 2009)**
  - **Fossil fuel $CO_2$ emissions (Lee, 2007).**

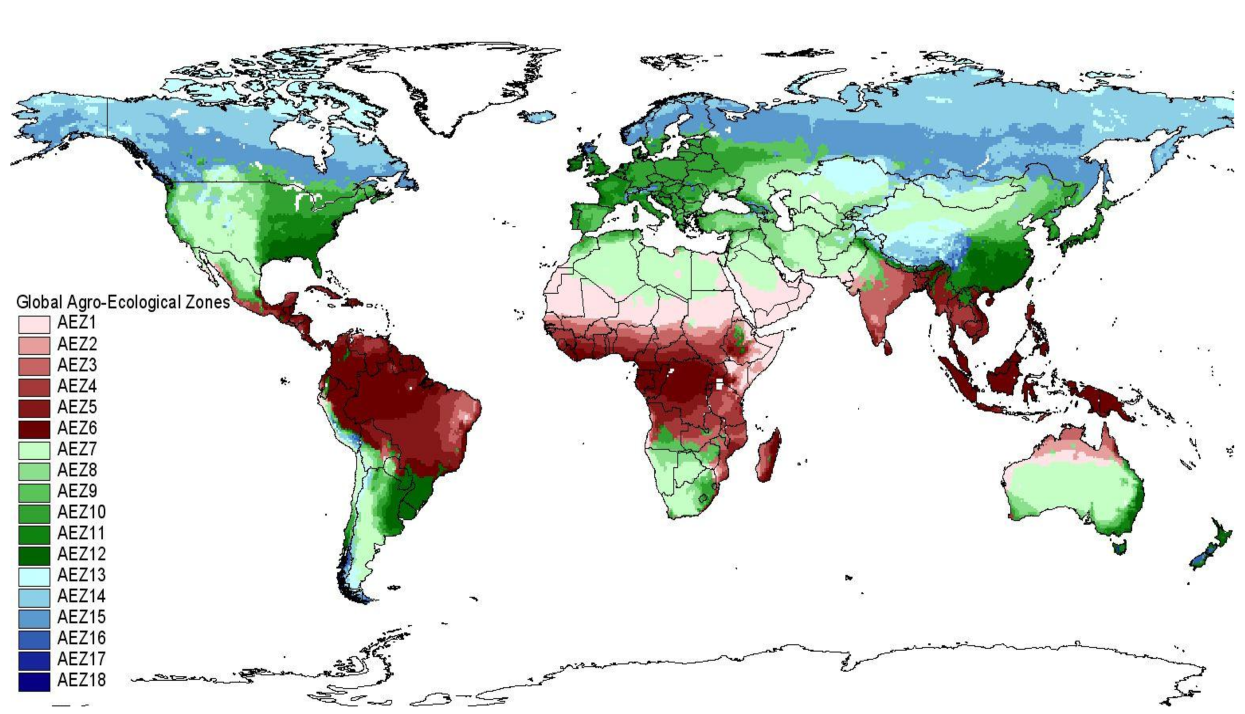


**Figure 1 Heterogeneous land: 6 growing periods x 3 climatic zones**

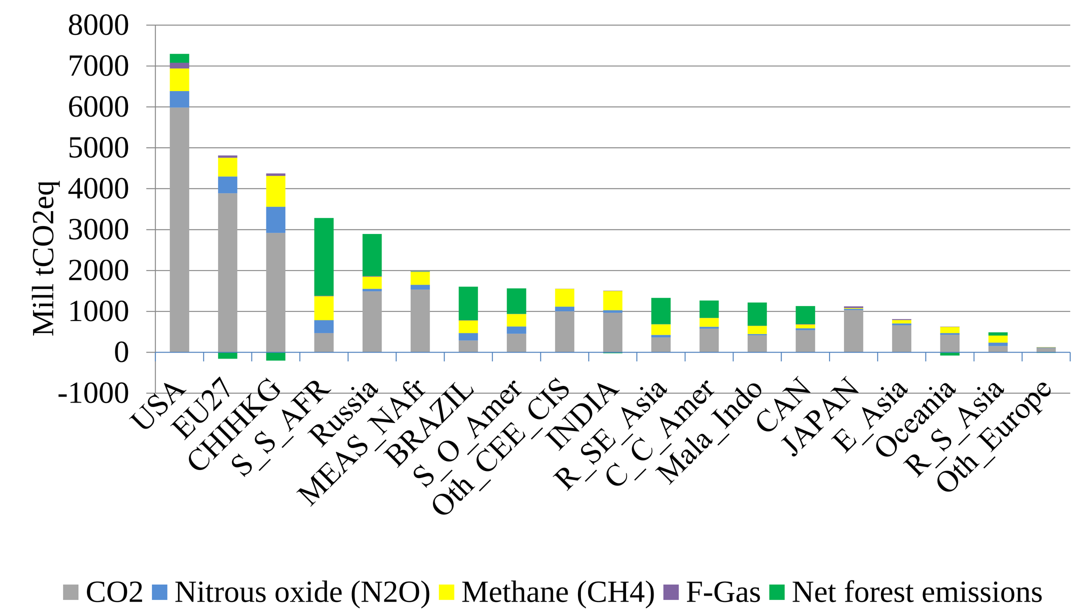


**Figure 2 Annual GHG emissions by region ( mill $tCO_2eq$)**
**Note: Net forest emissions include emissions from accessible and inaccesible forests**

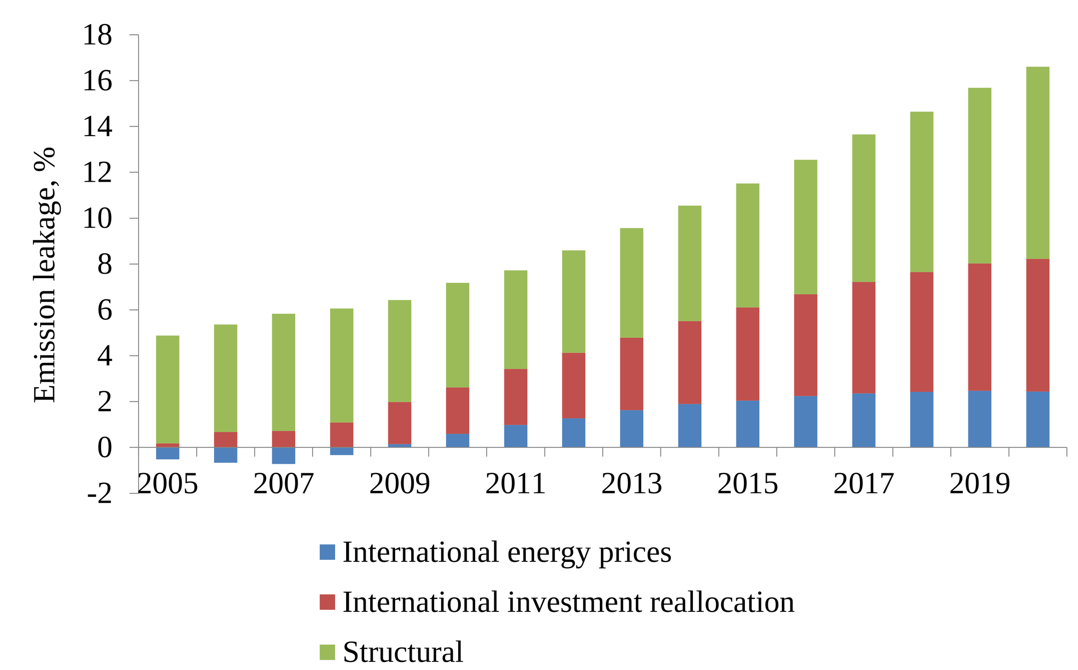


**Figure 3 Carbon leakage due to unilateral Annex I emission reduction decomposed into structural, energy prices and international investment reallocation components**

- **Scenario: Annex I $CO_2$ emissions from fossil fuel combustion reduction according to Copenhagen commitments**

## Baseline

- **Starting point is world economy in 2004**
  - **19 regions x 36 sectors**
- **Exogenous population and labor growth (GDyn baseline, Chappuis and Walmsley, 2011)**
- **GDP growth**
  - **Exogenous 2004-2011 historical rates**
  - **Endogenous 2012-2030, driven by assumption about non-accumulable factor productivity growth rate in industrial sectors**
- **TFP growth in agriculture (Fischer et al., 2009) from 0.86%/year in Sub Saharan Africa to 2.62%/year in Asia**
- **Forest input saving technical change to target timber price projection (Sohngen and Mendelsohn, 2003)**
- **Crude oil price projections (EIA AEO 2012)**

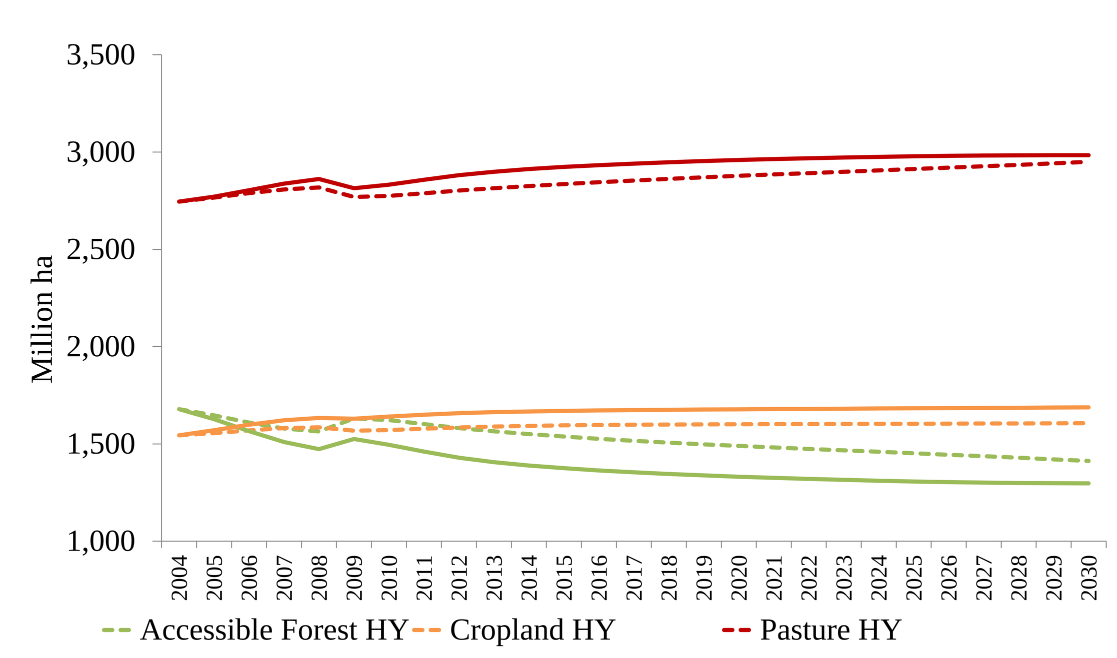


**Figure 4 2004-2030 baseline land cover , mill ha (HY = higher crop yield, LY = lower crop yield)**

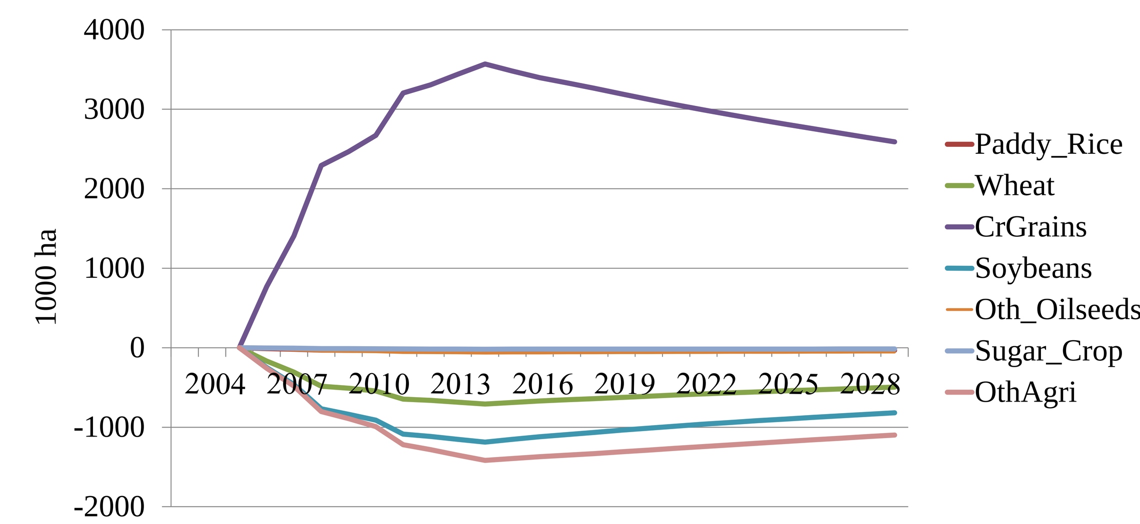


**Figure 5 Changes in US harvested area due to expanded production of US corn ethanol, 1000 ha deviation from baseline**

- **Scenario: US ethanol production achieves 15 billion gallons per year in 2015 and stays at this level**

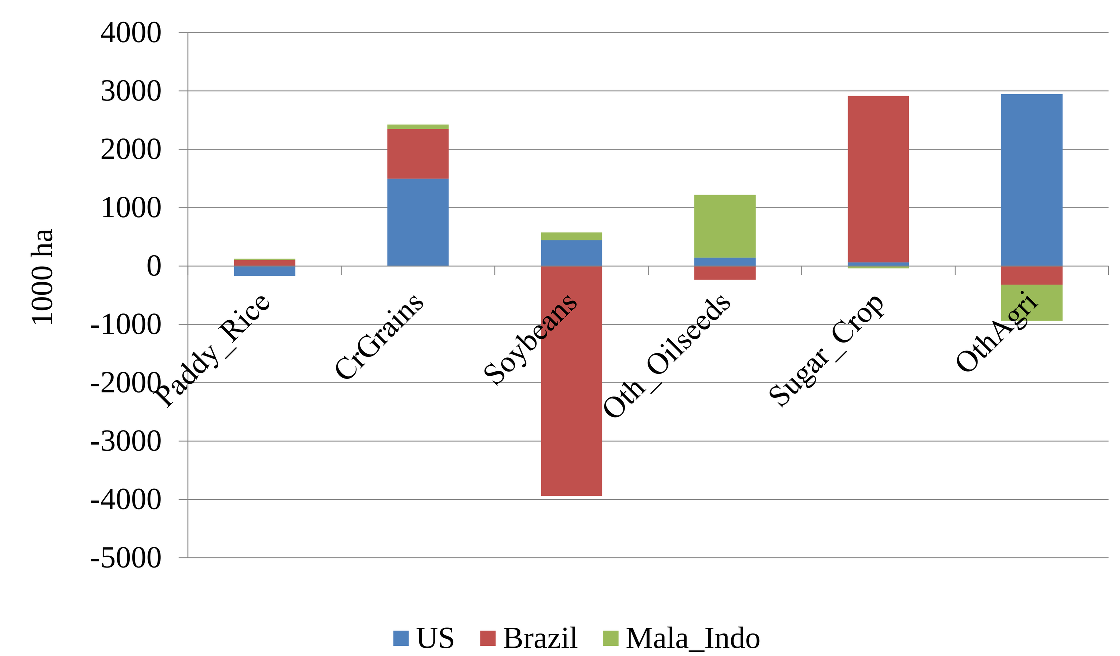


**Figure 6 2011-2030 changes in crop harvested area due to imposition of carbon tax on emissions from fossil fuel combustion, 1000 ha deviation from baseline**

- **Global 30$/$tCO_2$ tax on fossil fuels encourage expansion of biofuels production and feedstock harvested area**

## Environmental and energy policy interaction

- **Static analysis**
- **Set up scenario 1 (S1): impose global carbon tax**
  - **Tax on $CO_2$ and non-$CO_2$ emissions**
  - **Forest carbon sequestration subsidy**
- **Set up scenario 2 (S2) : increase in US ethanol production from 2001 level up to 15 bg/y**
- **Interaction scenario (I): impose global carbon tax on top of 15 bg/y**
  - **Flexible ethanol production level**
- **Compare abatement potential in S1 and I**

| Non agriculture | Forests | Agriculture | Private Consumption | Global |
|---|---|---|---|---|
| 5663 | 4634 | 1214 | 462 | 11973 |

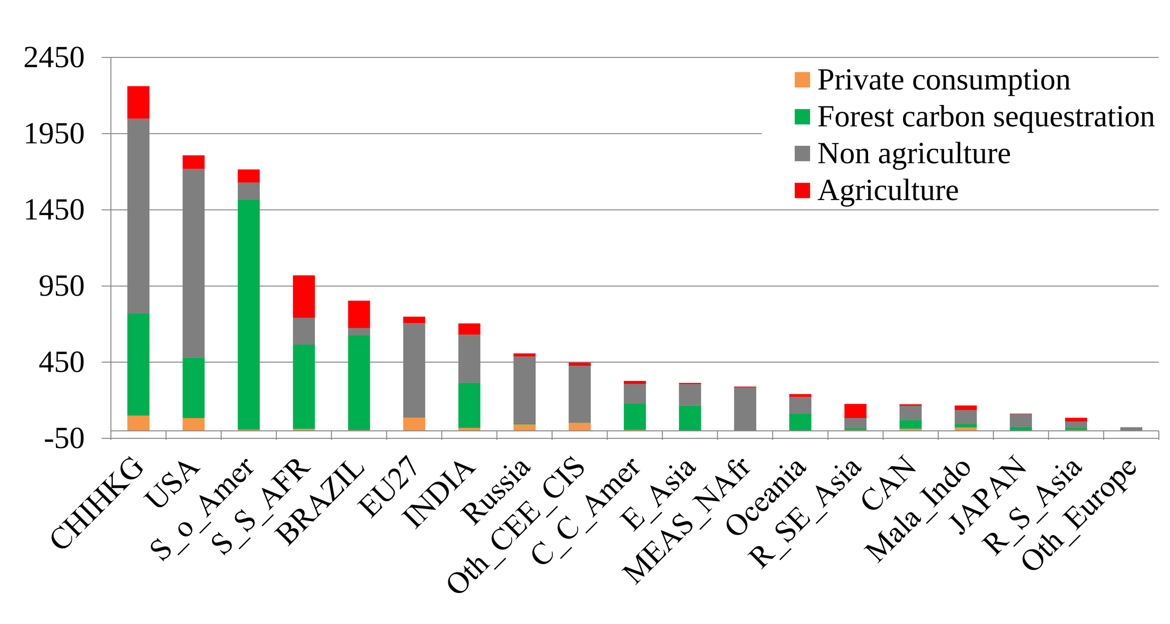


**Figure 7 S1: GHG GE annual abatement with $30/$tCO_2eq$ global tax/seq. subsidy (mill $tCO_2eq$)**

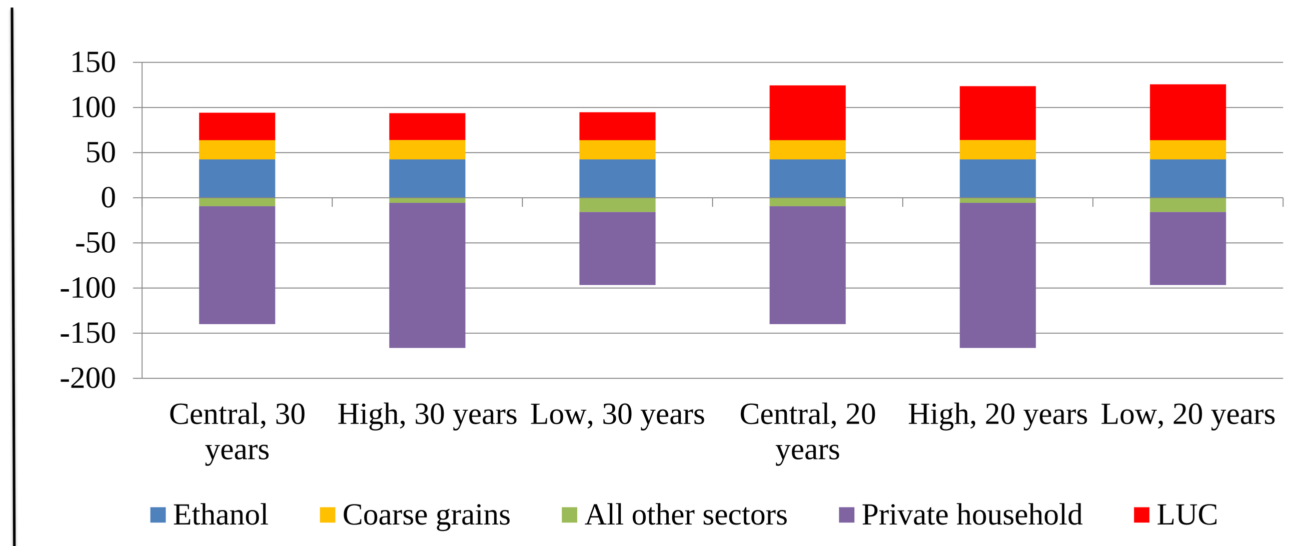


**Figure 8 S2: Change in global GHGs from increase in US ethanol production to 15 bg/y**

- **"One time" LUC 900 $MtCO_2eq$ are amortized over 30 and 20 years**
- **Central ±50% for the elasticity of substitution in hh liquid fuel mix**

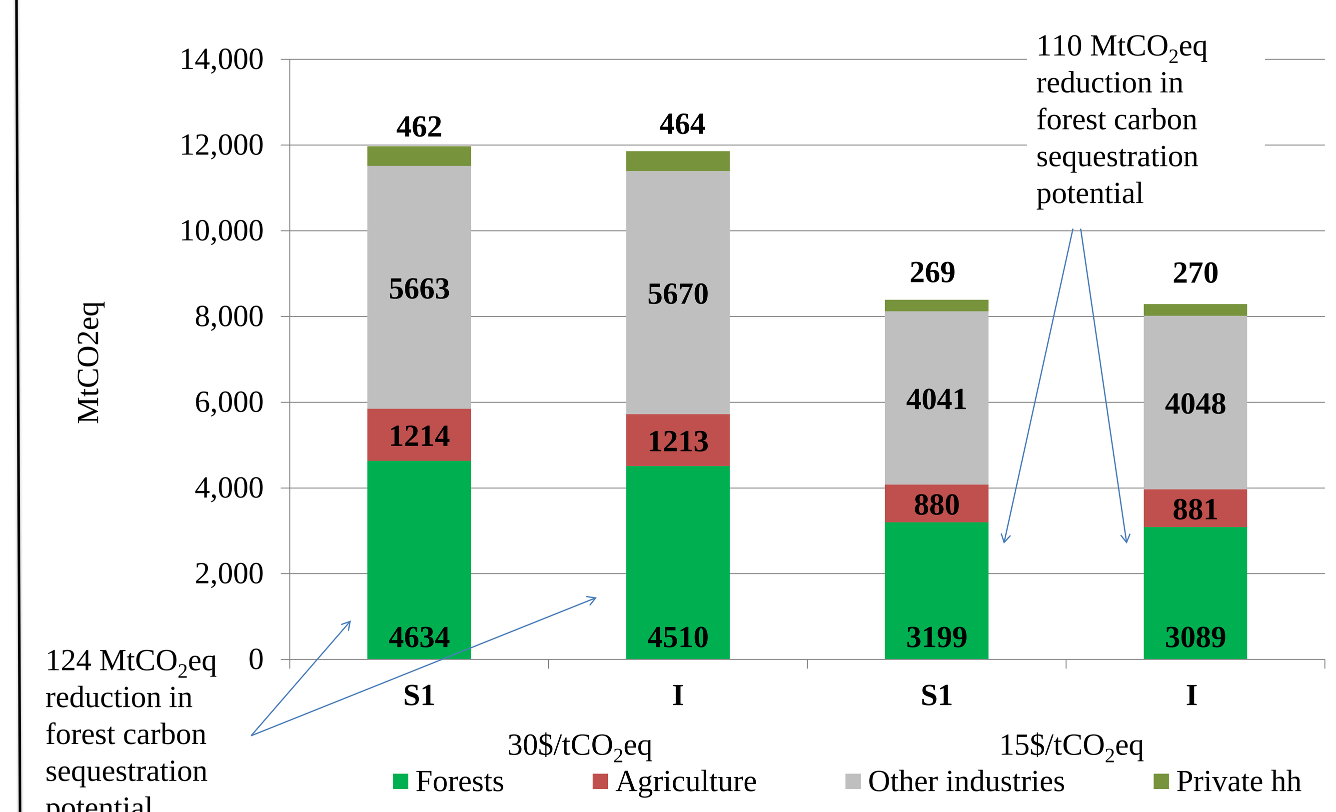


**Figure 9 S1 and I: Comparison of GHG GE global annual abatement without and with 15 bg/y of US ethanol, mill $tCO_2eq$**

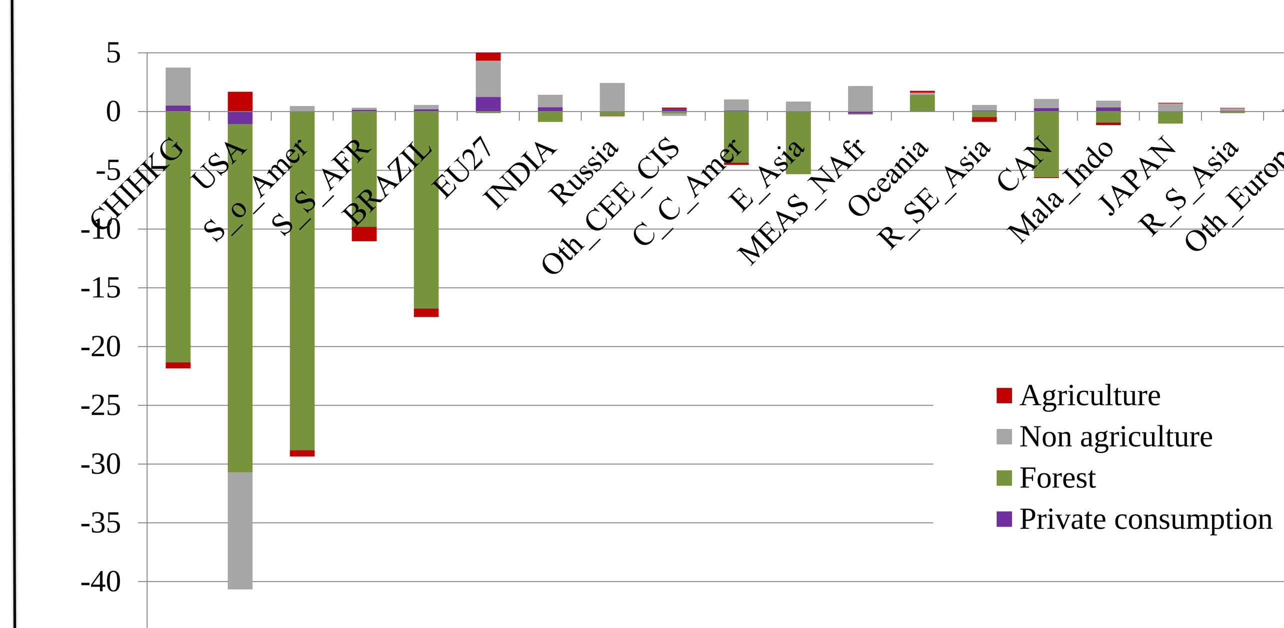


**Figure 10 S1 and I: Decomposition of differences in GHG abatement between interaction scenario (I) and set up scenario (S1), mill $tCO_2eq$**

## Conclusions

- **The new dynamic modeling framework integrates land based and fossil fuel based GHG mitigation and allows analysis of environmental and energy policies impacts on patterns of land use**
- **GDyn disequilibrium mechanism for determining the regional supply of investments is critical for analysis of carbon leakage due to unilateral GHG mitigation policy**
- **Future crop yields improvements affect patterns of land use and policy impacts**
- **When biofuels are not penalized for emissions from LUC, global carbon tax encourages their and agricultural land expansion**
- **Assumption about how easy biofuels can substitute for gasoline in liquid fuel mix affects biofuels quantities produced and changes in emissions from gasoline**
- **Static analysis shows 15 bg/y US ethanol mandate reduces global forest carbon sequestration potential by about 100 $MtCO_2eq$ (1% of global 12 $GtCO_2eq$ abatement at 30$/$tCO_2eq$)**
- **Next step is dynamic analysis of energy and environmental policies interactions**