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

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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).

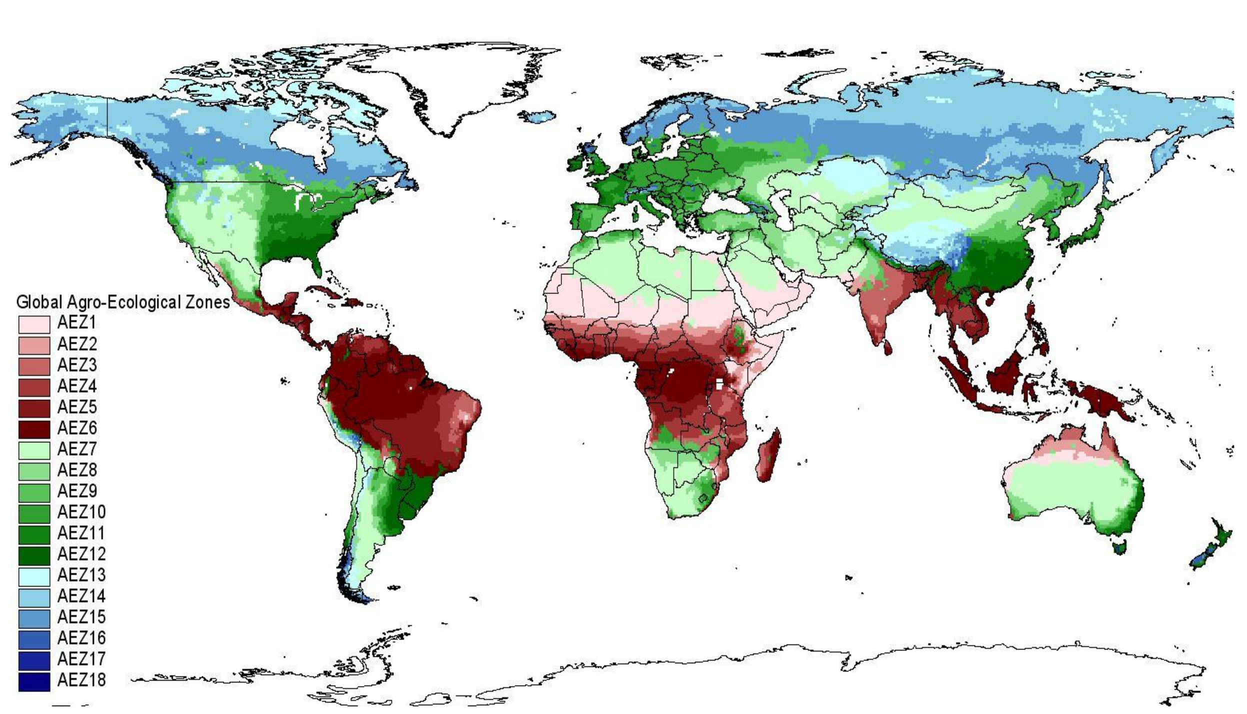

Figure 1 Heterogeneous land: 6 growing periods x 3 climatic zones

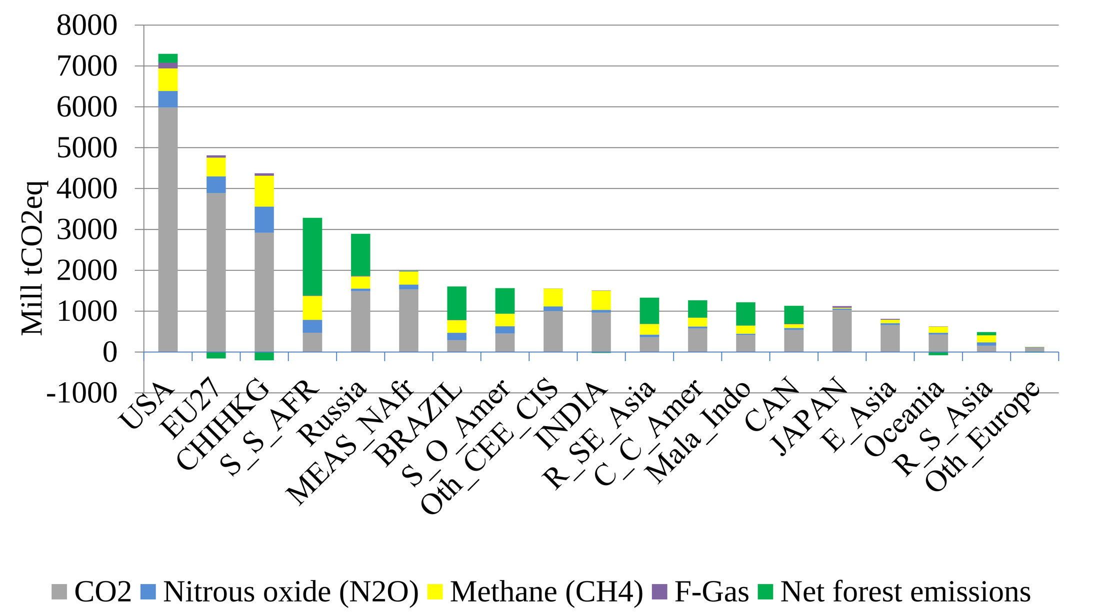

Figure 2 Annual GHG emissions by region (mill tCO_2eq)
Note: Net forest emissions include emissions from accessible and inaccesible forests

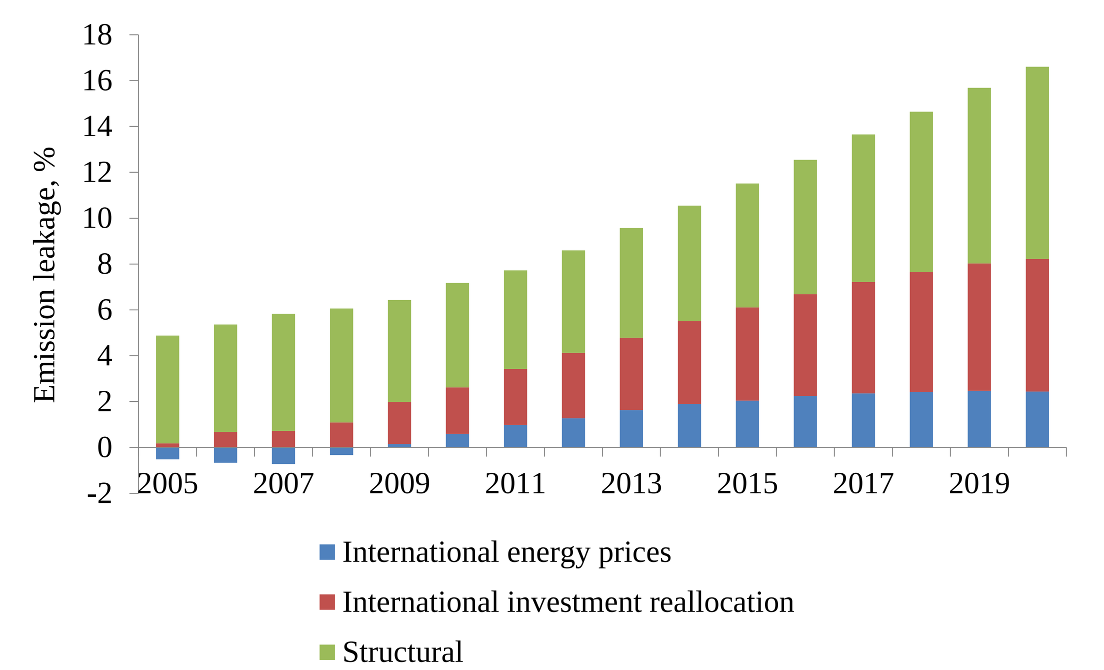

Figure 3 Carbon leakage due to unilateral Annex I emission reduction decomposed into structural, energy prices and international investment reallocation components

- 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)

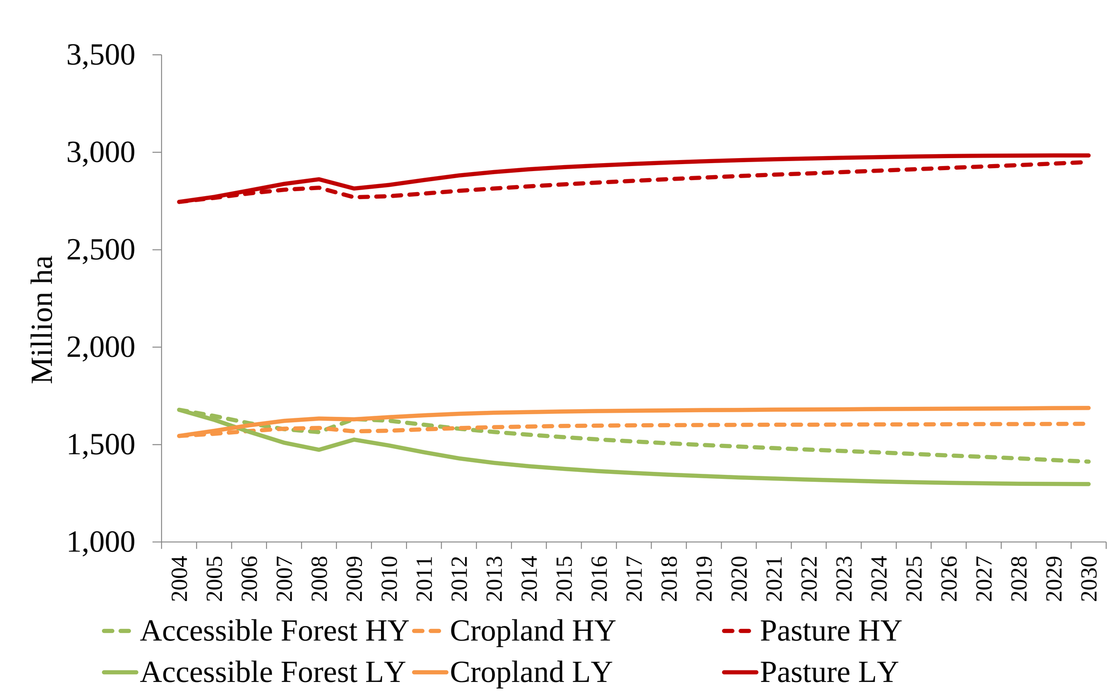

Figure 4 2004-2030 baseline land cover , mill ha
(HY = higher crop yield, LY = lower crop yield)

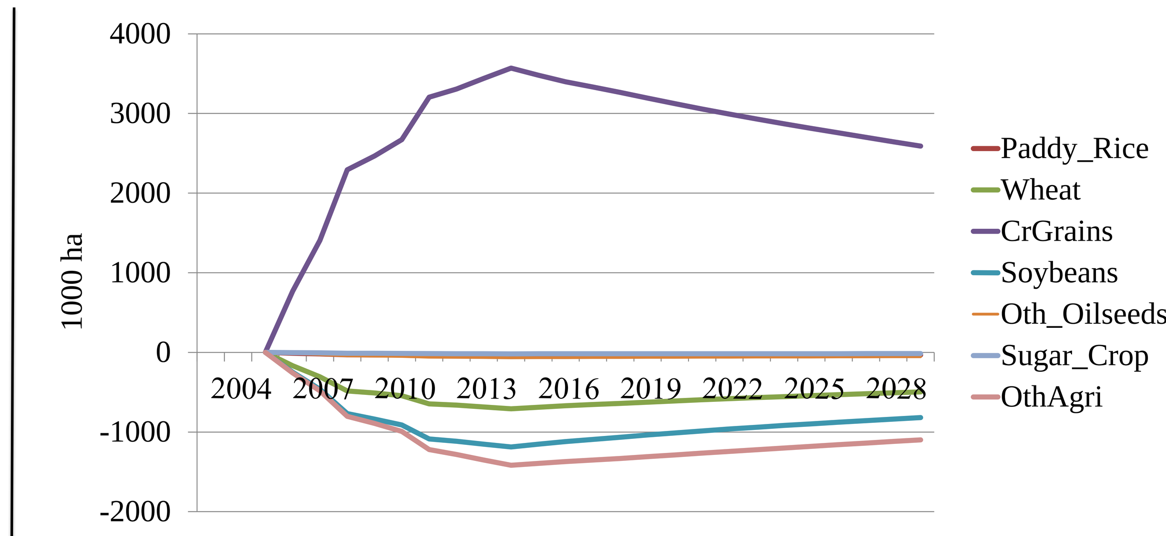

Figure 5 Changes in US harvested area due to expanded production of US corn ethanol, 1000 ha deviation from baseline

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

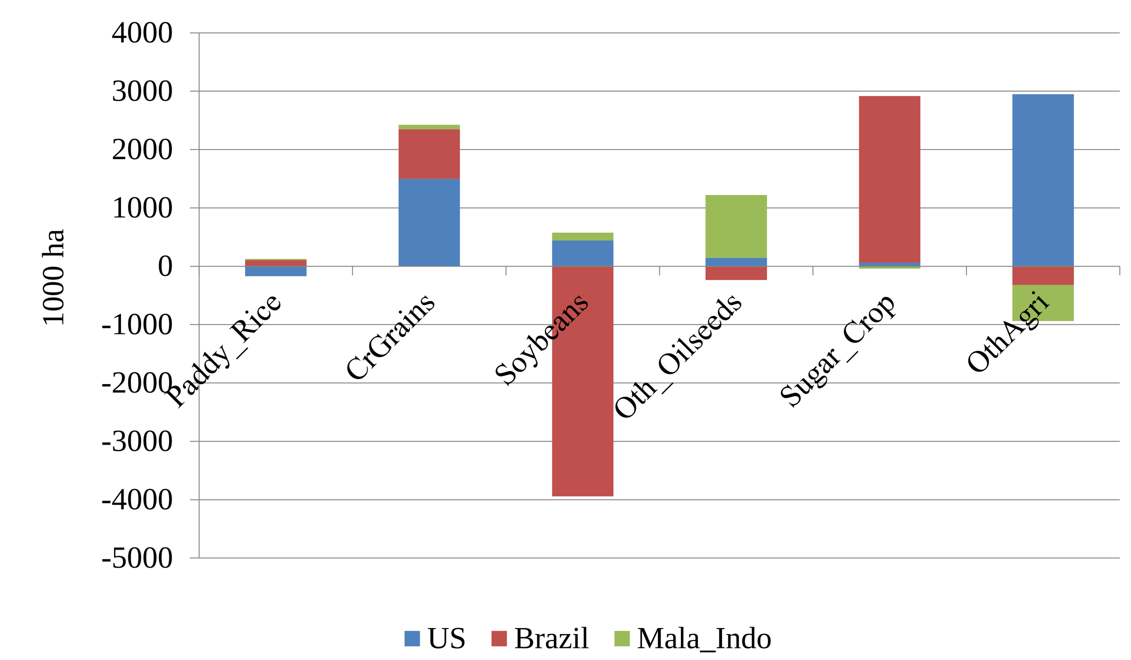

Figure 6 2011-2030 changes in crop harvested area due to imposition of carbon tax on emissions from fossil fuel combustion, 1000 ha deviation from baseline

- 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

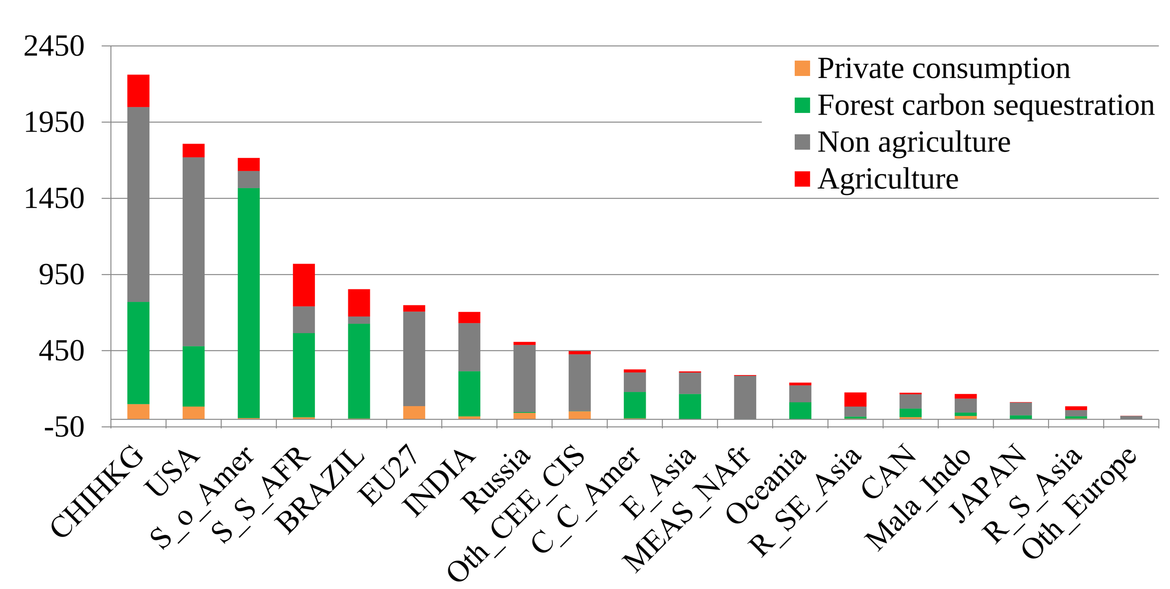

Figure 7 S1: GHG GE annual abatement with $30/$tCO_2eq$ global tax/seq. subsidy (mill tCO_2eq)

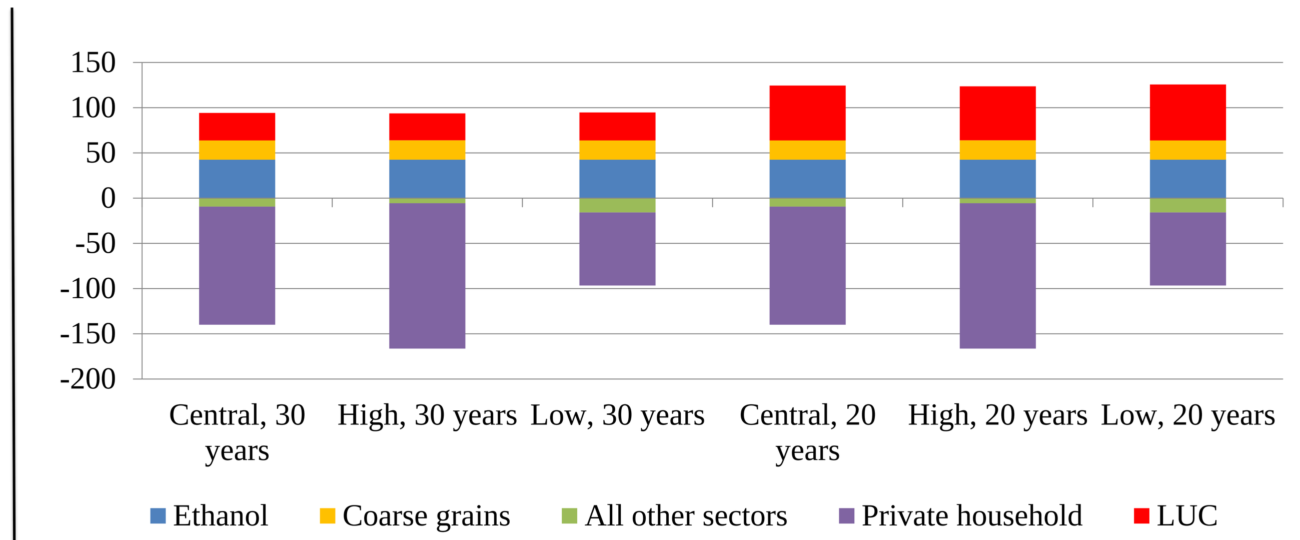

Figure 8 S2: Change in global GHGs from increase in US ethanol production to 15 bg/y

- "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

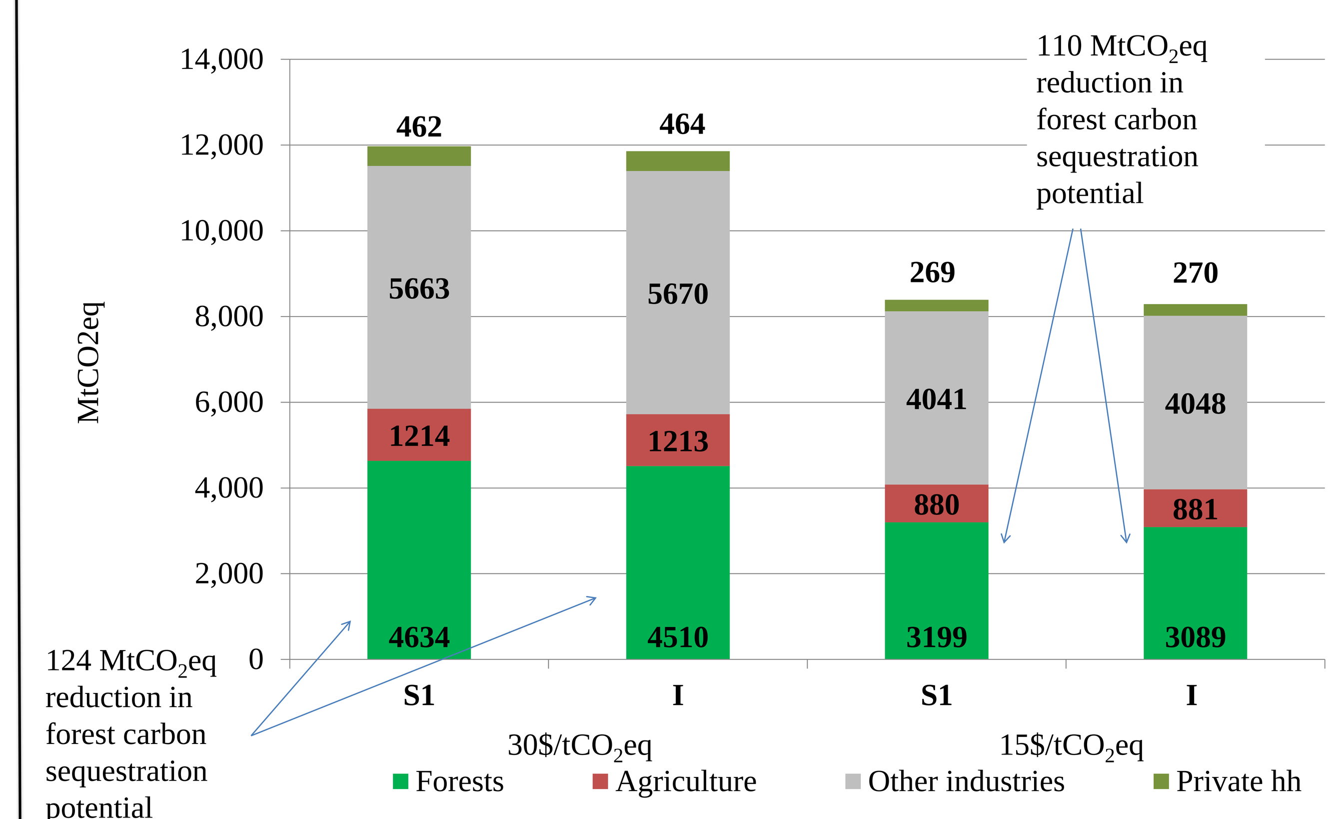

Figure 9 S1 and I: Comparison of GHG GE global annual abatement without and with 15 bg/y of US ethanol, mill tCO_2eq

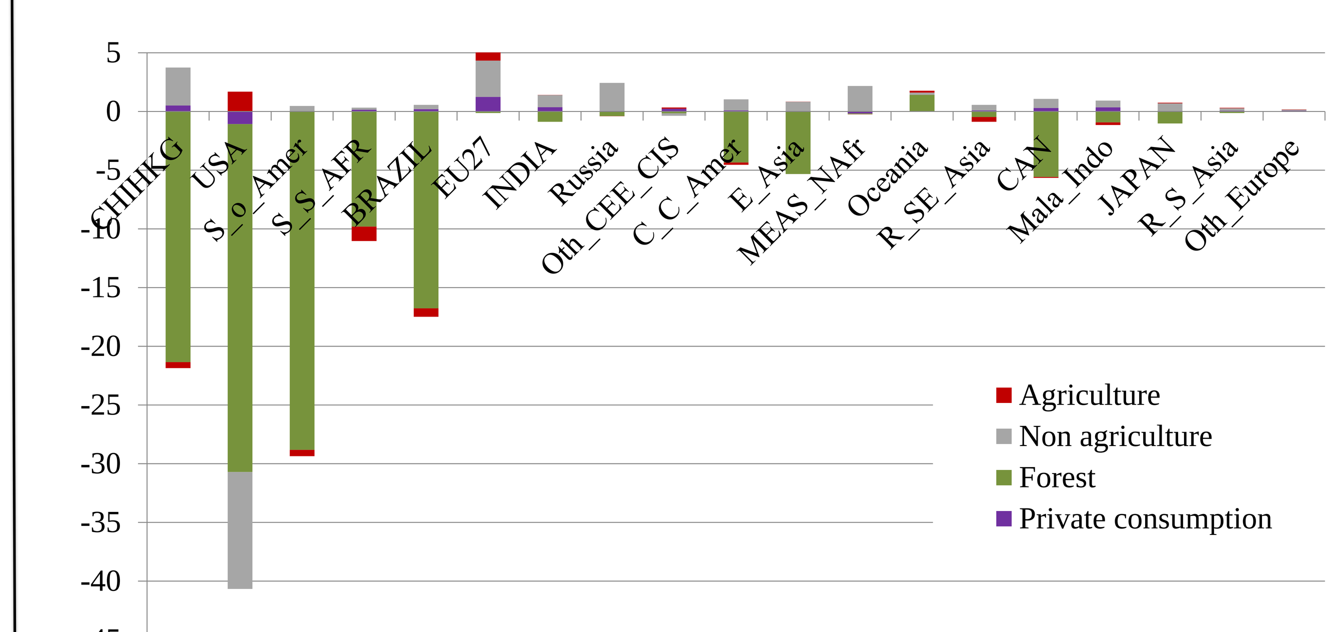

Figure 10 S1 and I: Decomposition of differences in GHG abatement between interaction scenario (I) and set up scenario (S1), mill tCO_2eq

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