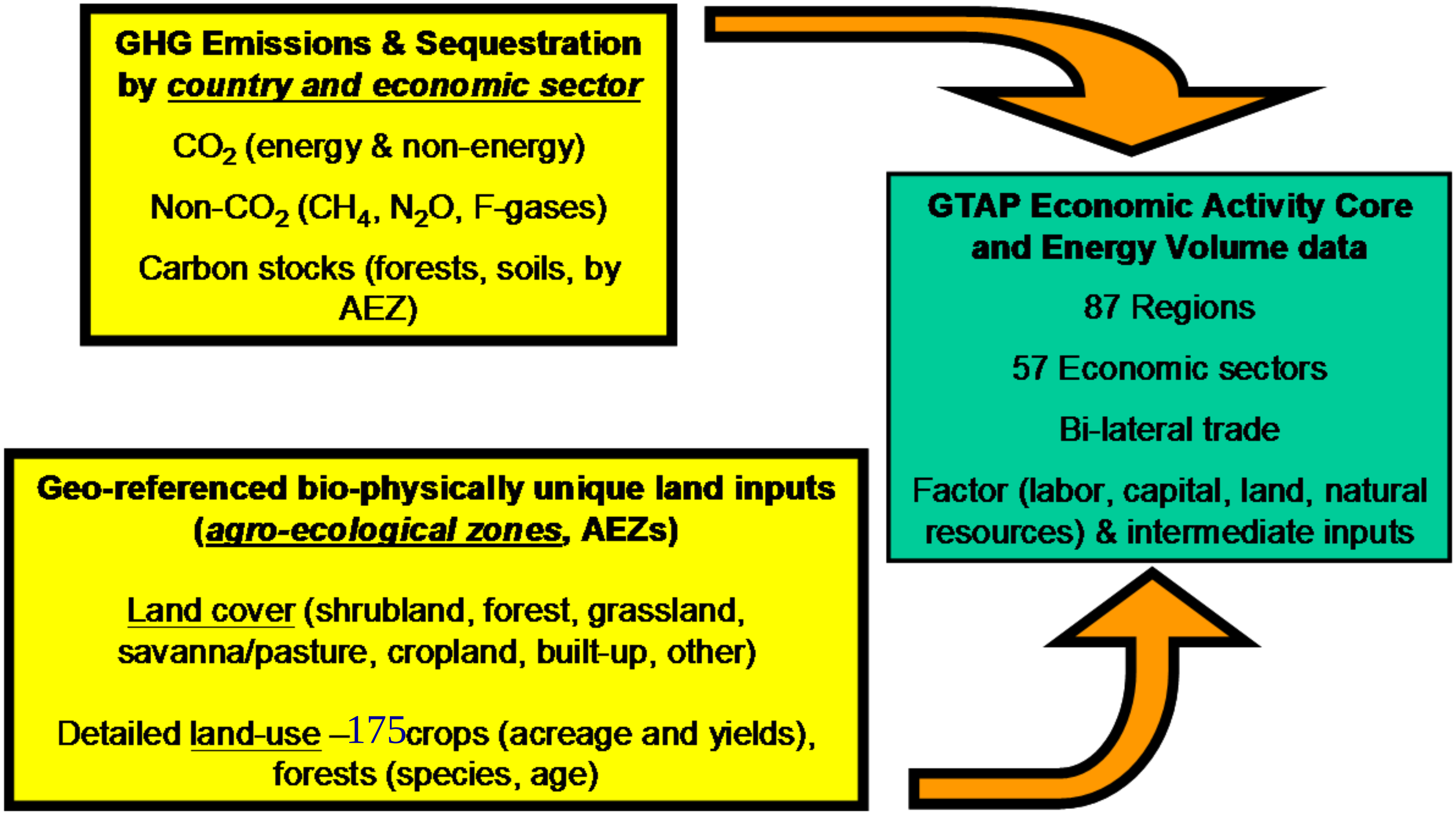
Greenhouse Gas Emissions in GTAP: Data, Applications and Insights

Alla Golub, Thomas Hertel and Misak Avetisyan, Purdue University

and Steven Rose, Electric Power Research Institute

Presentation to the 2009 GTAP Advisory Board, Santiago Chile

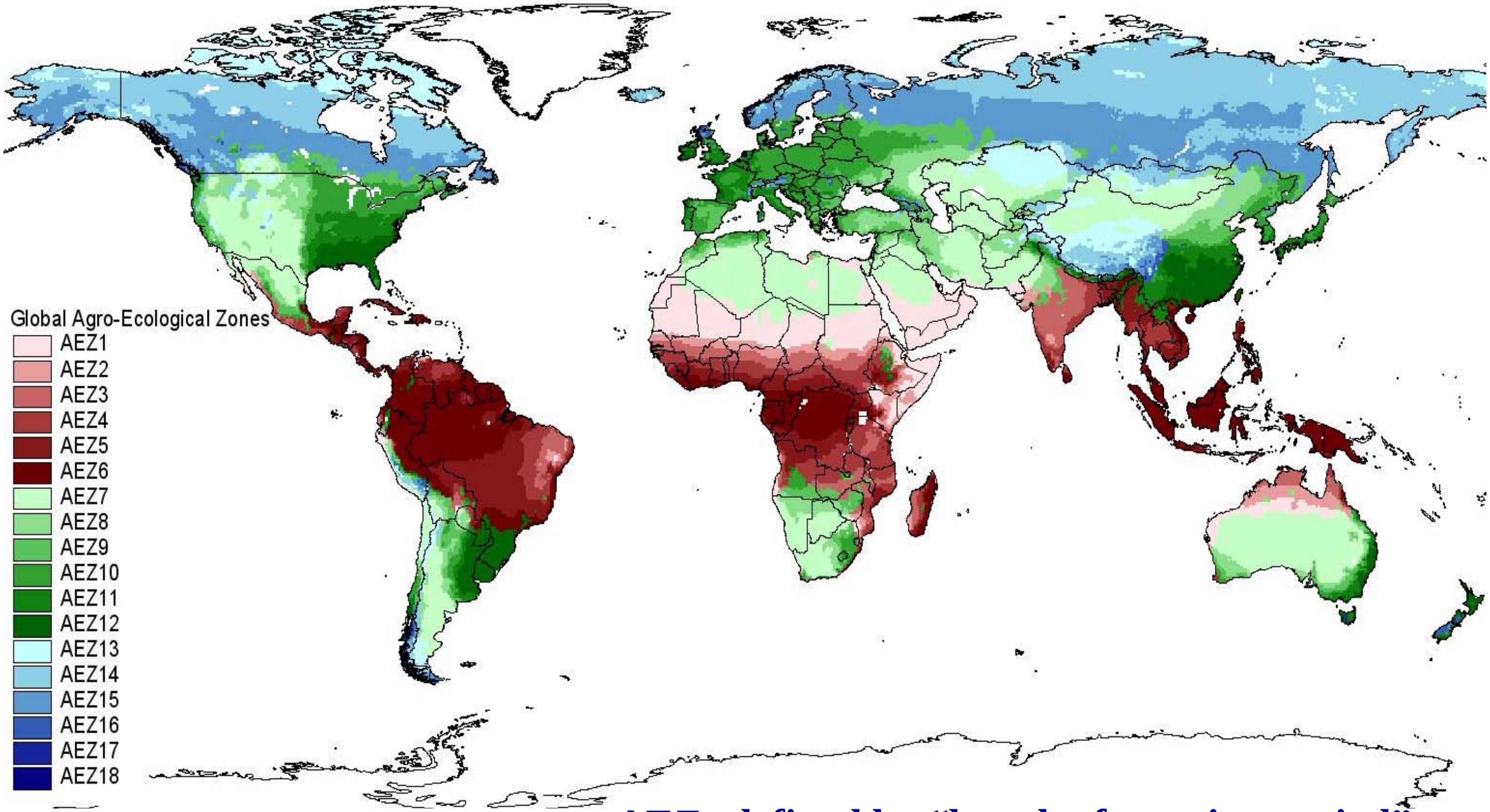
- **GHG emissions framework permits a new set of policy questions to be addressed:**
  - **Assessing the carbon footprint of global food trade**
  - **Implications of biofuels expansion for GHG emissions**
  - **Impacts of climate/carbon policies for land use and trade**
  - **Interactions between biofuels and climate policies**



Data base infrastructure

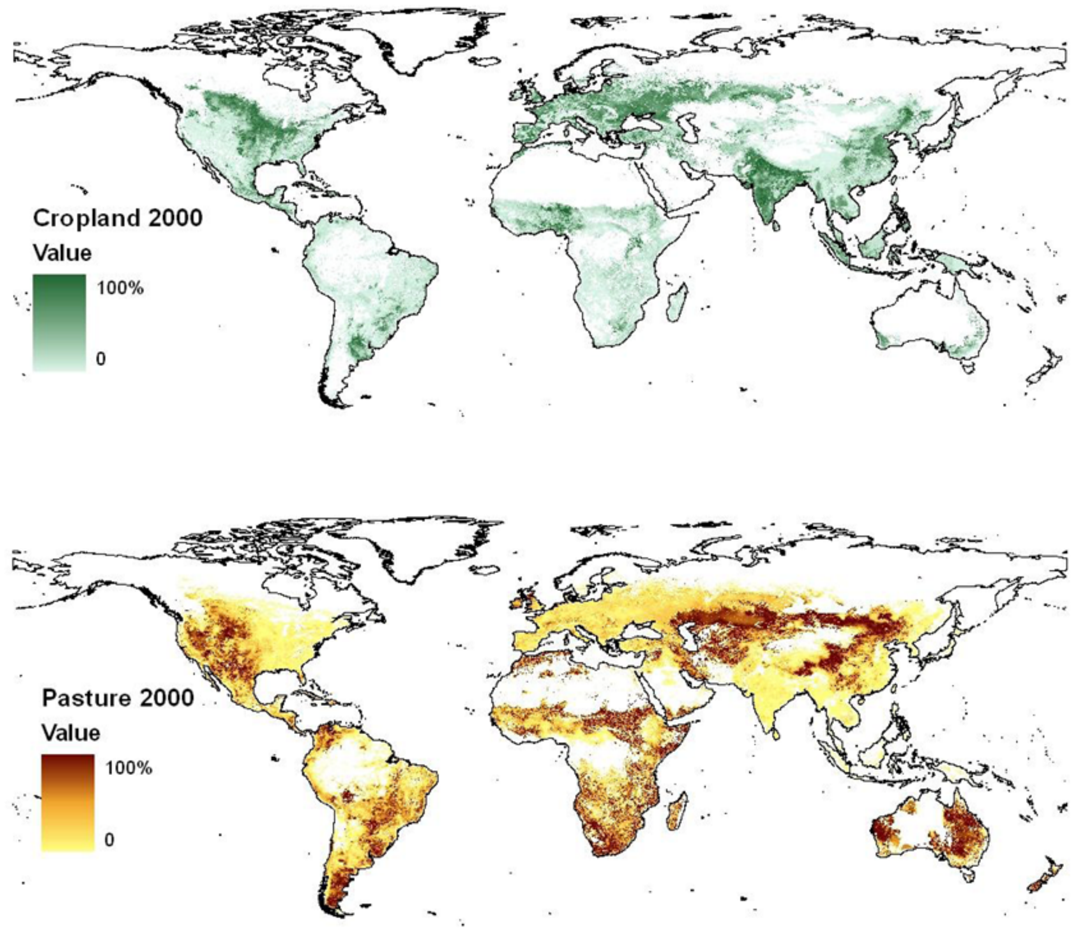
- Spatial data on land use:
  - Crop harvest area and yields: Monfreda/Ramankutty et al.
  - Land cover data base: Ramankutty et al.
  - Forestry data by AEZ: Sohngen et al.
- Carbon stock data:
  - GHG emissions factors assoc with land cover change – currently working with Woods Hole data
  - Forest carbon stocks from Sohngen et al.
- CO2 emissions from fossil fuels:
  - Derived from IEA/GTAP combustion data (volumes)
  - Take account of non-combusted feedstocks
- Non-CO2 emissions by activity and driver

Global Distribution of AEZs



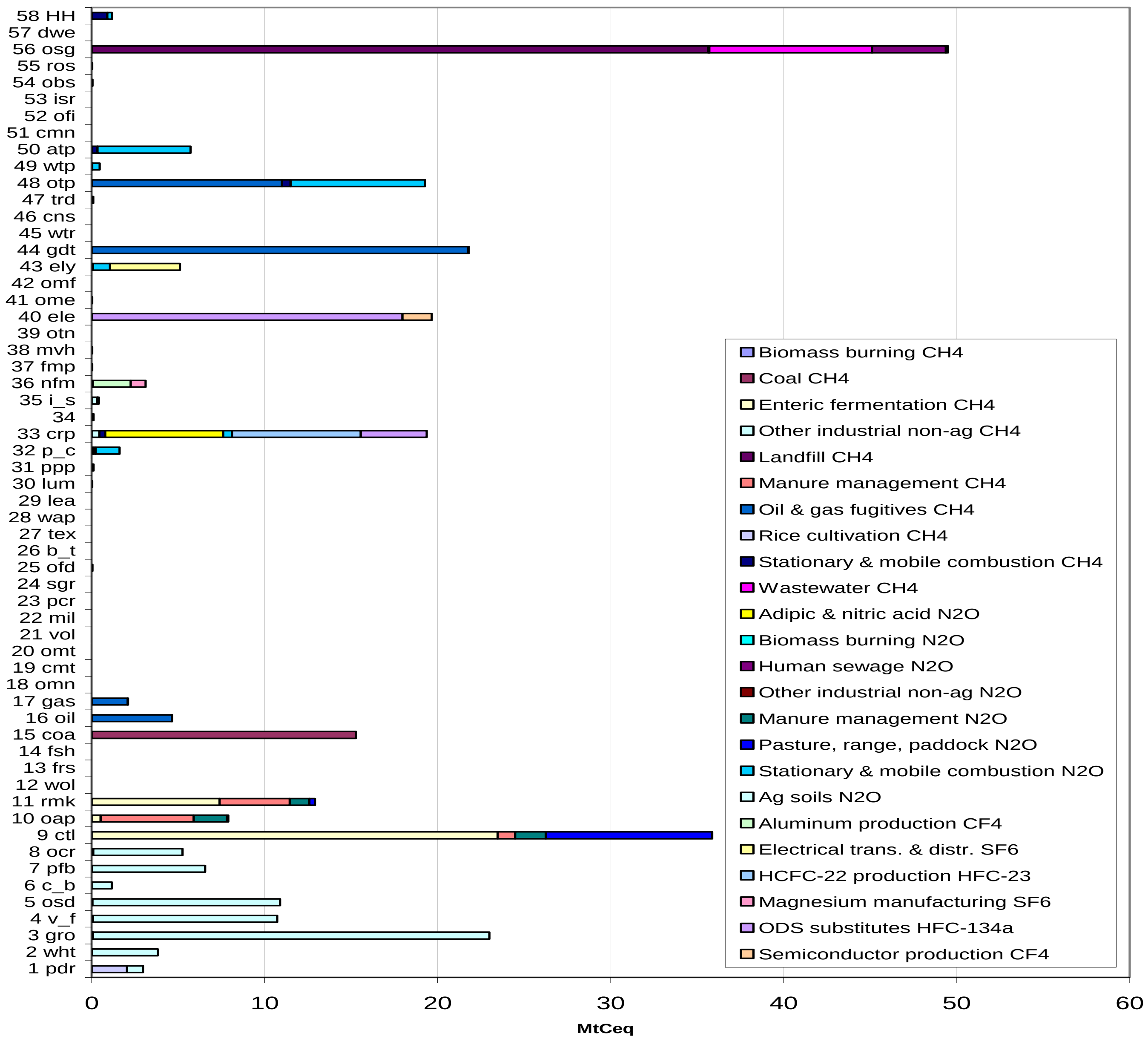
AEZs defined by "length of growing period"
Determined by: temperature, precipitation, soil and Topography, combined with a water balance model

The global distribution of crop and grazing lands *ca*. 2000: % of agricultural land rents



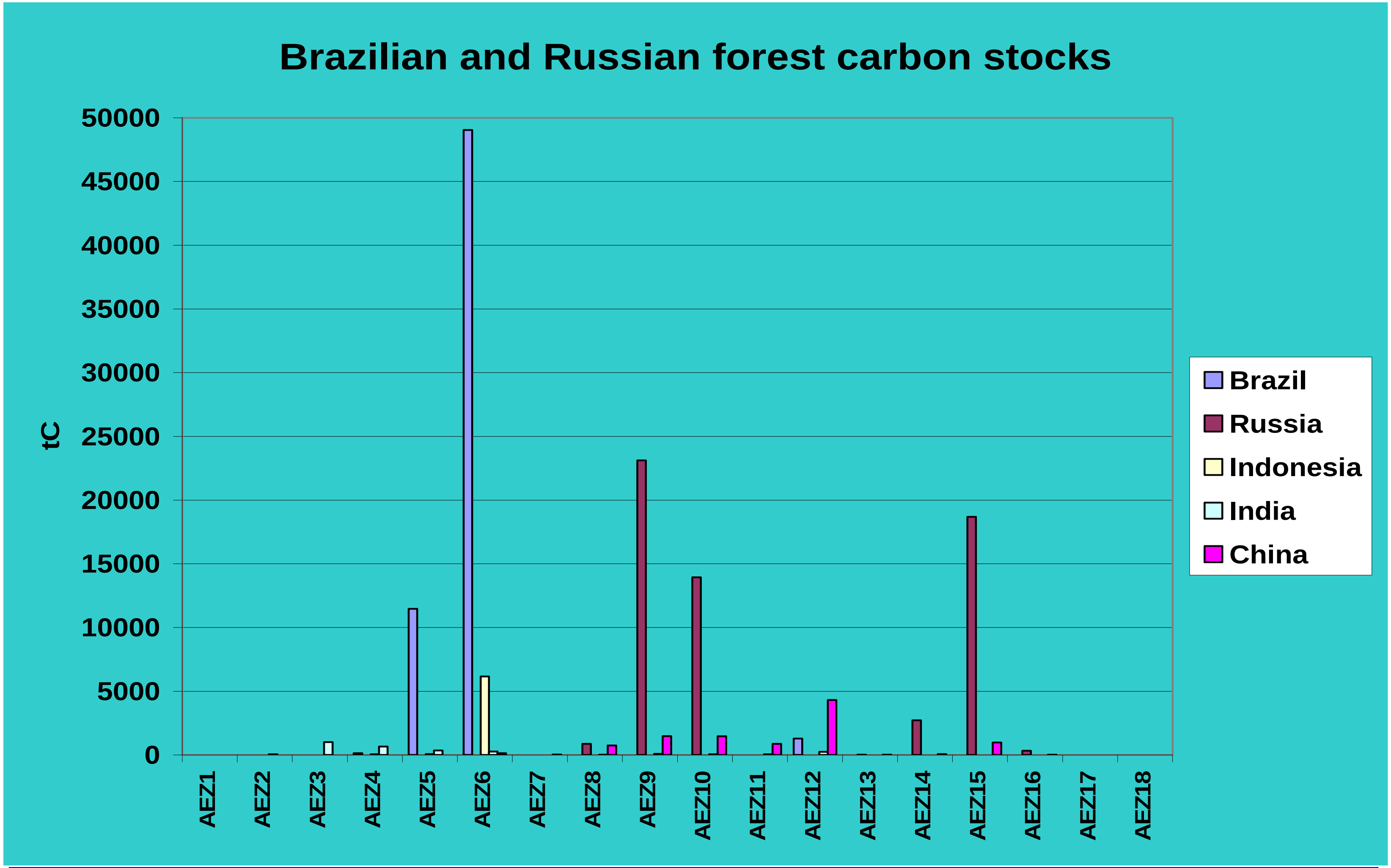
USA Non-CO_2 GHG emissions: By sector, 2001

- 150+ emissions sources in 226 countries
- map emissions drivers/sectors; e.g., N2O emissions from fertilizer use in coarse grains production tied to fertilizer input use in that sector



Forest carbon stock: 2001

by AEZ for selected countries



Aggregated over age classes, management types, and species classes

Application #1: Food Miles Debate

- **Joint project between Purdue and ITC-Geneva**
- **Agriculture and transportation sectors are responsible for 15% (World Bank, 2008) and 21% (Gorham, United Nations, 2002) of global emissions.**
- **Increased consumption of local food can potentially reduce carbon footprint.**
- **However, the intensity of input use in food production varies widely across regions, so total impact uncertain.**
- **It is important to combine estimates of emissions associated with the production and transportation of food, known as the "food miles" debate.**
- **Impossible to study all the indirect impacts using input-output stage-by-stage LCA models.**
- **GTAP allows estimation of direct and indirect effects of substituting domestic for imported food.**

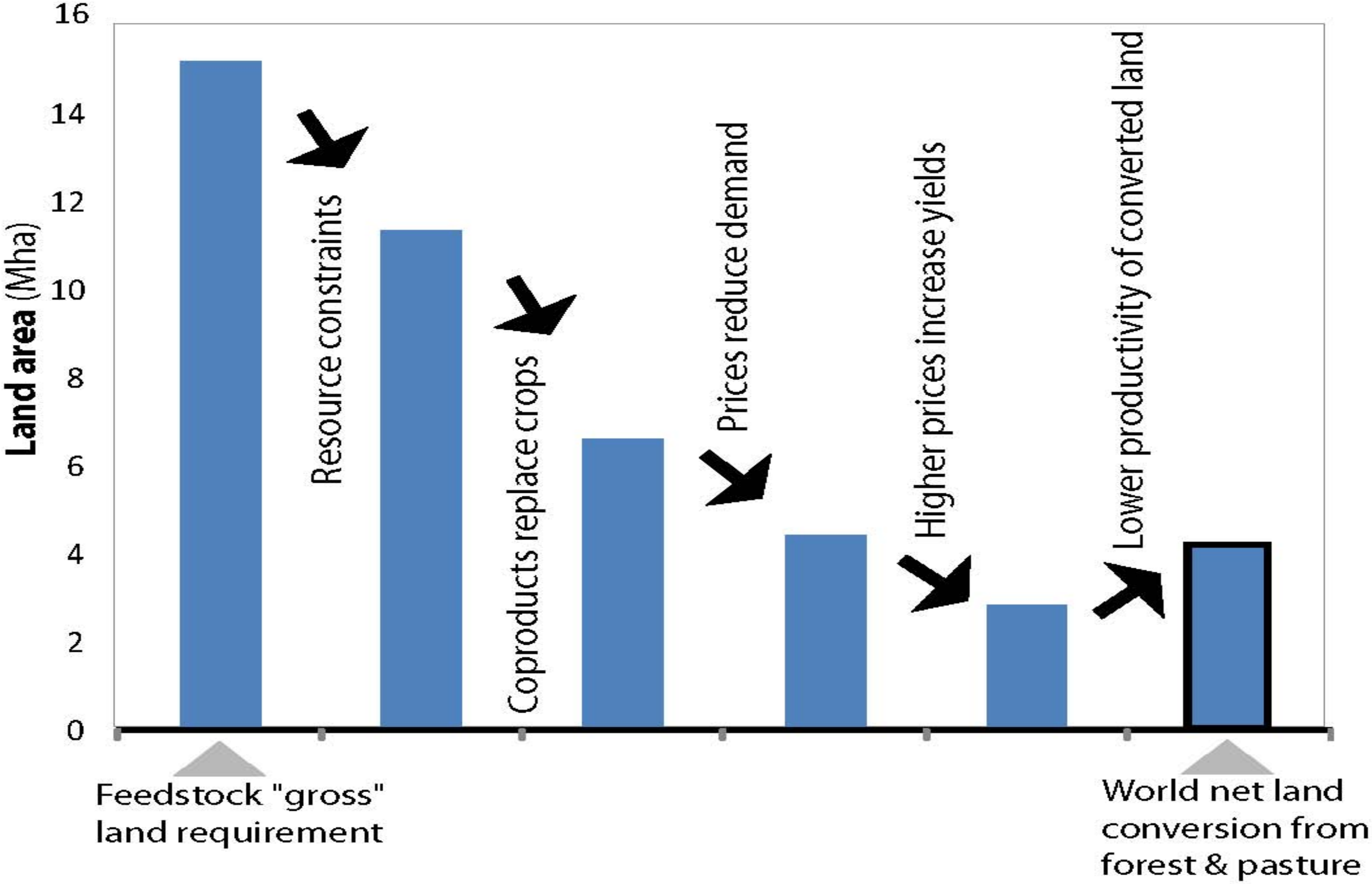
Application to Food Miles Debate: Illustrative Results

- **Illustrative example: shift the composition of ruminant meat consumption from imported to domestic commodities in the US, while holding composite utility constant**
- **Key determinants of US impacts:**
  - **Increased CH4 emissions from incr ruminant prod in US**
  - **US ruminants are intensive in feedgrains; feedgrains are intensive in fertilizer which releases N2O**
  - **Increased CO2 emissions from domestic transport activity**
- **RoW impacts:**
  - **Reduced CH4 emissions (dominates increase is US due to higher ruminant emissions intensity in RoW)**
  - **Reduced CO2 emissions from reduced international transport dominated by increase in US due to:**
    - **High liquid fuel transport intensity of US industry**
    - **Increase in US imports of other products**
- **Overall, emissions fall, but not due to reduced transport emissions; Illustrates inherent complexity of the problem**

Application #2: Biofuels Debate

- **Research published last year in *Science* raised the issue of "indirect" LUC:**
  - **Induced land use change (crop land conversion) due to increased demand for agricultural products could result in emissions which dwarf the direct gains of replacing petroleum with biofuel**
- **Purdue approached by UC Berkeley and CARB to provide improved estimates of iLUC:**
  - **Results to be replicable in Sacramento/elsewhere**
  - **Used these estimates in CA LCFS regulations**
- **Highly charged political issue: ethanol industry vs. environmentalists and corn users**

GTAP estimates of iLUC are only ¼ of Searchinger et al. estimates due to market-mediated effects



Source: Hertel, Golub, Jones, O'Hare, Plevin and Kammen, 2009

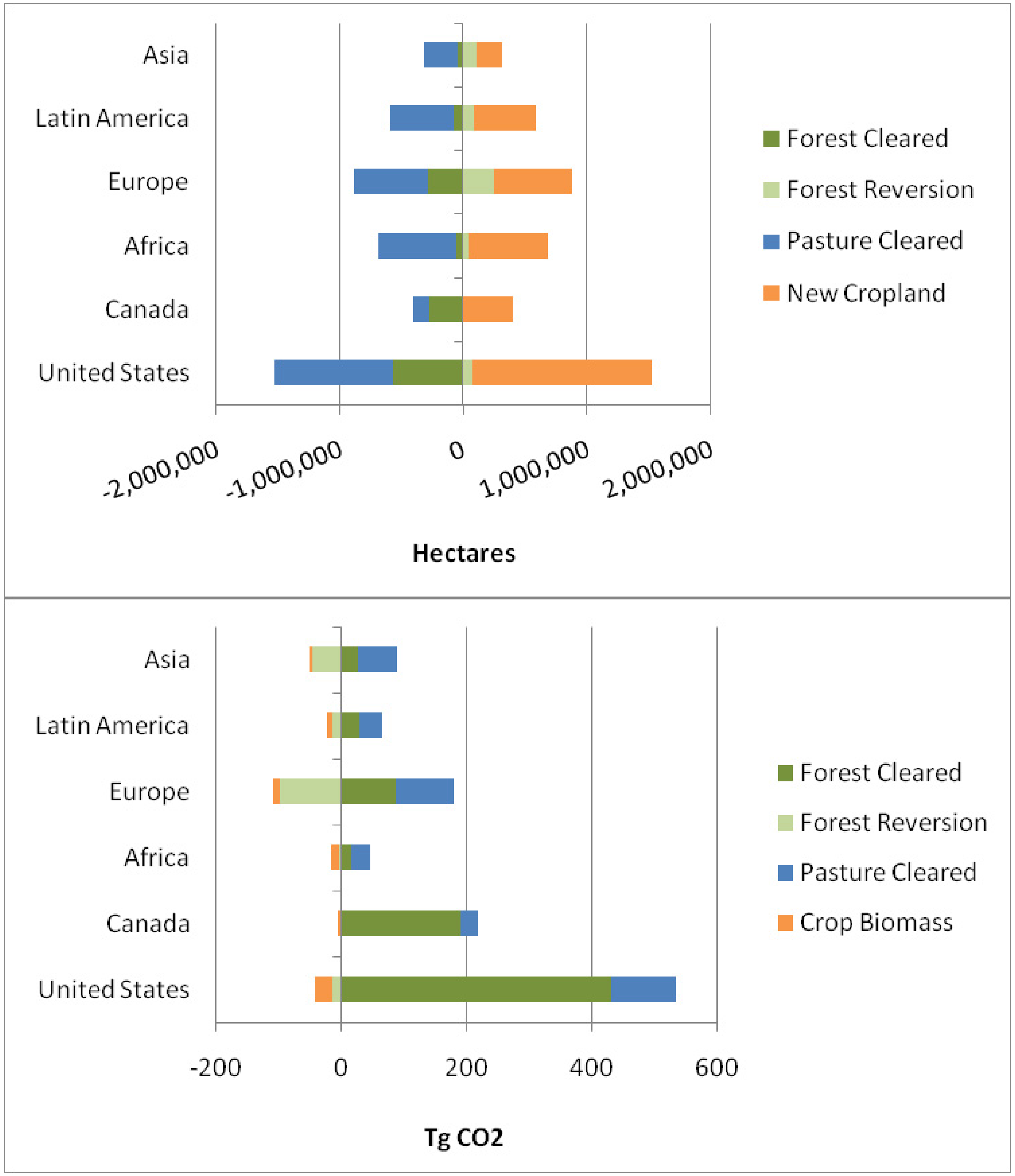
Land Conversion and Emissions due to increased US corn ethanol production

- **Use modified GTAP model: AEZs and Biofuel**
- **Estimate cropland expansion into accessible forest land and pasture**
- **Emissions factors based on Woods Hole**
- **GHG emissions:**

 - 27 g MJ^{-1} for 30 years of ethanol production

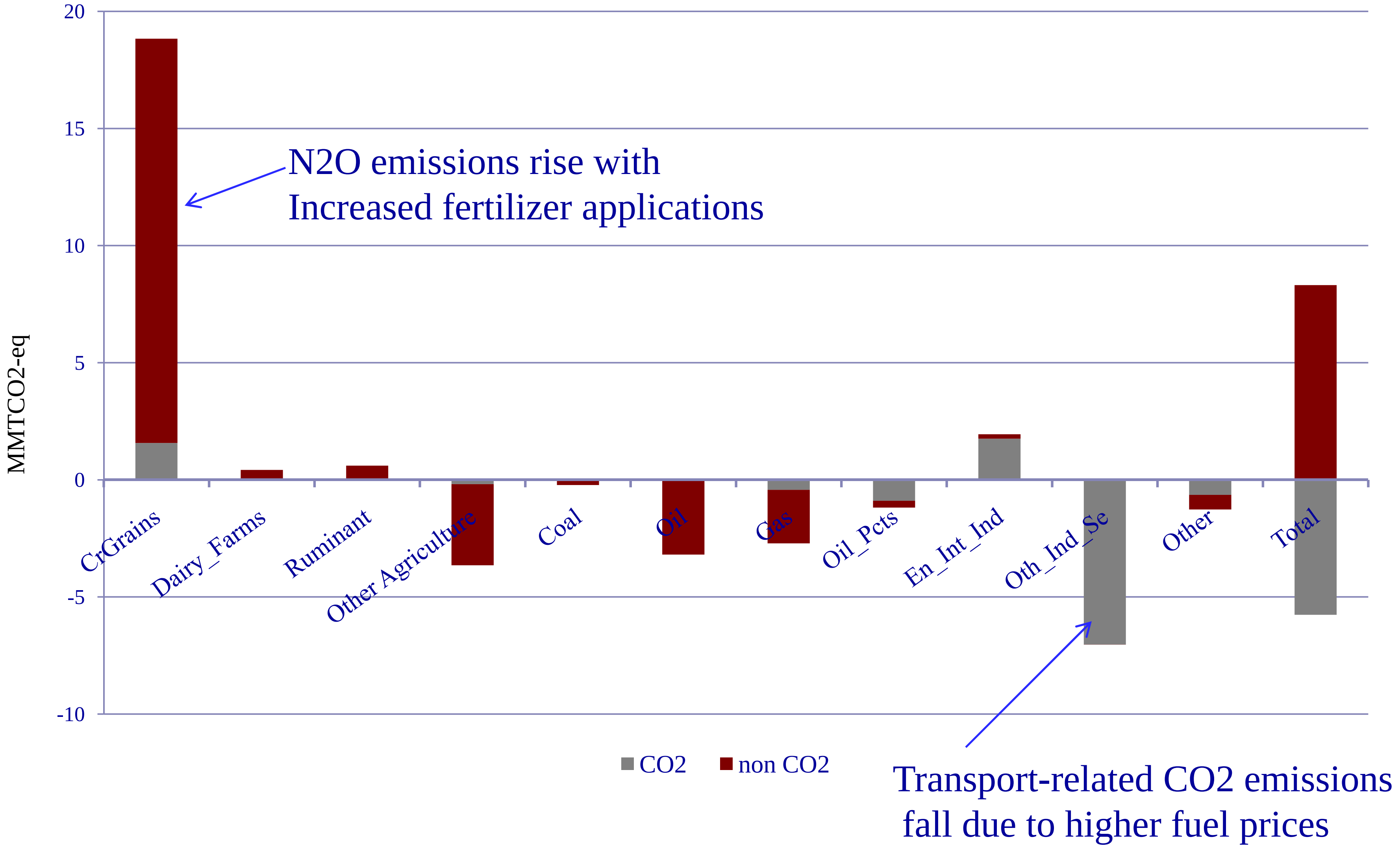
 - 2/5's previous estimate

 - still large enough to preclude corn ethanol in LCFS



Source: Hertel, Golub, Jones, O'Hare, Plevin and Kammen, 2009

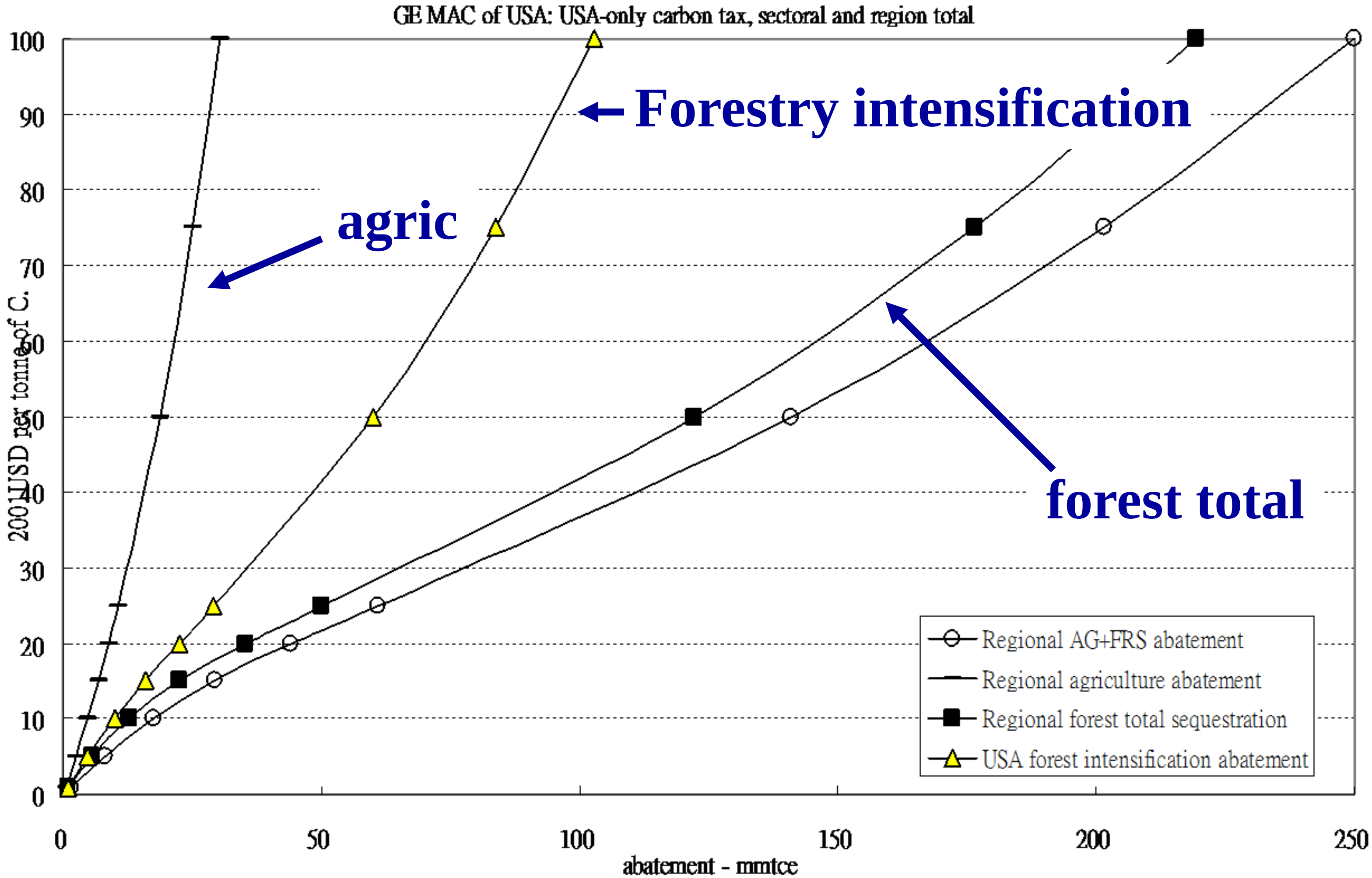
US corn ethanol production also changes non-LUC emissions: CO2 vs. non-CO2 (MMTCO2e)



Application #3: Climate Change Mitigation

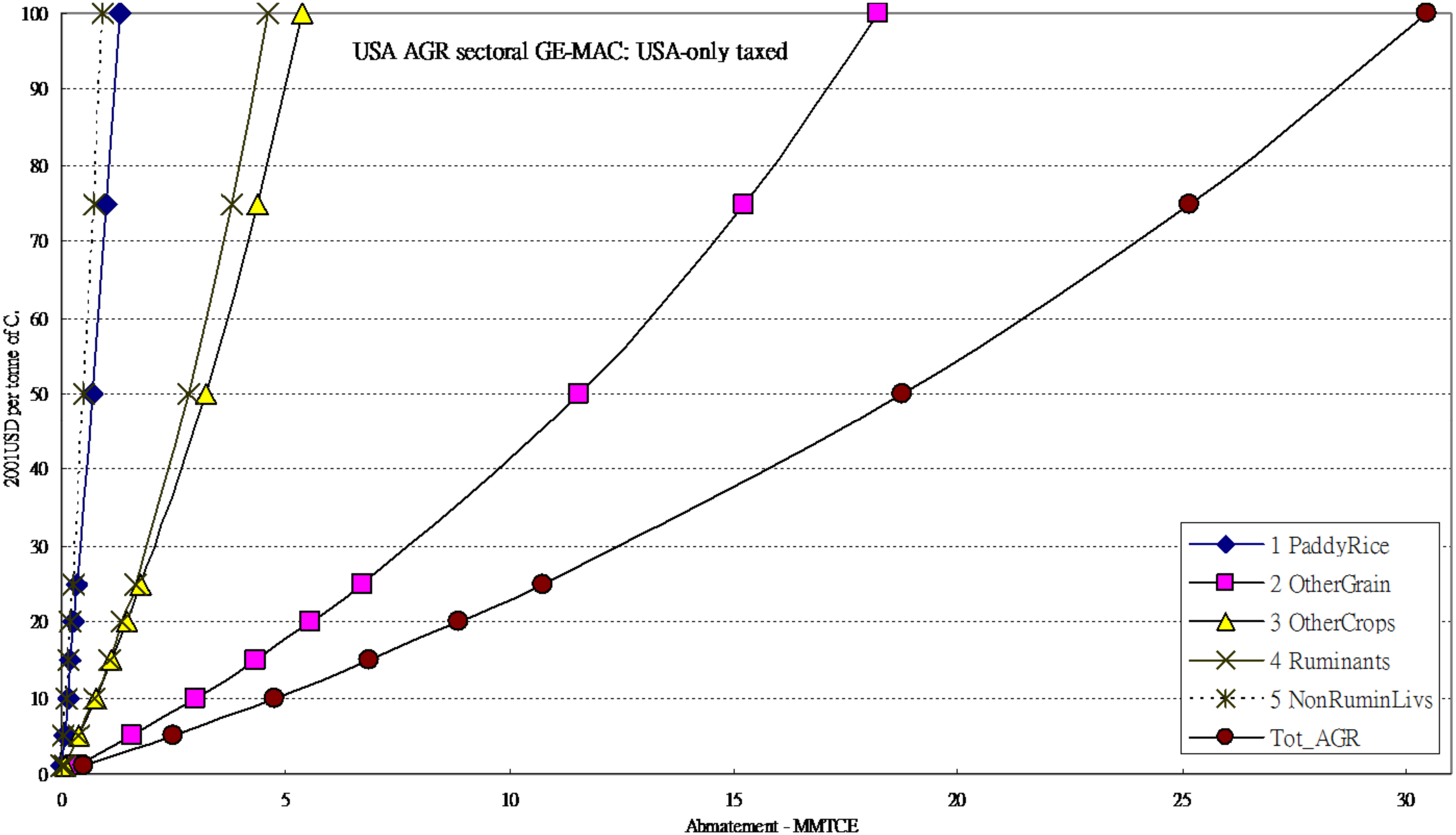
- **Land is a significant source of global GHG emissions**
  - **Deforestation: 1/3 of total carbon emissions since 1850**
  - **Land management/land use change: 75% of N2O, 50% of CH4**
- **Studies suggest land-based mitigation cost-effective, however:**
  - **Land not treated in *global* general equilibrium context**
  - **CGE research has focused on industrial/energy CO2 emissions**
- **Fundamental analytical challenges to capturing: Land-based emissions, competition for land and heterogeneity of land**
- **Key findings of this new work:**
  - **GHG incentives change pattern of comparative advantage and hence trade in agricultural and forest products, as well as chemical inputs**
  - **Intensification of production is key to land related mitigation**
  - **Domestic (US) agriculture and forestry abatement supply is a function of global climate policies**

USA agriculture and forestry general equilibrium GHG annual abatement supply schedules: USA-only carbon tax



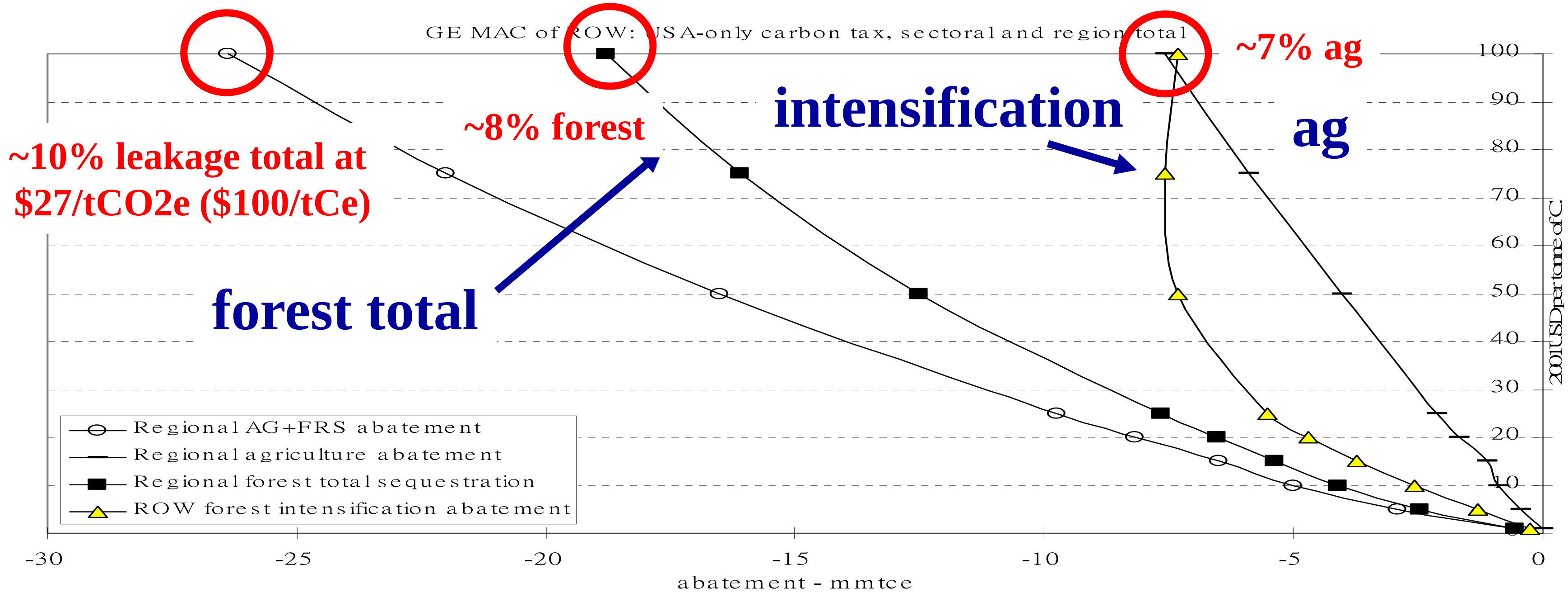
Source: Golub, Hertel, Lee, Rose and Sohngen, 2010

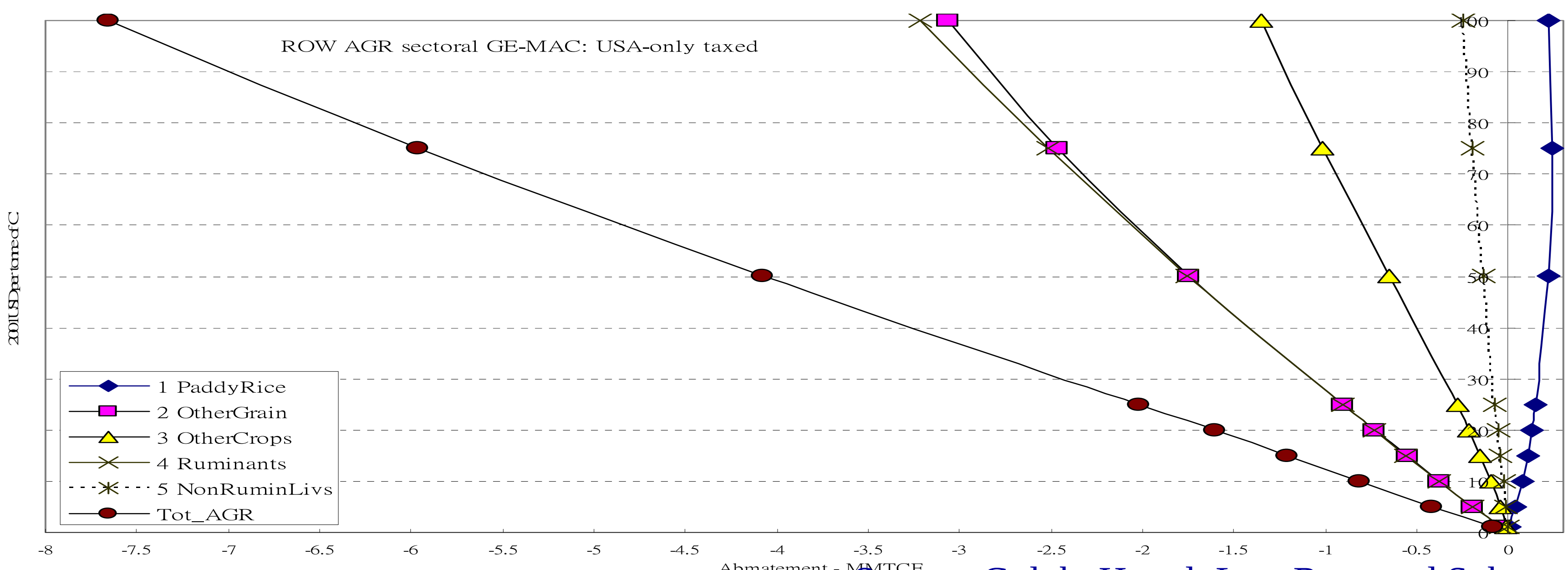
US Agricultural Supply of GHG Abatement, by sector (mill m.ton carbon as vary carbon price)



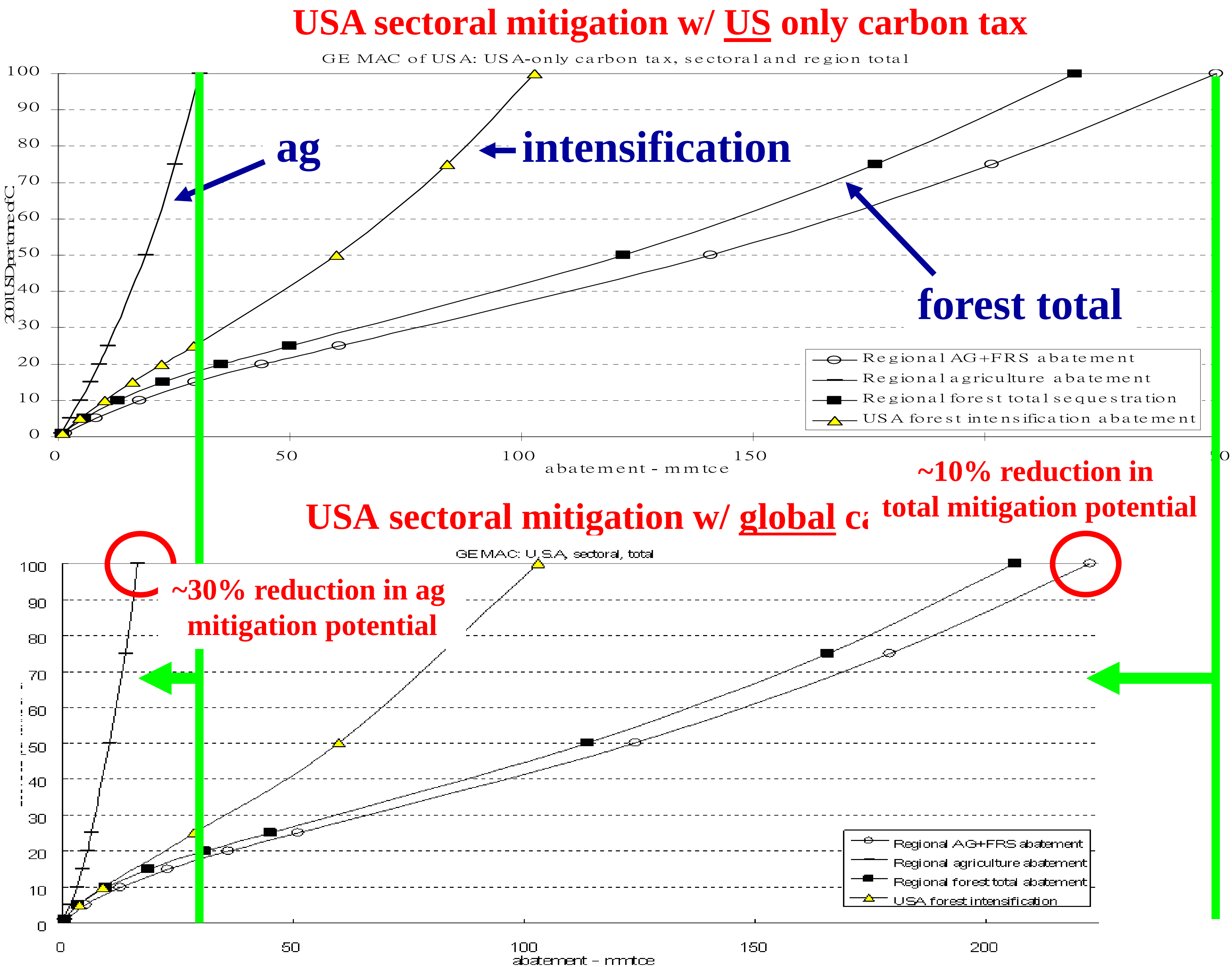
Source: Golub, Hertel, Lee, Rose and Sohngen, 2010

Leakage in ROW due to US carbon taxes



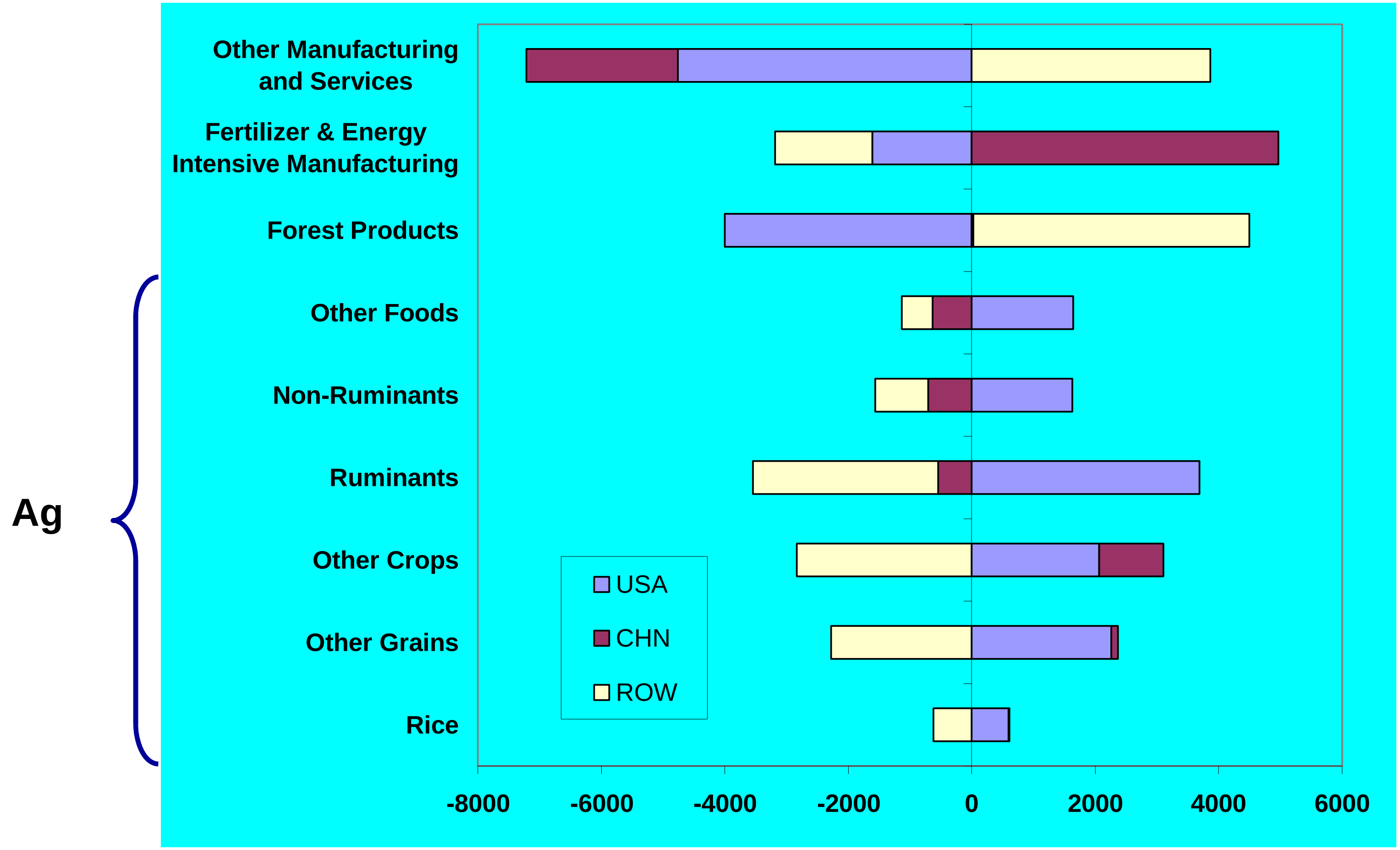


Source: Golub, Hertel, Lee, Rose and Sohngen, 2010



USA sectoral mitigation w/ US only carbon tax
GE MAC of USA: USA-only carbon tax, sectoral and region total
2001 USD per tonne of C
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
0
50
abatement - mmtce
ag
intensification
forest total
Regional AG+FRS abatement
Regional agriculture abatement
Regional forest total sequestration
USA forest intensification abatement
~10% reduction in
total mitigation potential
USA sectoral mitigation w/ global ca
GE MAC: USA, sectoral, total
~30% reduction in ag
mitigation potential
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
abatement - mmtce
Regional AG+FRS abatement
Regional agriculture abatement
Regional forest total abatement
USA forest intensification

A global carbon tax changes the pattern of trade: d_TBAL ($Usmill) with global tax of $100/tCe



- US increases net agric exports, decreases forest product net exports
- Increase in fertilizer and energy intensive manufacturing exports from China and increase in manufacturing and services exports from RoW

Source: Golub, Hertel, Lee, Rose and Sohngen, 2010

New book

(thanks to all who contributed!)

- **Part I: Overview and synthesis**
- **Part II: Data bases**
- **Part III: Applications including:**
  - **GTAP-AEZ**
  - **AgLU**
  - **EPPA/biofuels**
  - **LETAP/IMAGE**
  - **G-Dyn/Global Timber Model**
  - **KLUM**

Economic Analysis of Land Use in Global Climate Change Policy
Edited by **Thomas W Hertel, Steven K Rose, Richard S. J. Tol**
Series: Routledge Explorations in Environmental Economics
ISBN: **978-0-415-77308-9**
Binding: **Hardback**
Published by: **Routledge**
Publication Date: **04/20/2009**
Pages: **368**

Additional References

- Golub, Alla, T. W. Hertel, H. Lee, S. Rose and B. Sohngen, (2010). "Analysis of Global Land Use and the Potential for Greenhouse Gas Mitigation in Agriculture and Forestry", *forthcoming in Resource and Energy Economics.*
- Hertel, T., A. Golub, A. Jones, M. O'Hare, R. Plevin and D. Kammen (2009) "Comprehensive Global Trade Analysis Shows Significant Land Use Change GHG Emissions from US Maize Ethanol Production", under review with *BioScience*.
- Hertel, T., W. Tyner and D. Birur (2010). "The Global Impacts of Biofuels", *forthcoming in the Energy Journal.*