# Global Forestry and Agricultural Model Initial Results

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# Two Issues:

- Are Forests a Transition Tool?
  - Results from Link with Integrated Assessment Model assessing a 500 ppm constraint.
  - WITCH Model (FEEM) linked to Global Timber Model, with Massimo Tavoni (FEEM)

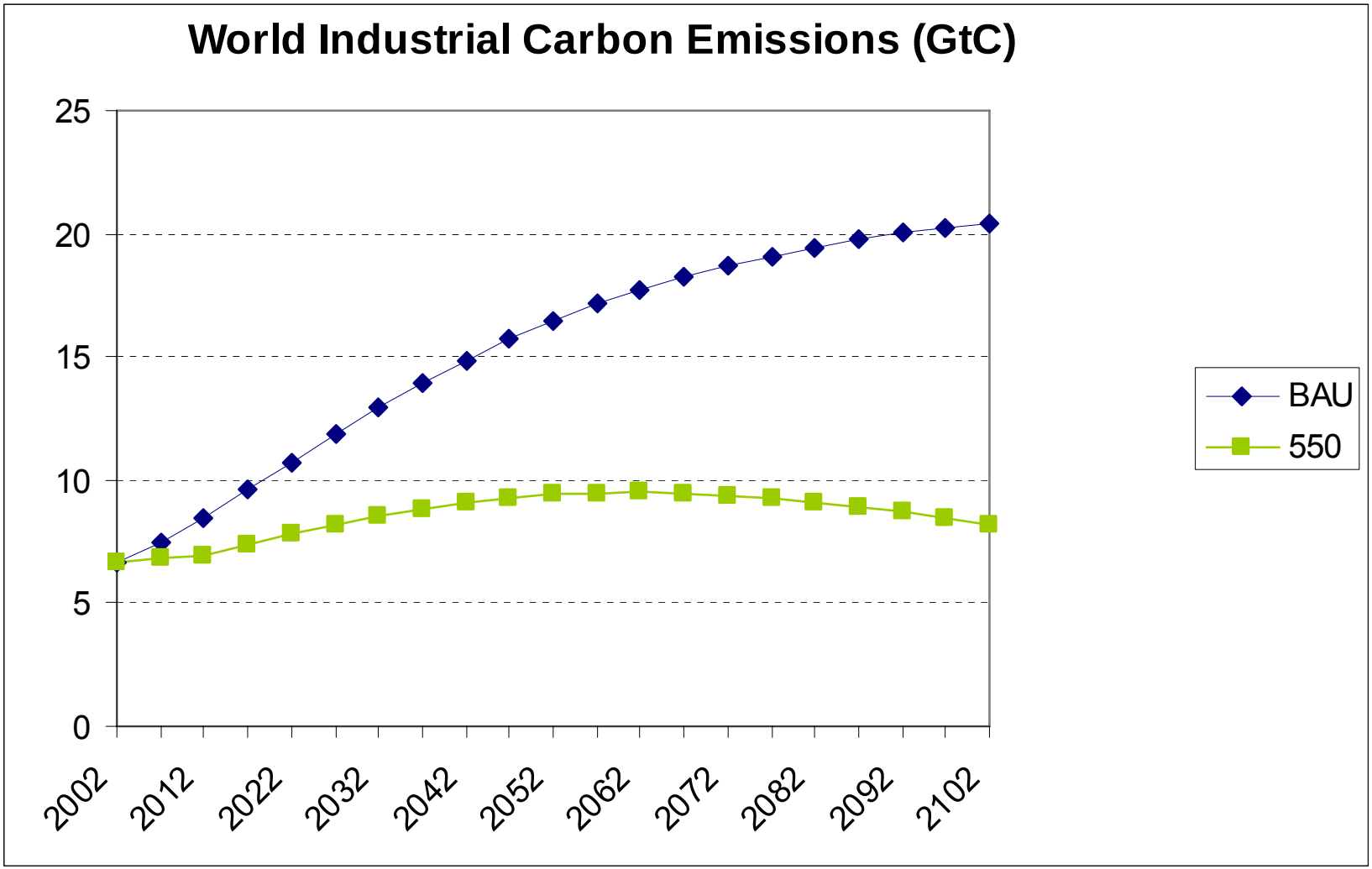
- Toward Development of PE Forest and Agr. LU Model
  - PE Forest and Agricultural LU model
  - Structure of global forestry and agriculture model
  - Data
  - Analysis so far
  - Next Steps

# Are Forests a Transition Tool?

- **Link an IAM with Forestry/LU Model.**
- **WITCH**
  - **A dynamic model to study the economics of climate change**
  - **TOP DOWN optimization framework, with a energy sector description and a game theory set up.**
    - **World, 12 regions**
    - **Economy: optimal growth**
    - **Energy: Energy sector specification**
    - **Climate: damage feedback**
    - **The 12 regions interact strategically**
- **Analysis: What Impact does forestry have on "optimal" carbon prices under a stabilization scenario?**
  - **550 ppm**

# Emission Profile

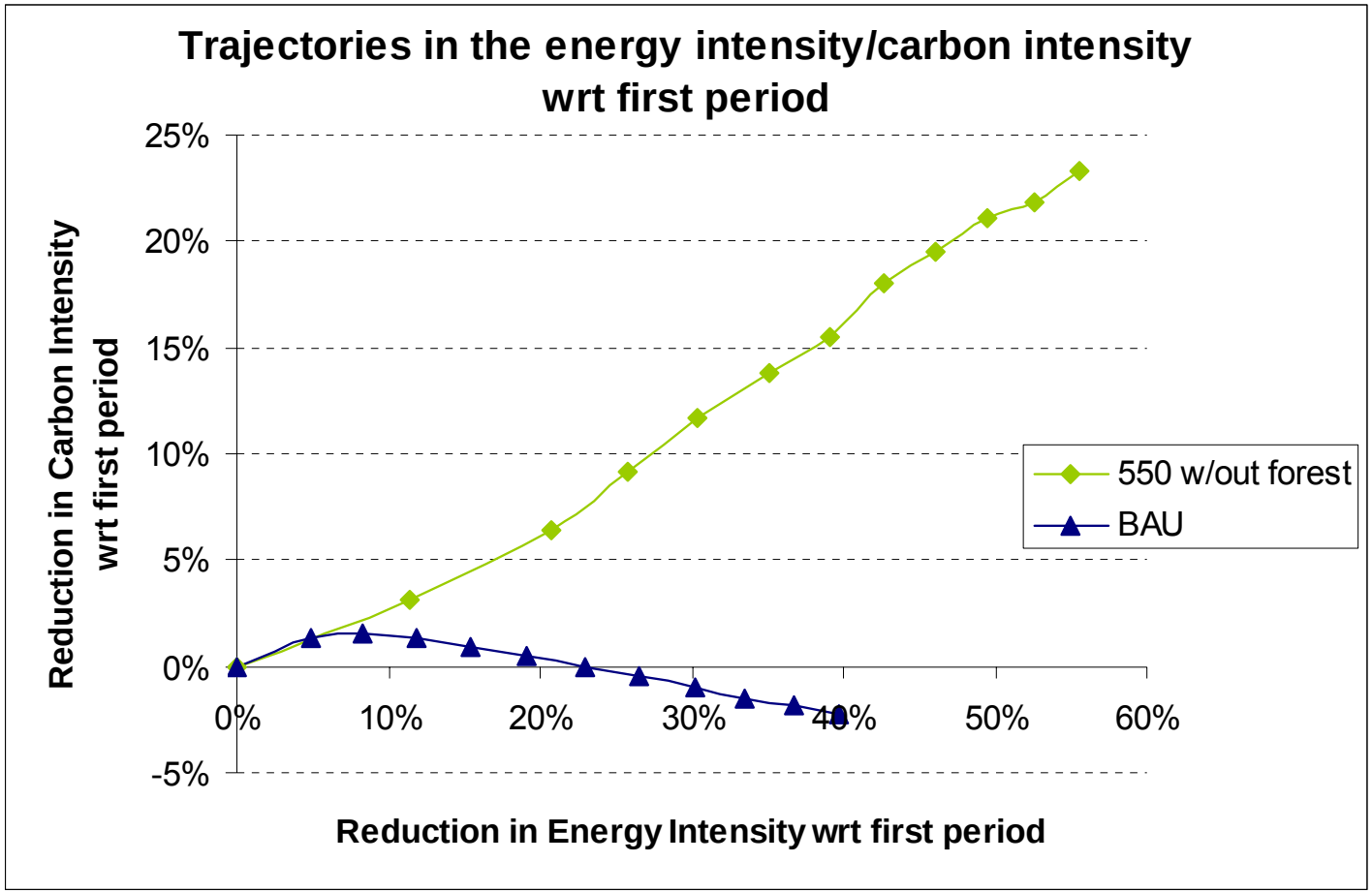
*Policy: 550 ppm constraint.*
*Without Forestry*



# Energy Abatement Options

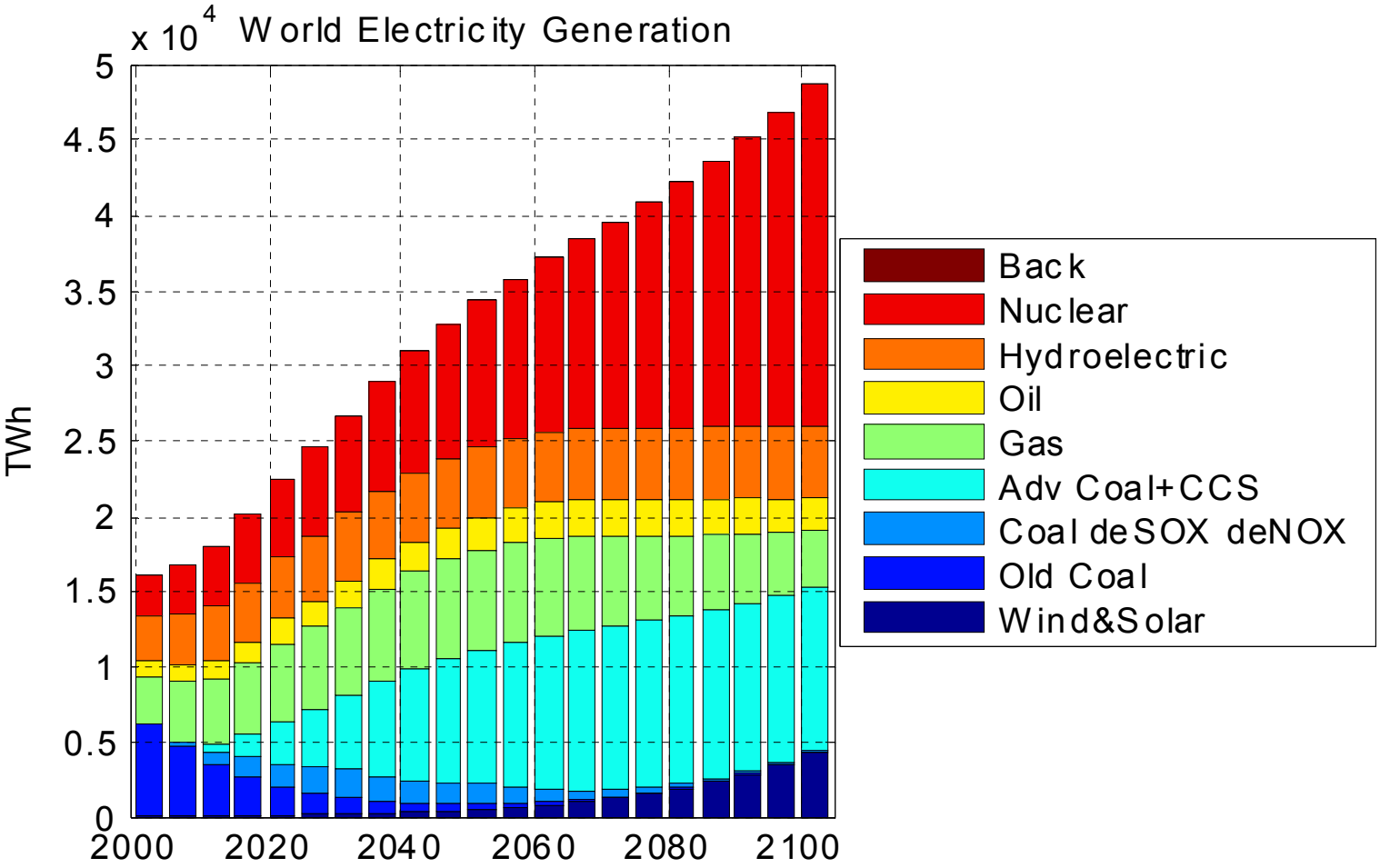
*550 PPM; Without Forestry*

**Policy induces significant reduction in carbon and energy intensities**

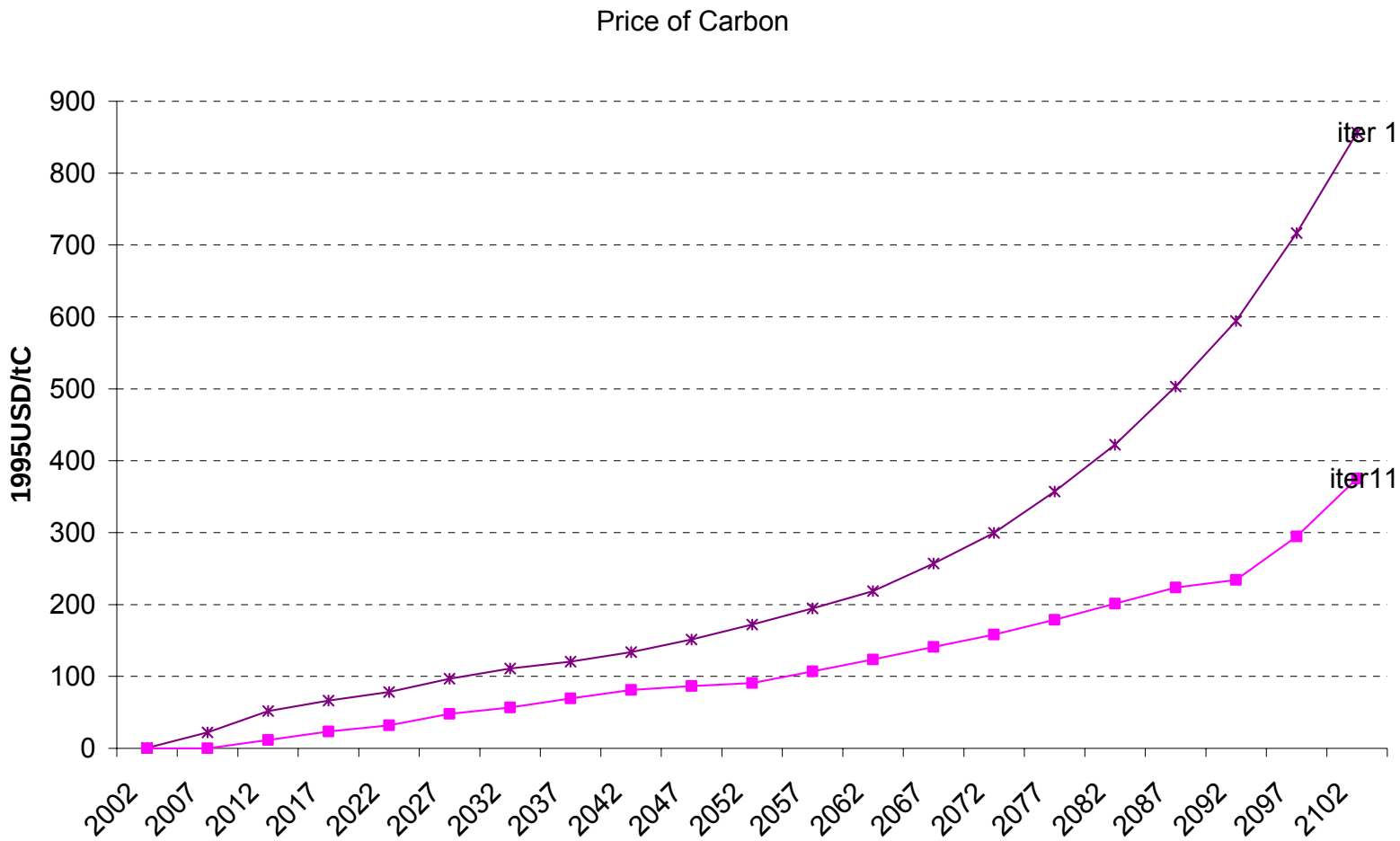


# Energy Abatement Options

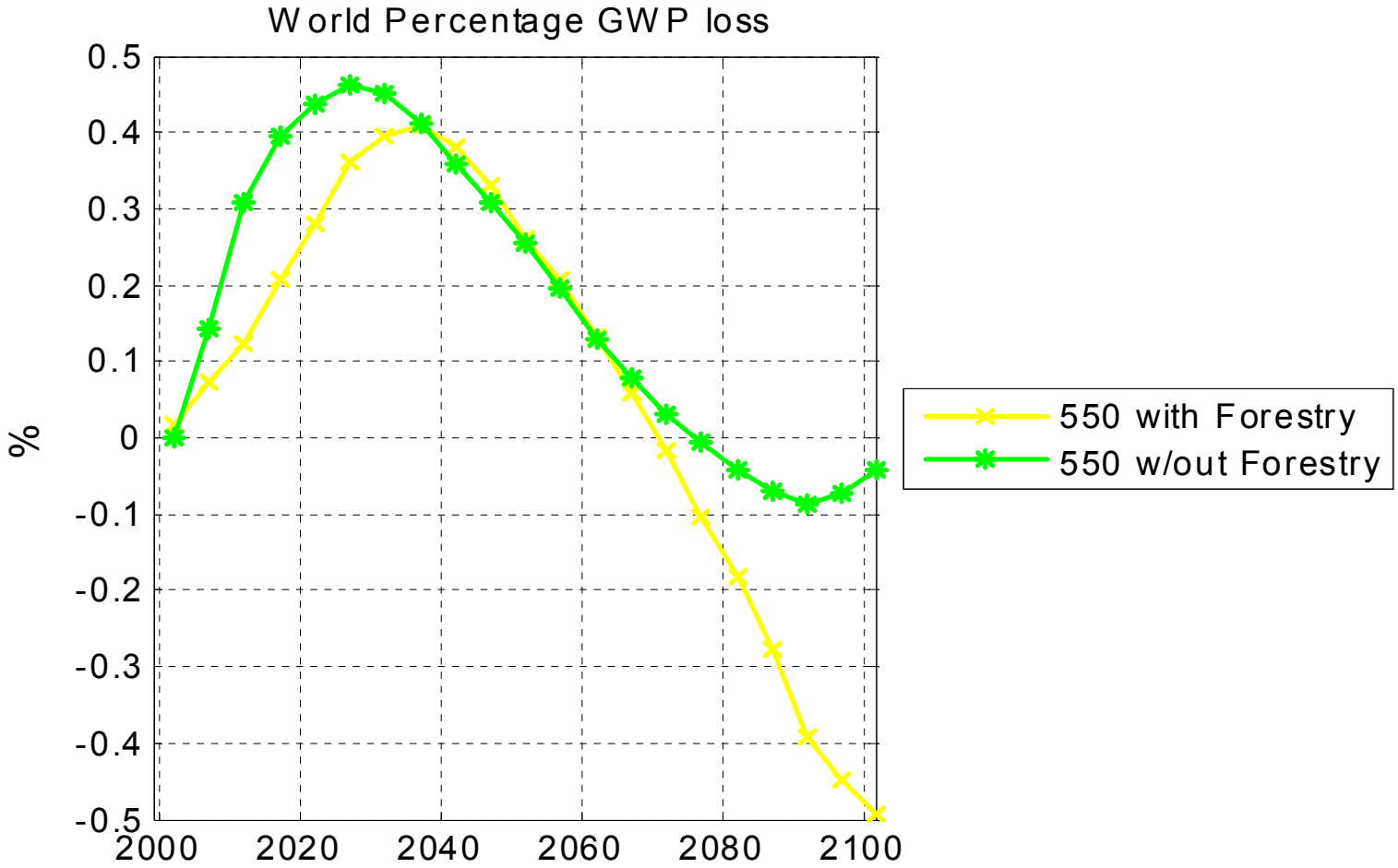
*550 PPM; Without Forestry*



# Adding Forestry Reduces Carbon Prices by ~ 56% over Century & Reduces average rate of price growth from >7% to 3.8% per year.



# Reduces Near-Term Income Losses

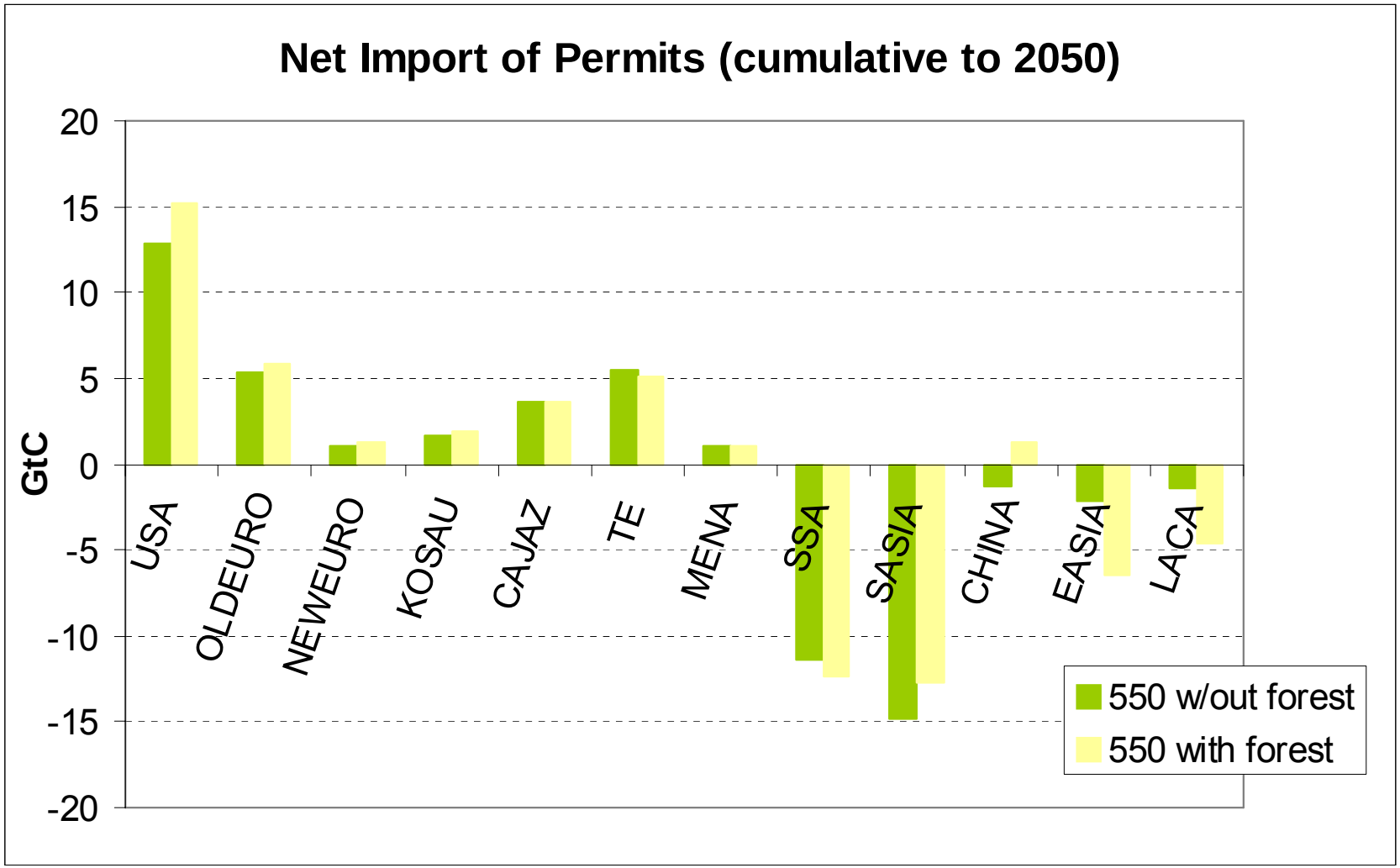


# Where Does the Sequest. Occur?

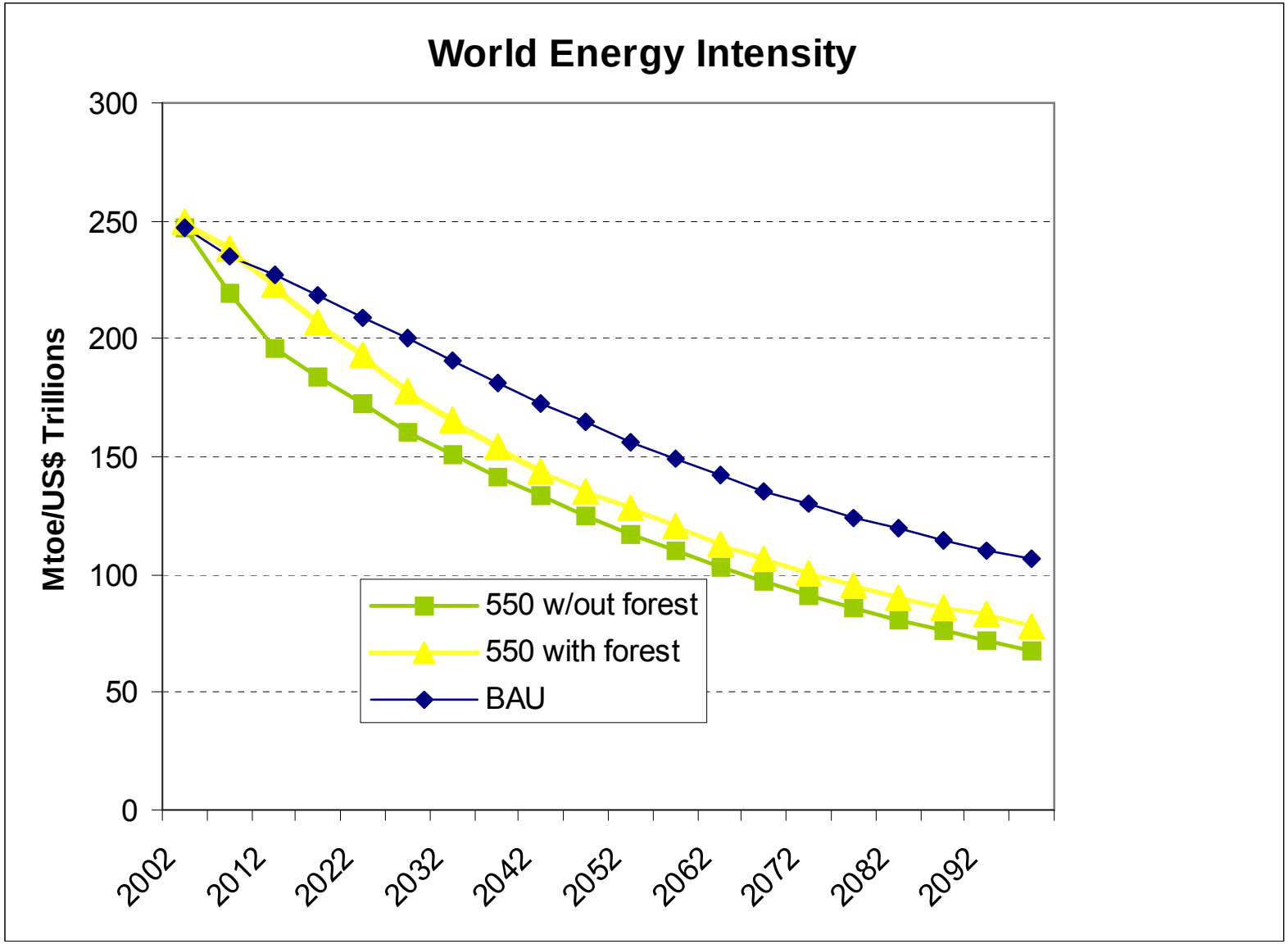
Red Areas are Largely due to Reducing Defor.

| | 2025 | 2055 | 2095 |
|---|---|---|---|
| | Million TCE/year (TgC) | | |
| USA | 42 | 144 | 193 |
| OLDEURO | 37 | 82 | 132 |
| NEWEURO | 8 | 18 | 29 |
| KOSAU | 25 | 27 | 36 |
| CAJAZ | 31 | 115 | 125 |
| Trans. Ec. | 179 | 117 | 134 |
| ME/NA | 73 | 49 | 31 |
| SubSahA | 270 | 175 | 106 |
| S. ASIA | 34 | 57 | 32 |
| CHINA | 109 | 155 | 431 |
| E. ASIA | 451 | 481 | 371 |
| LACA | 391 | 326 | 330 |
| Total | 1649 | 1746 | 1950 |
| C Price | $57 | $113 | $271 |

# Increases the Trade of Permits



# Delays Abatement in Energy



# Forest In "Transition"

- Forests delay energy abatement. Are forests a transition tool?
  - Forest Carbon worth $1.1 trillion ($55 billion/yr AEA)
  - Total Economic cost: $2.5 – 12 Trillion (Richels et al.)
- Transition tools:
  - Allow forest projects to enter CDM?
    - Continue efforts to build projects, even though project based approach suboptimal…
  - Develop rules for reducing deforestation
    - Project based?
    - National targets?
    - Indirect programs?
  - Use under national caps in developed countries
    - Current approach – but rules for forestry slow to evolve.
- Competition with Biomass will be a key feature of future.

# Global Forest & Ag Model - Model Structure

## *Dynamic Optimization- Three Sectors*

$$Max\rho\sum^{T}\left\{\begin{array}{l}\int^{QF} D_F\left(\sum_{region}^{16}\sum_{AEZ}^{18}\sum_{timber}^{6} Y_F(a,H,m)\right)dQF + \int^{QAg} D_{Ag}\left(\sum_{region}^{16}\sum_{AEZ}^{18} Y_{Ag}(X_{Ag},K,L)dQ_{Ag}\right. \\ \left. + \int^{QLv} D_{Lv}\left(\sum_{region}^{16}\sum_{AEZ}^{18} Y_{Lv}(X_{Lv},K,L)\right)dQ_{Lv} - \sum_{region}\sum_{AEZ}\sum_{timber} C_F - \sum_{region} C_{Ag} - \sum_{regiion} C_{Lv}\right.\end{array}\right\}$$

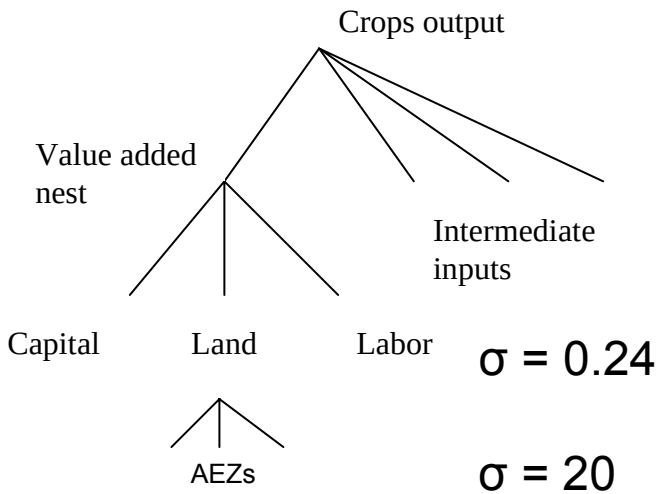
Subject to:

- Forestry Production (Dynamic)
- Crop Production
- Livestock Production
- Land Supply

# Structure of Production

Forestry ⟶ $Q^F(\cdot) = \sum_i \sum_a H^i{}_{a,t} Y^i_{a,t}$

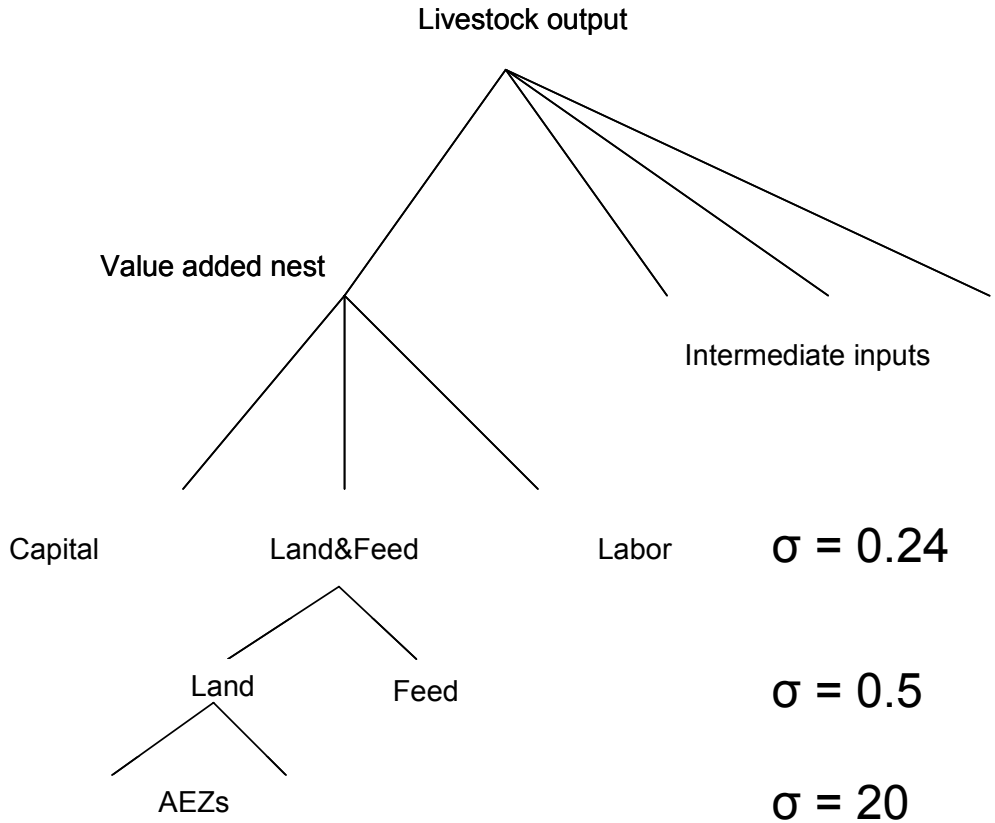
## Crops




σ = 0.24

σ = 20

## Livestock

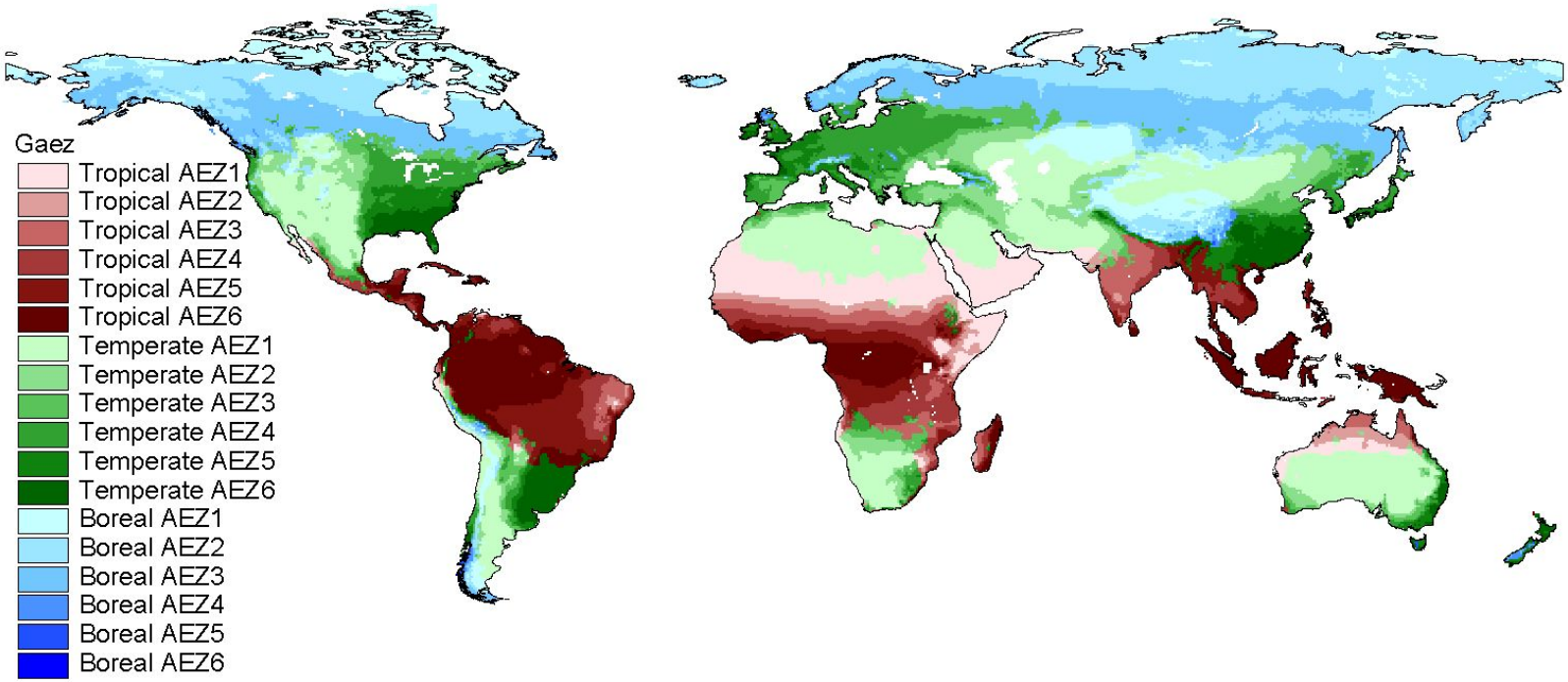



σ = 0.24

σ = 0.5

σ = 20

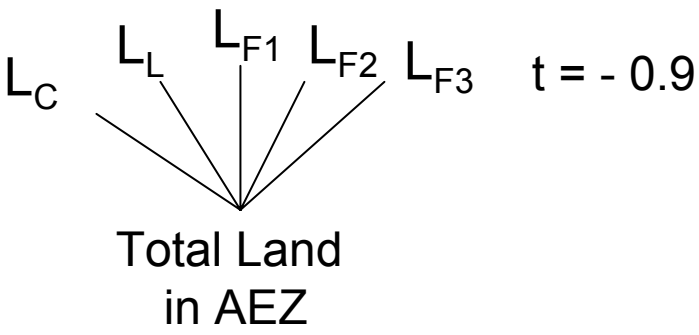
# Production units are denominated by AEZ's and 16 regions



# Regions

| | AEZs | F. Types |
|---|---|---|
| US | 10 | 6 |
| CHINA | 12 | 6 |
| BRAZIL | 6 | 5 |
| CANADA | 8 | 4 |
| RUSSIA | 7 | 5 |
| EU ANNEX I | 9 | 5 |
| EU NON-ANNEX | 7 | 4 |
| SOUTH ASIA | 9 | 5 |
| CENT AMERICA | 12 | 5 |
| REST SOUTH AM | 18 | 5 |
| SUB SAHARAN AF | 9 | 4 |
| SOUTHEAST ASIA | 5 | 3 |
| OCEANIA | 9 | 5 |
| JAPAN | 5 | 2 |
| AF MIDDLE E | 3 | 2 |
| EAST ASIA | 4 | 3 |

# Land Supply




$$XL_L^{Ag} = \frac{XE_j\left(\alpha_{C,j}^{\tau} \Big/ R_{C,j}^{\tau}\right)}{\left[\alpha_{c,j}^{\tau} R_{c,j}^{1-\tau} + \alpha_{L,j}^{\tau} R_{L,j}^{1-\tau} + \alpha_{F,j}^{\tau} R_{F,j}^{1-\tau}\right]^{\left(\frac{\tau}{\tau-1}\right)}}$$

- Land imperfectly mobile across crops, livestock and forests.
- Use CET function
- Calibrated on initial areas & rents
- t = 0.9

# Land Supply Calibration

- Land Supply calibration based on current area of accessible land

- Can purchase new units of endowment in regions with substantial inaccessible land
  - Brazil, RSAM, Central Amer., S. Asia, SE Asia, Sub Saharan Africa

# Baseline Information

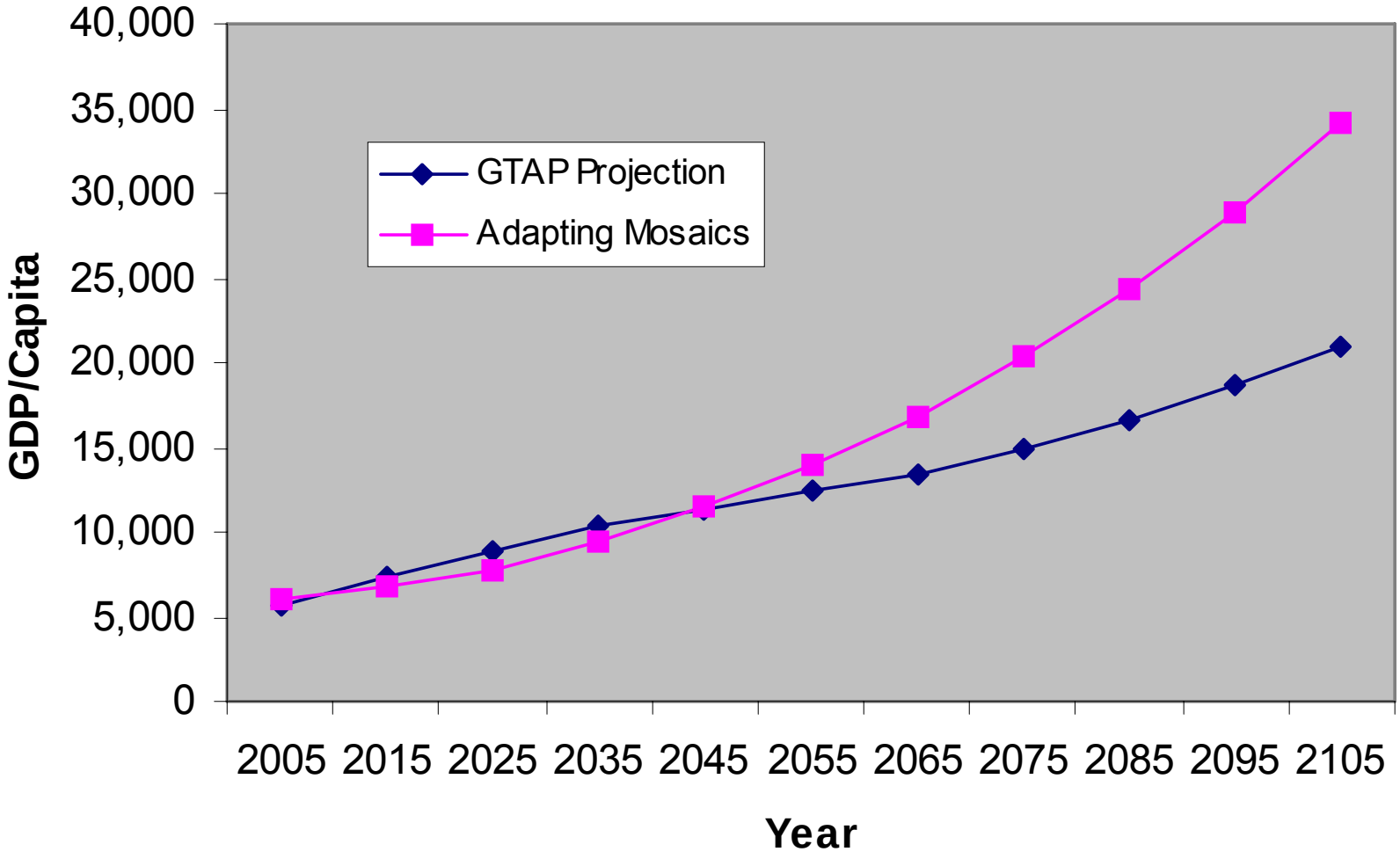
- Demand Functions

$$Q_{i,t} = (A_{i,t})(I_t)^{e_{i,t}} (P_{i,t})^{-n_i}$$

- Demand Functions

| | | | |
|---|---|---|---|
| $e_{Crops}$ | = 0.17 ↓ 0.06 | $n_{Crops}$ | = 0.25 |
| $e_{Livestock}$ | = 0.62 ↑ 0.76 | $n_{Livestock}$ | = 0.71 |
| $e_{Forest}$ | = 0.88 ↑ 0.93 | $n_{Forest}$ | = 1.10 |

# GDP/Capita Projections



Technical Change

% Ann. Chg. TFP

Nin et al. (2003)

| | Crops | Livestock |
|---|---|---|
| US | 2.50 | 1.20 |
| CHINA | 0.70 | 1.80 |
| BRAZIL | -0.45 | -0.95 |
| CANADA | 2.50 | 1.20 |
| RUSSIA | 0.55 | -0.20 |
| EU ANNEX I | 2.50 | 1.20 |
| EU NON-ANNEX | 1.55 | 0.63 |
| SOUTH ASIA | -1.70 | 0.83 |
| CENT AMERICA | 0.03 | 0.83 |
| REST SOUTH AM | 0.98 | 0.52 |
| SUB SAHARAN AF | -0.32 | -0.01 |
| SOUTHEAST ASIA | -0.53 | 1.32 |
| OCEANIA | 2.50 | 1.20 |
| JAPAN | 1.00 | 1.00 |
| AF MIDDLE E | 0.20 | 0.01 |
| EAST ASIA | -0.53 | 1.30 |

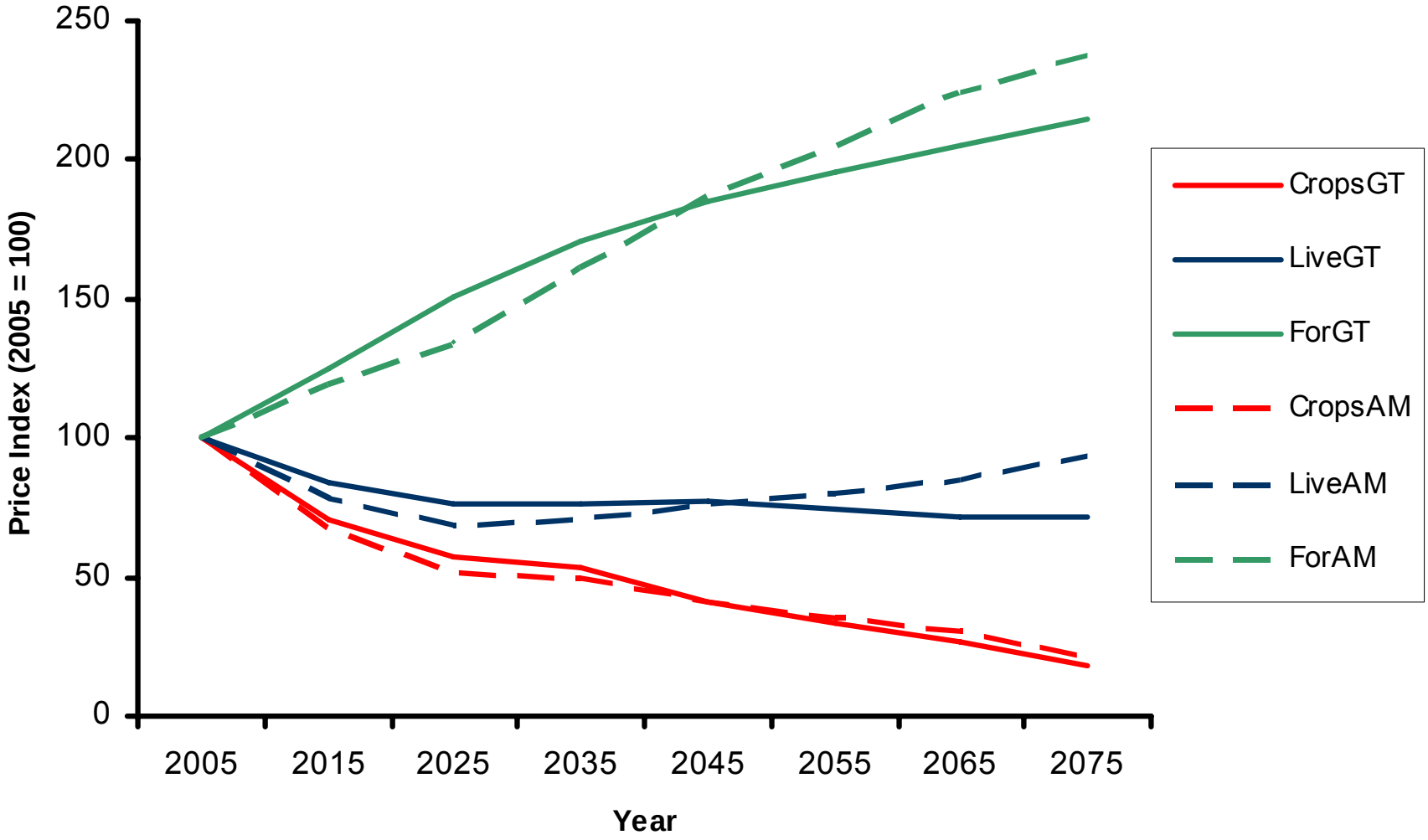


# Caution:

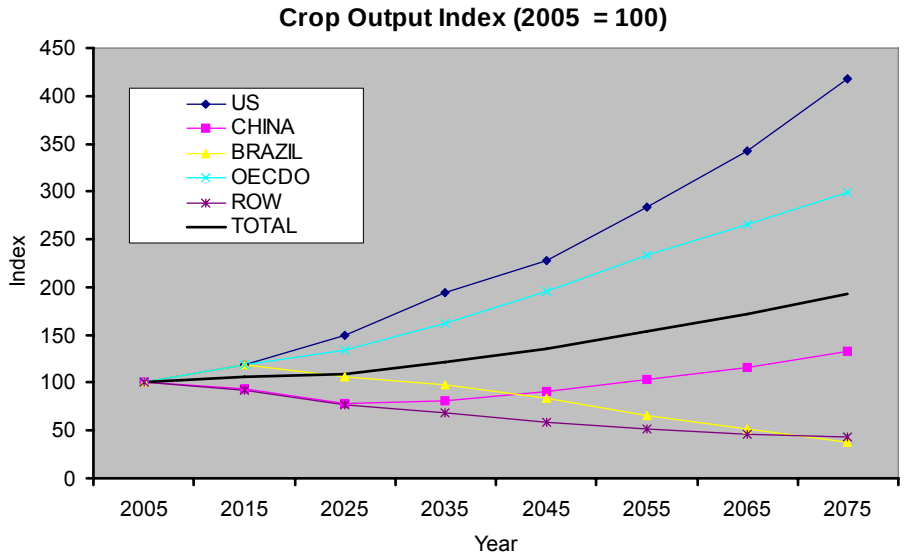
# ALL RESULTS ARE PRELIMINARY

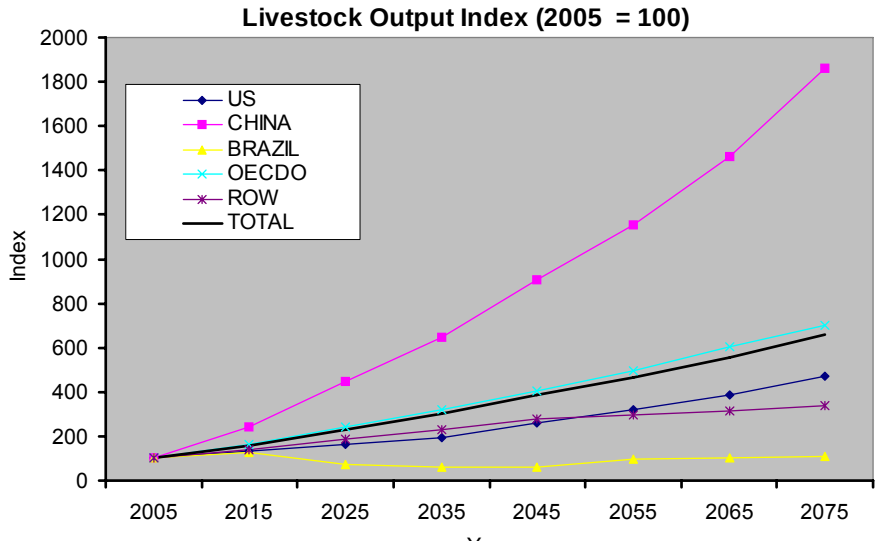
# Comments Welcome….

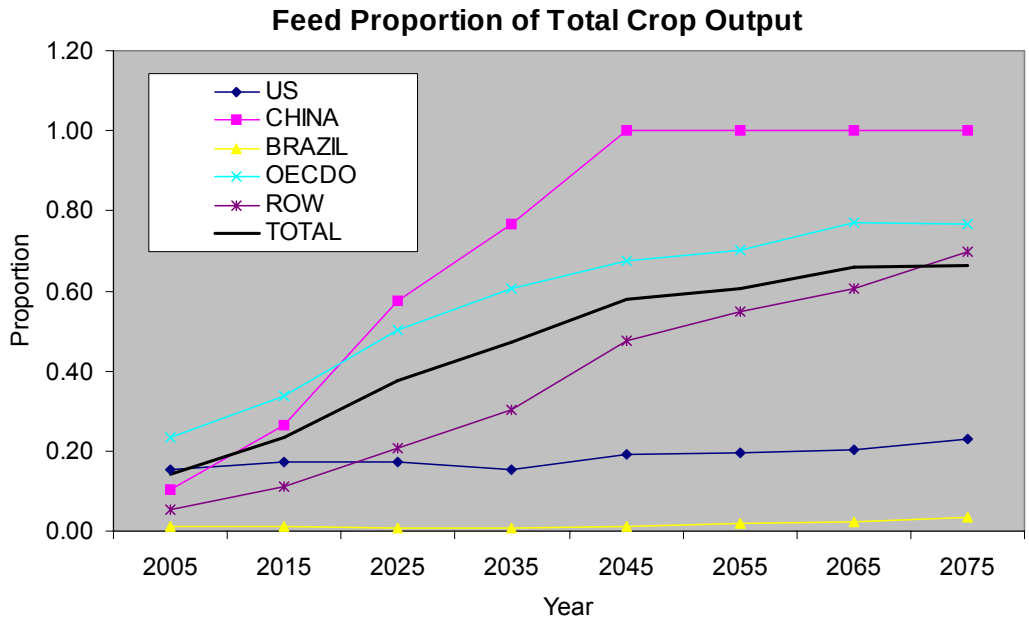
# Results: Prices



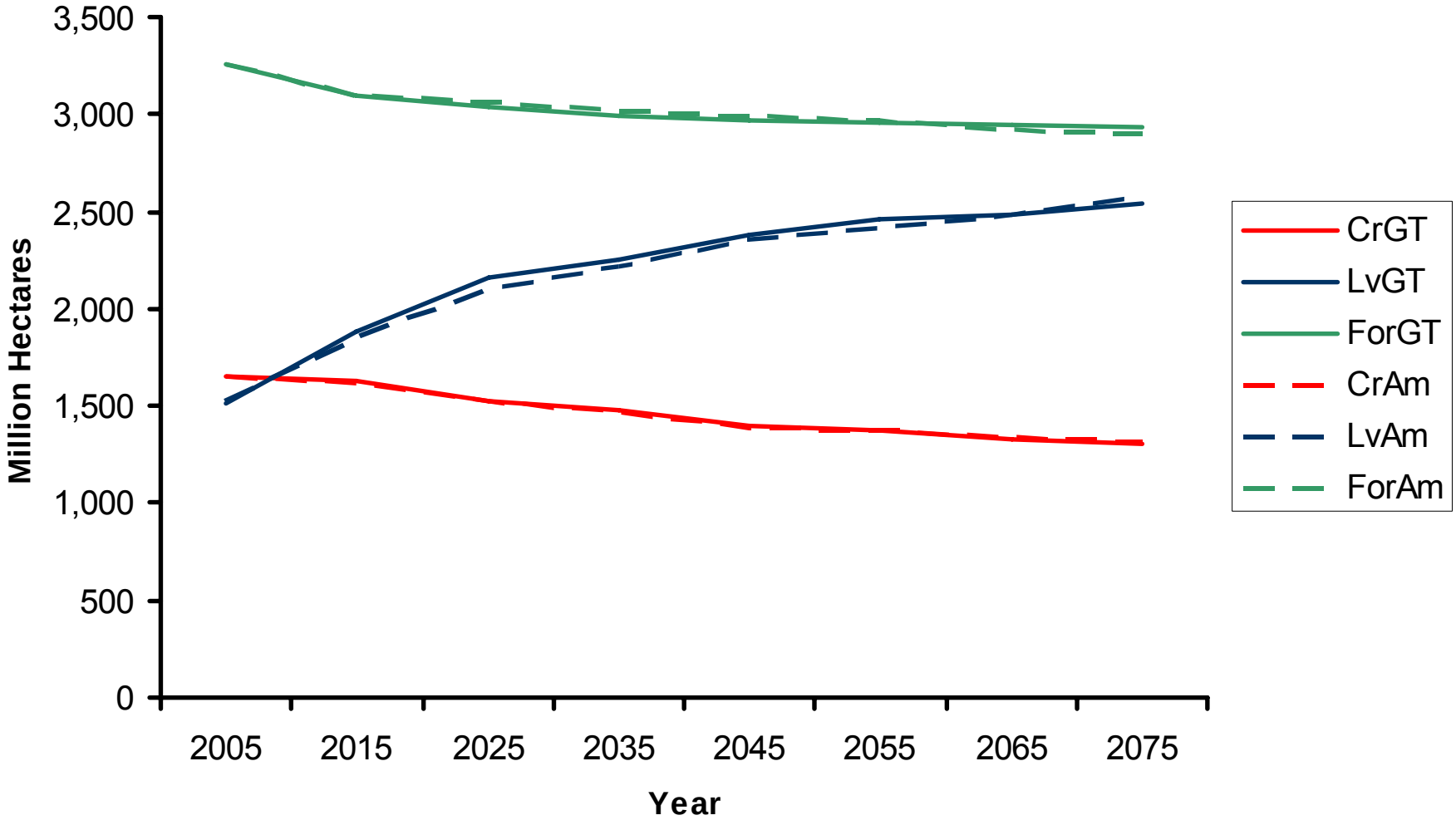
# Results: Outputs



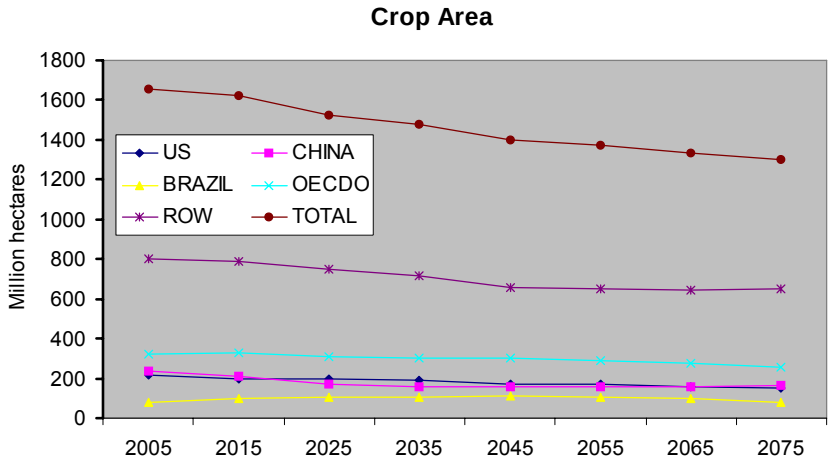



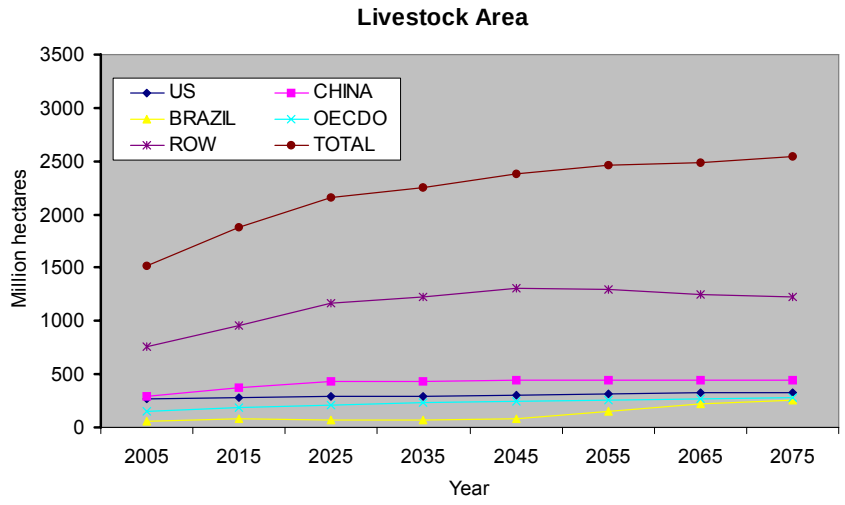
# Results: Global Land Area

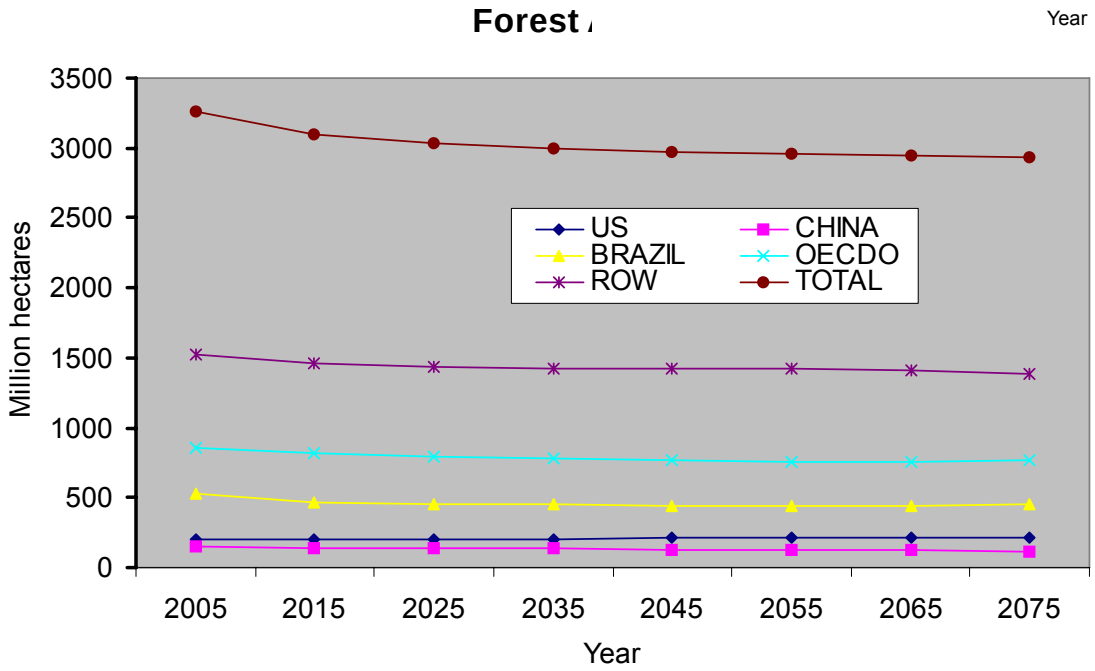


# Results: Regional Land Areas

## *GTAP GDP & Population*

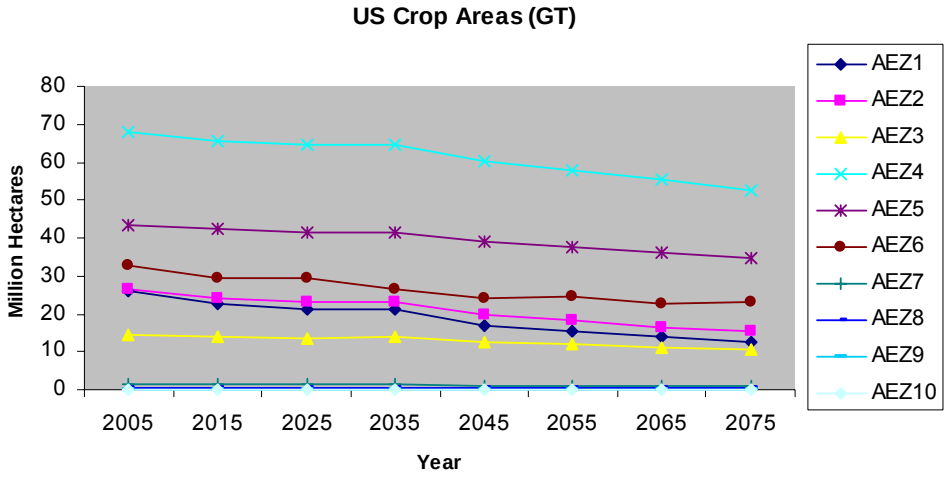


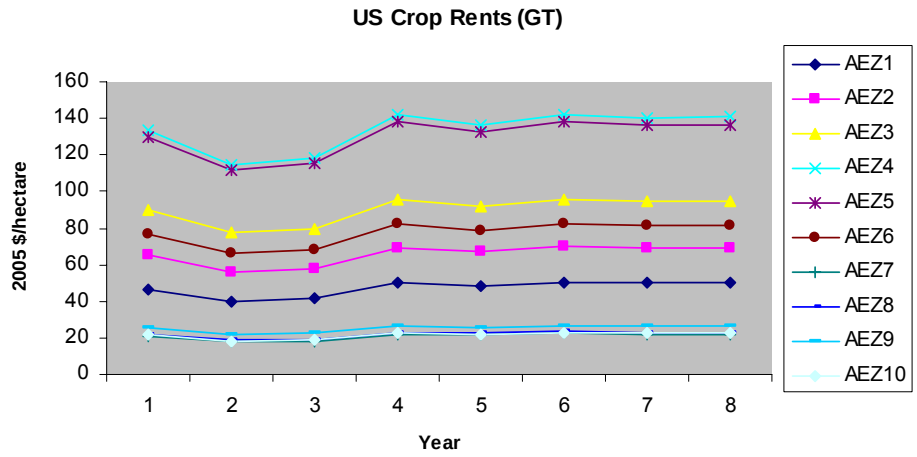



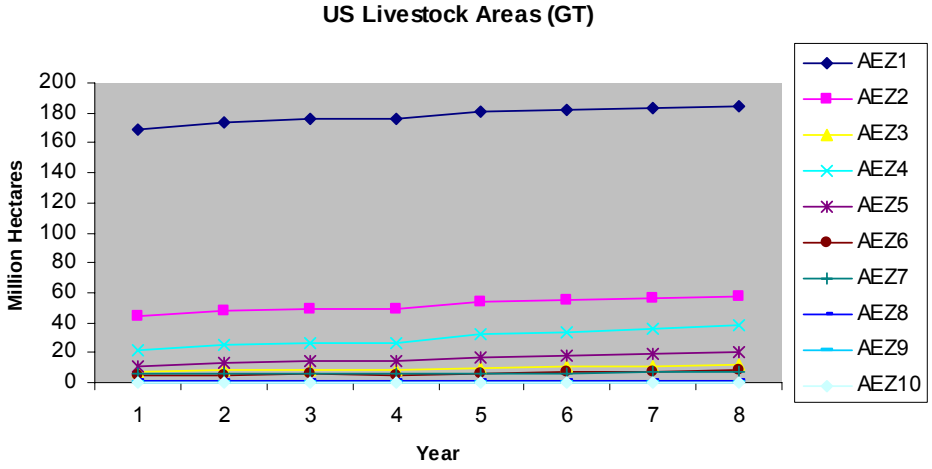



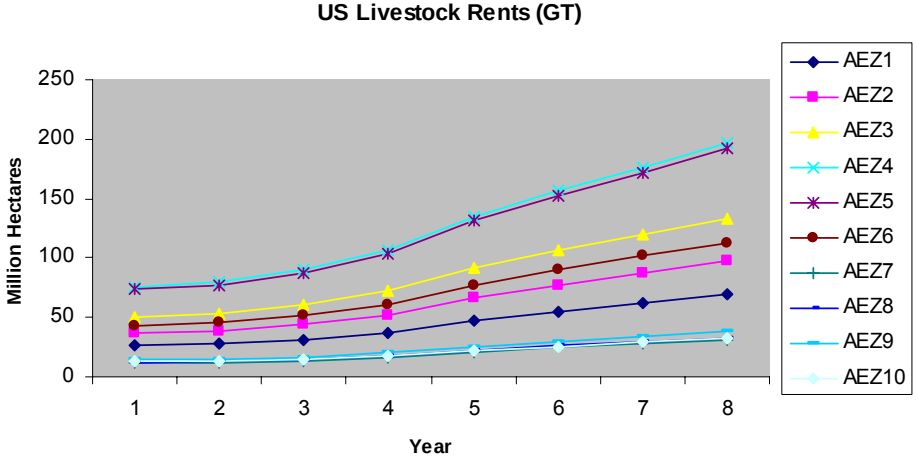
# Results: US Crops & Grazing

## *GTAP GDP & Population*



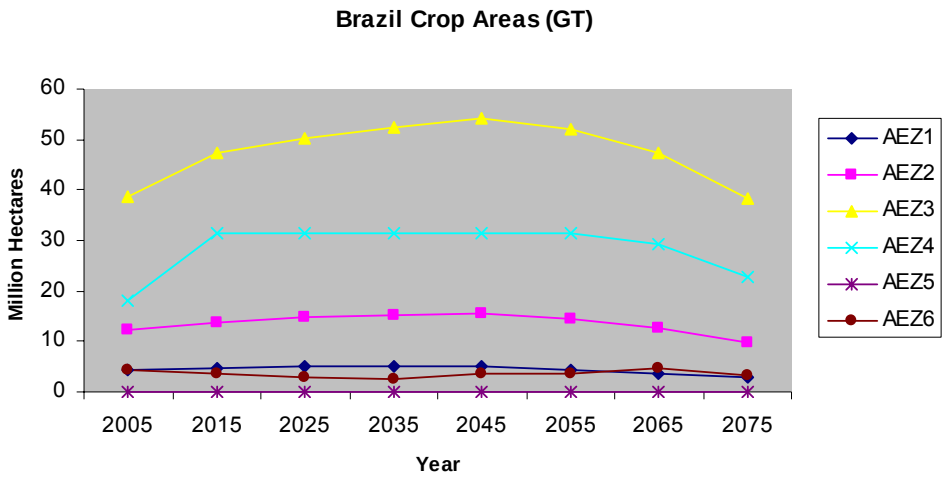



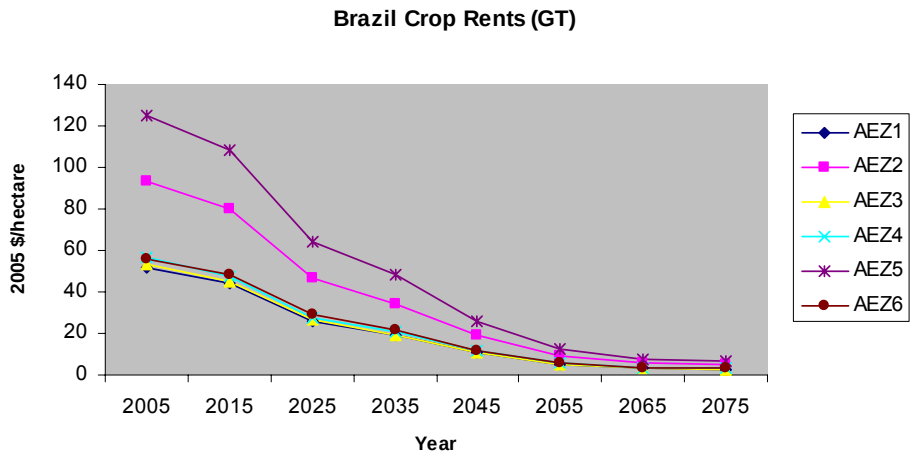



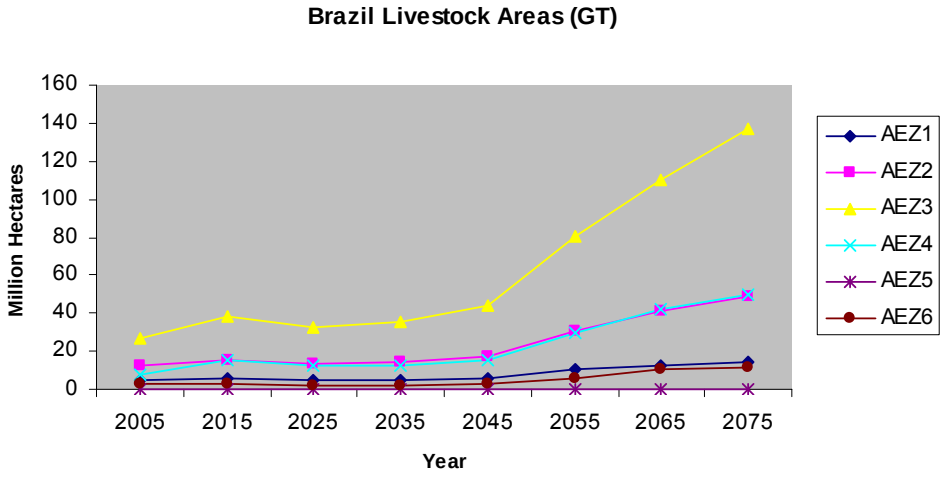

Tech change is positive in both crops and livestock

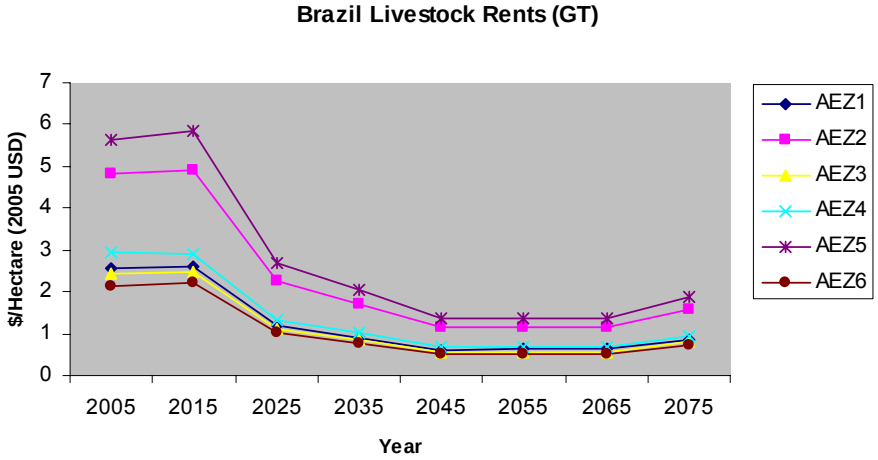
# Results: Brazil Crops & Grazing

## *GTAP GDP & Population*



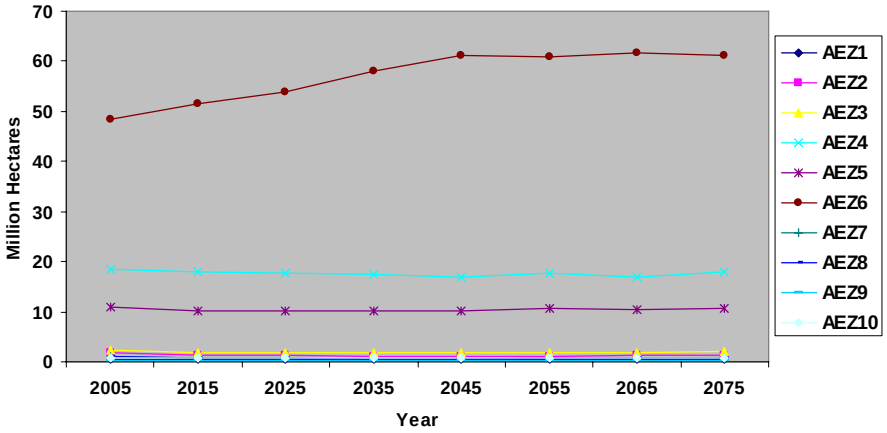



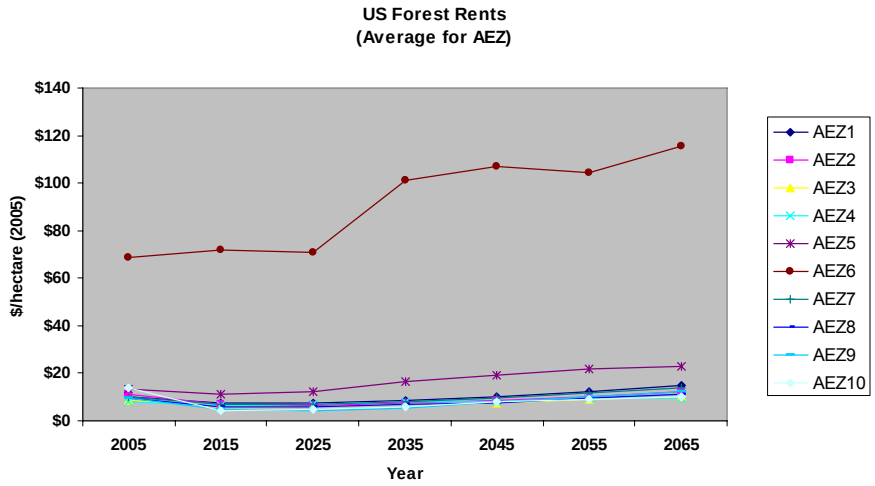



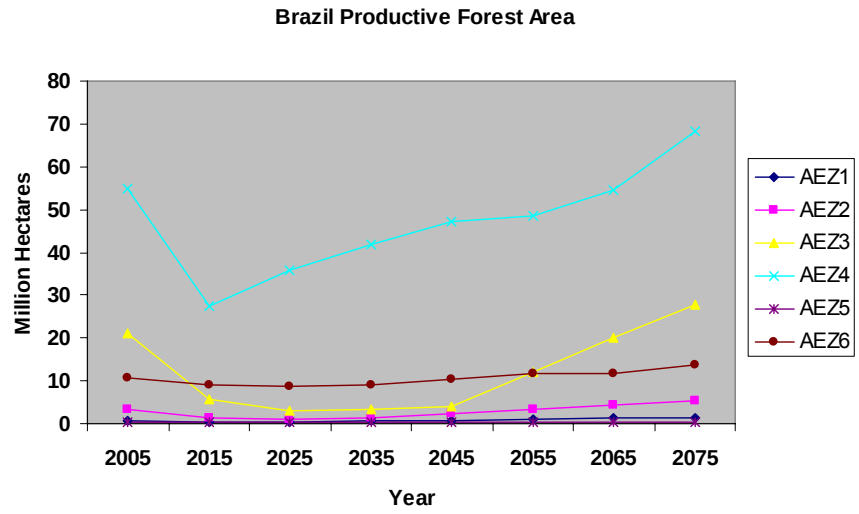

Tech change is negative in both crops and livestock

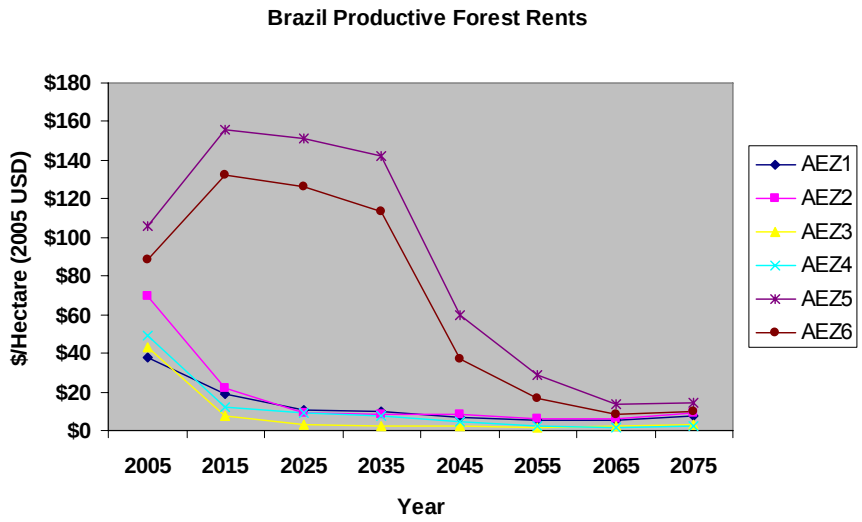
# Results: US & Brazil Forests

## *GTAP GDP & Population*



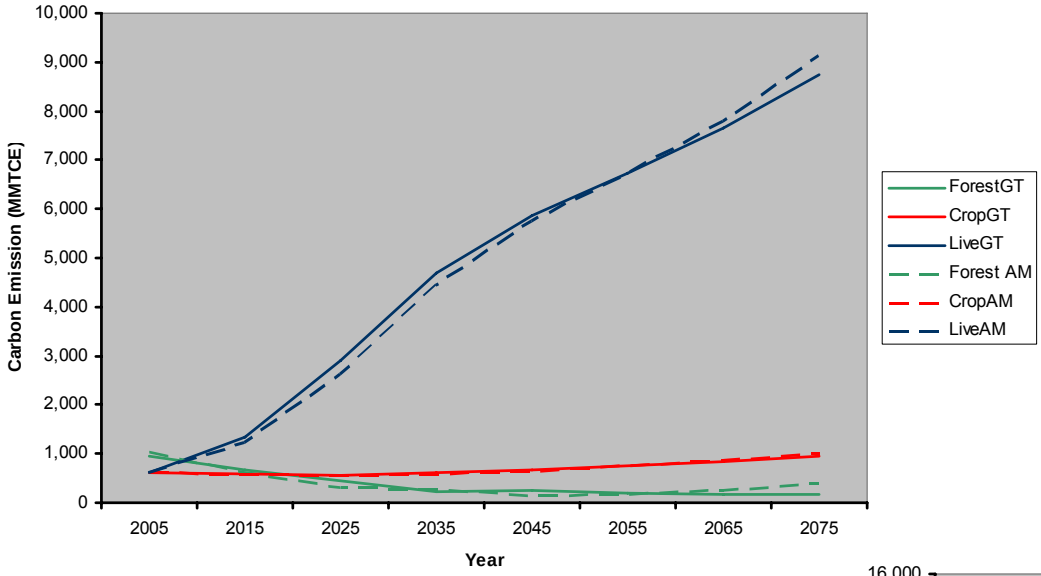



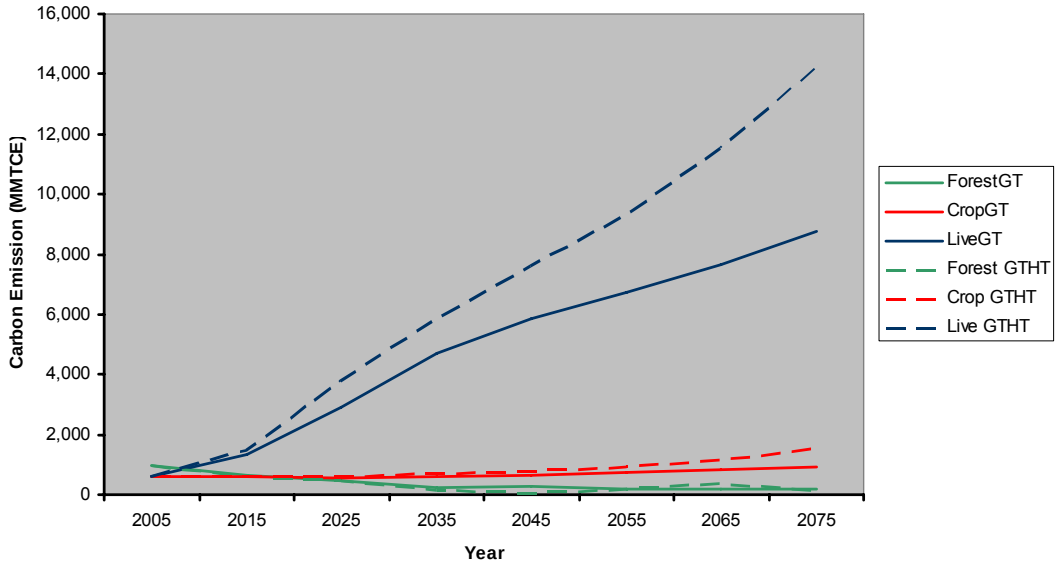
# Carbon Emissions

## *Sensitivity to Demand & Technology*



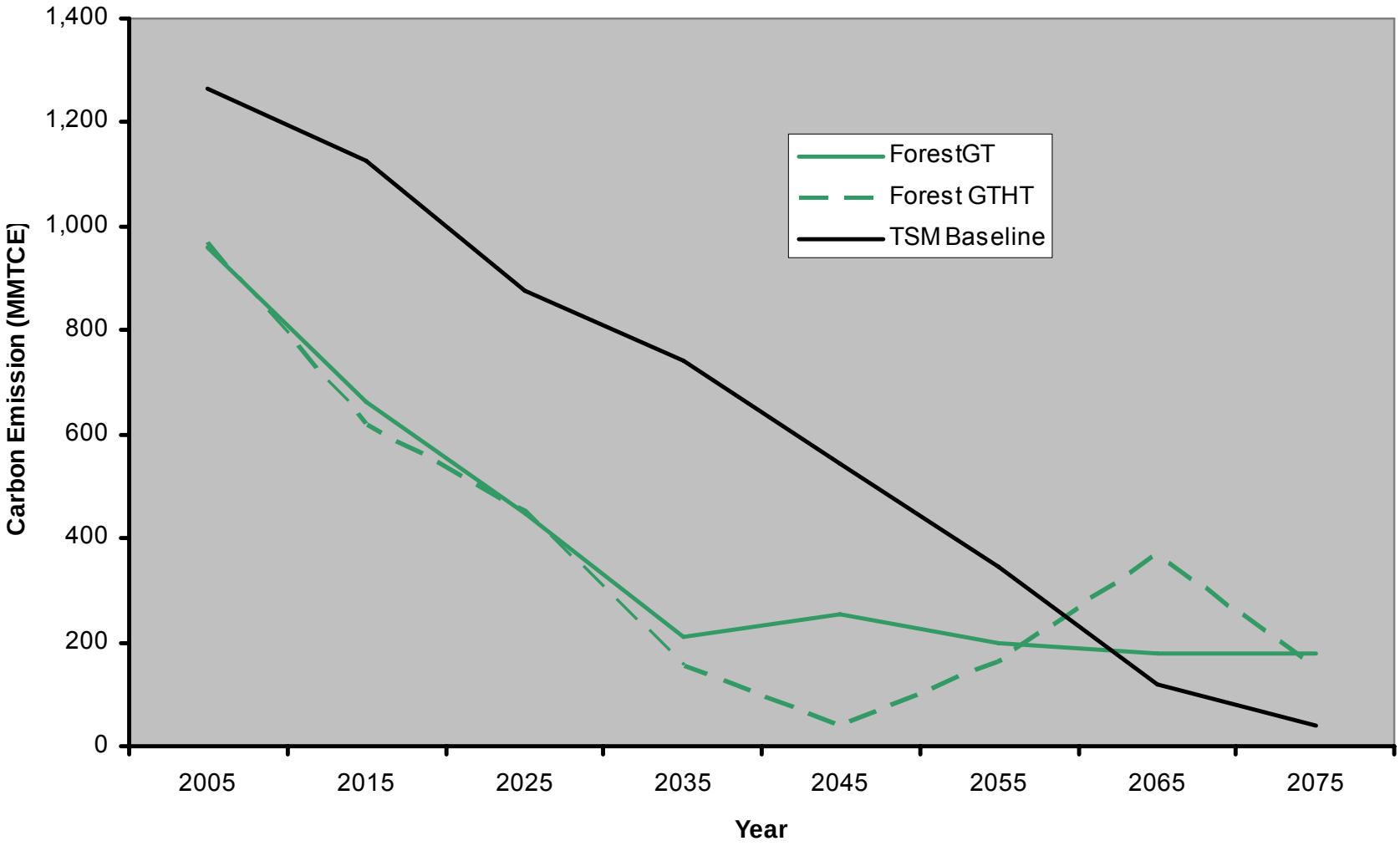

Alternative Demand

Alternative Tech. Chg.



# Forestry Carbon Emissions

*Sensitivity to Tech. Chg.*



# Next Steps

- Refine Baseline
- Develop carbon sequestration scenarios – forest only
- Introduce new sectors
  - Ruminant/non-ruminant
  - Different crops (e.g., rice paddies)
- Introduce abatement in agriculture