

# GHG Mitigation Potential and Costs for the LULUCF Sector: Methodology

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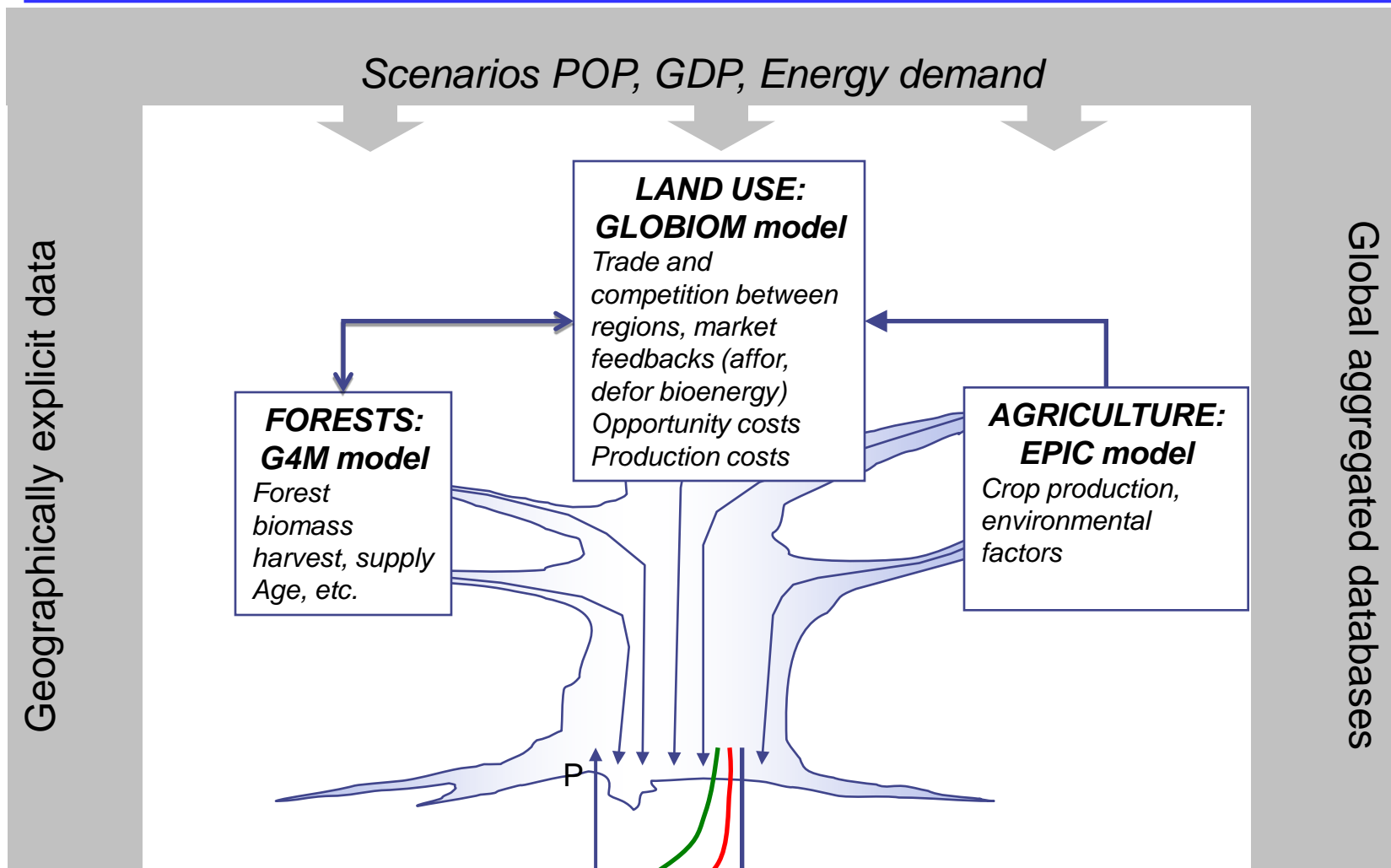
# LULUCF options considered

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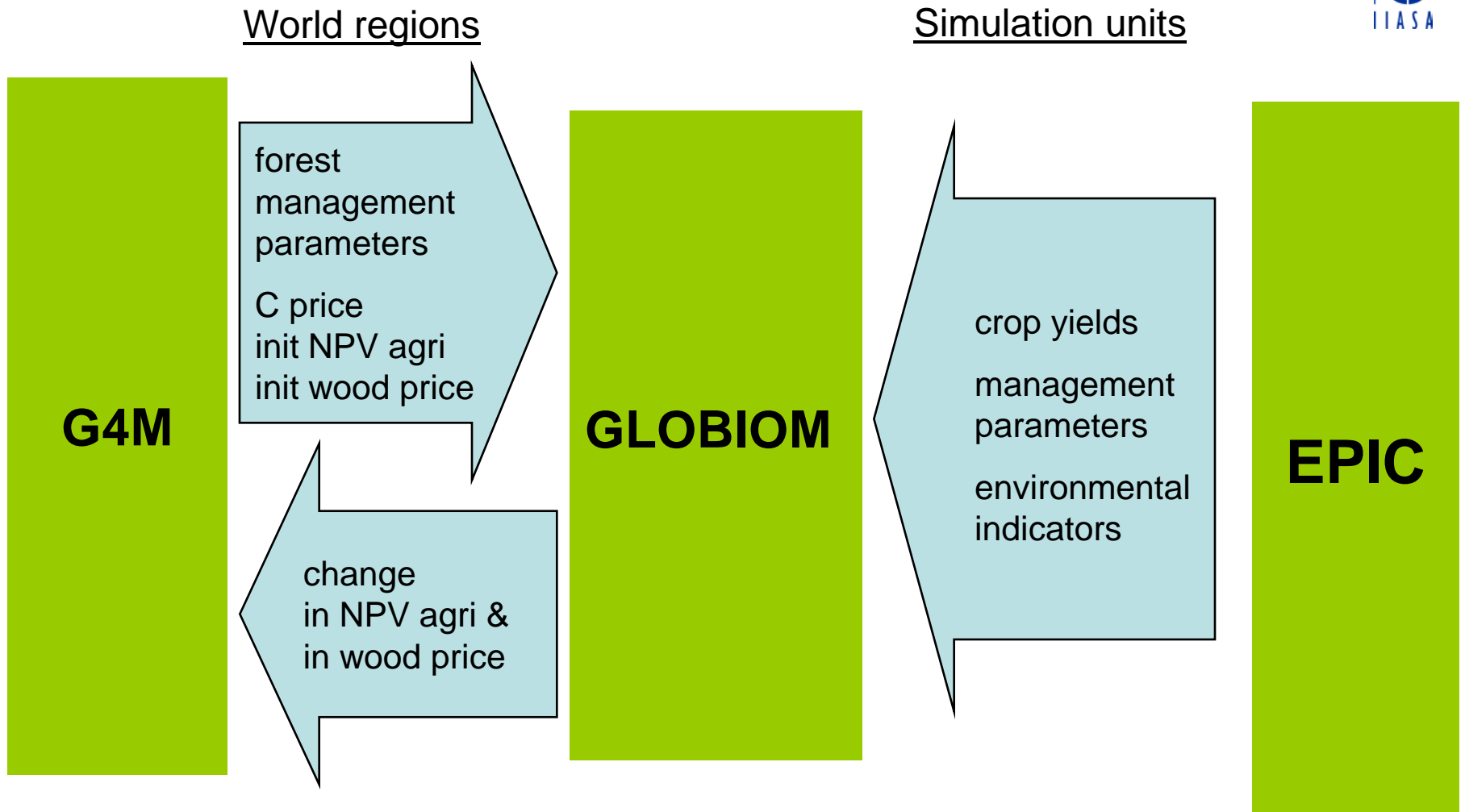
1. *Conservation*, prevent emissions from existing carbon pools, e.g., avoided deforestation
2. *Sequestration*, increase stocks in existing carbon pools, e.g., longer rotations (FM), afforestation on agricultural land
3. *Substitution*, substitute fossil fuel products with renewables, e.g., sustainable bioenergy: ethanol, biodiesel, fuel for combustion



# LULUCF mitigation model tree



# Data Flows between Models



# Modeling: Main data sources



Data	Res.	Year	Source
Landcover, GLC 2000	1x1 km	2000	Bartholom and Belward, 2005
Litter and Soil C, Dead Trees	0.5°x0.5°	2005	Kindermann et al., 2008 based on FAO data
NPP	0.5°x0.5°	Av.	Alexandrov et al. 1999
Aboveground biomass	0.5°x0.5°	2005	Kindermann et al., 2008 based on FAO data OR =f(NPP,A)
Protected areas	0.5°x0.5°	2004	WDPA Consortium, 2004
Agriculture suitability	0.5°x0.5°	2002	Ramankutty et al., 2002
Population density, GDP	0.5°x0.5°	1990 2100	Grubler et al., 2006 (IPCC Scenarios)
Buildup, Cropland	0.5°x0.5°	2010 2080	Tubiello & Fisher, 2006 (IPCC Scenarios)

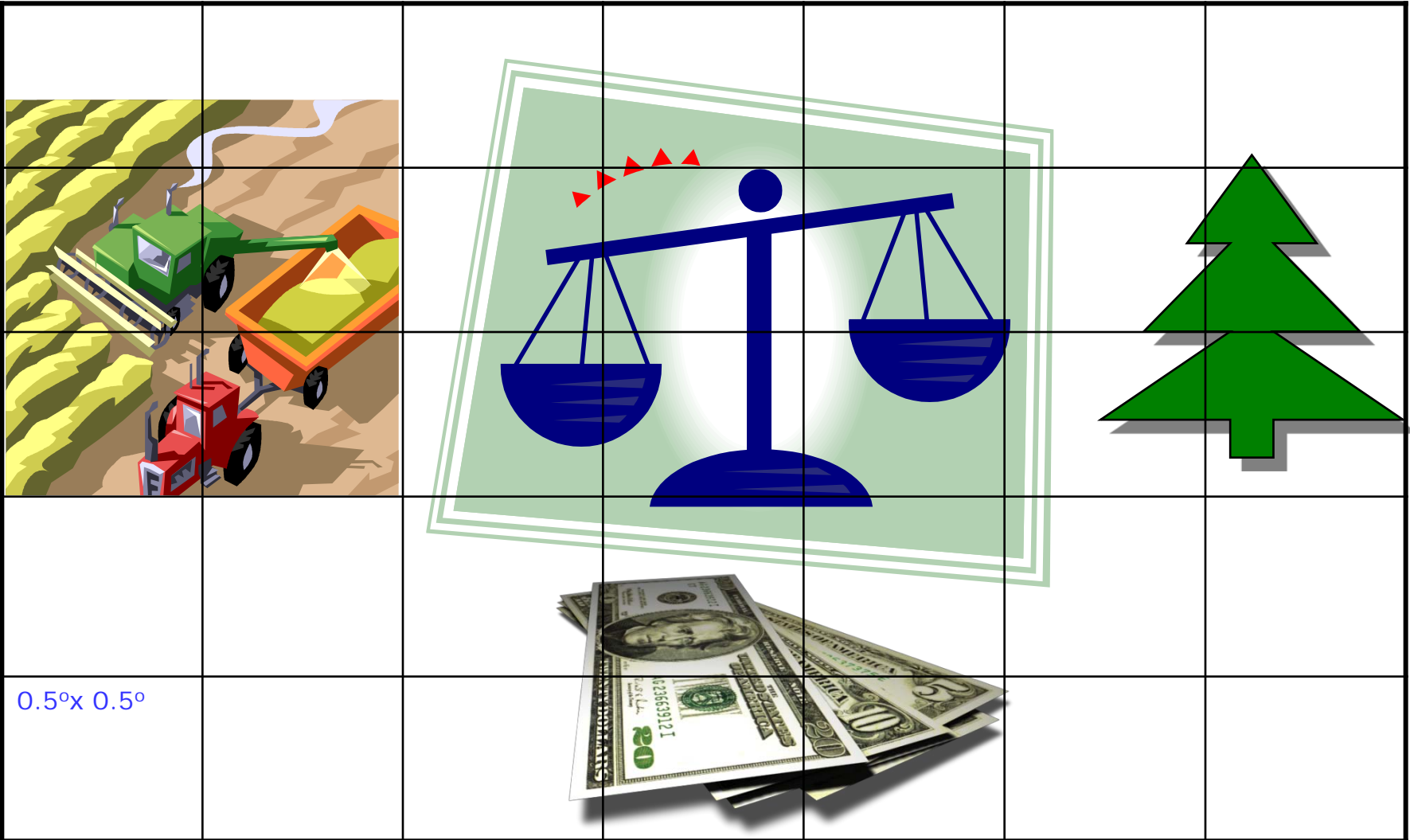
# Modeling: Main data sources

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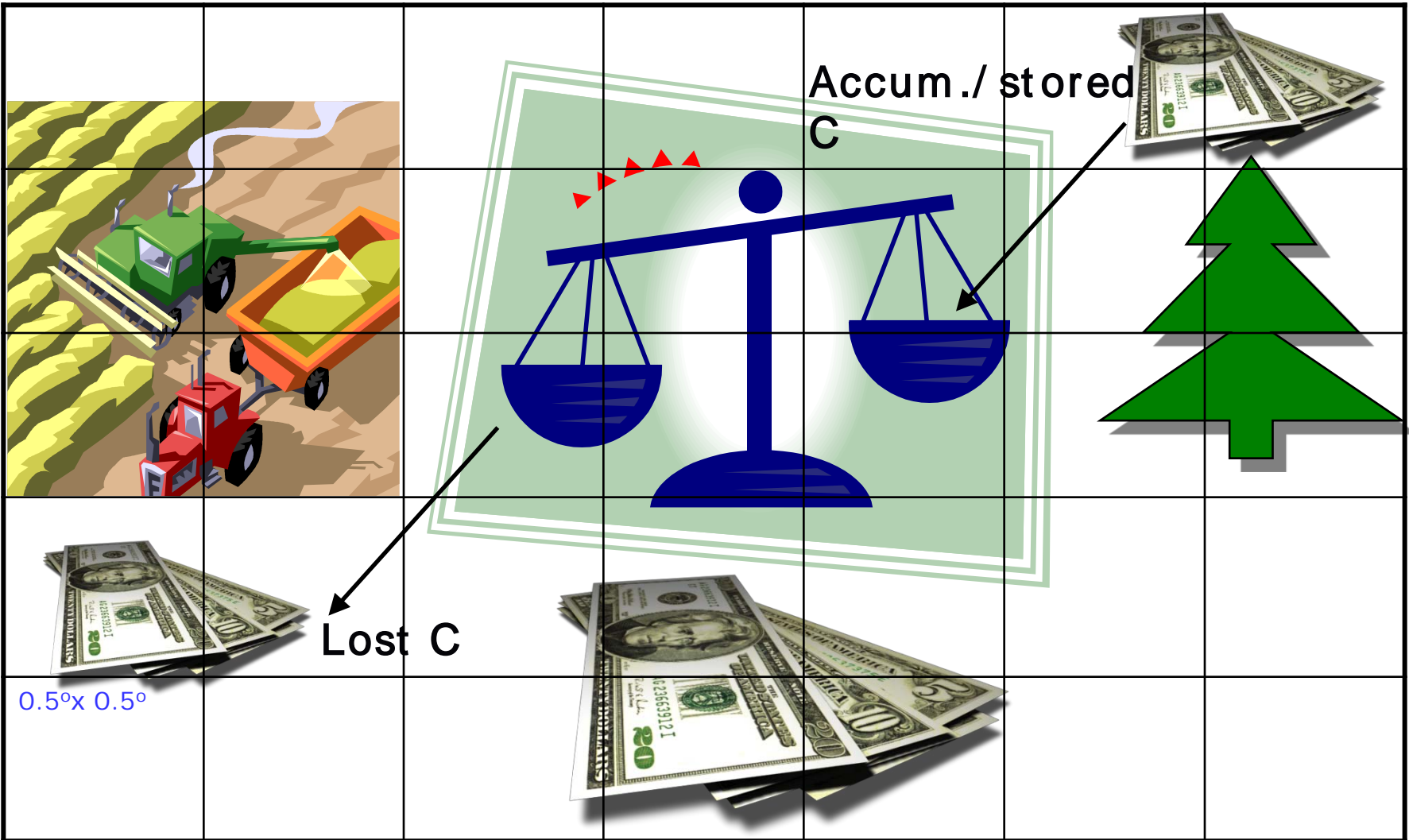


Data	Res.	Year	Source
Afforestation and deforestation rates	Annex-1 Country	2000 2005	Countries' reports to UNFCC (processed by K.Aoki)
Net forest area change rate	Country	2000 2005	FAO, FRA 2005
Forestry harvest statistics	Country	2005	FRA, 2005
Agricultural production, consumption, prices	Country	2000- 2005	FAOSTAT, 2008
Afforestation and deforestation rates	Global	2000 2005	FAO, FRA 2005

# G4M: Modeling Approach



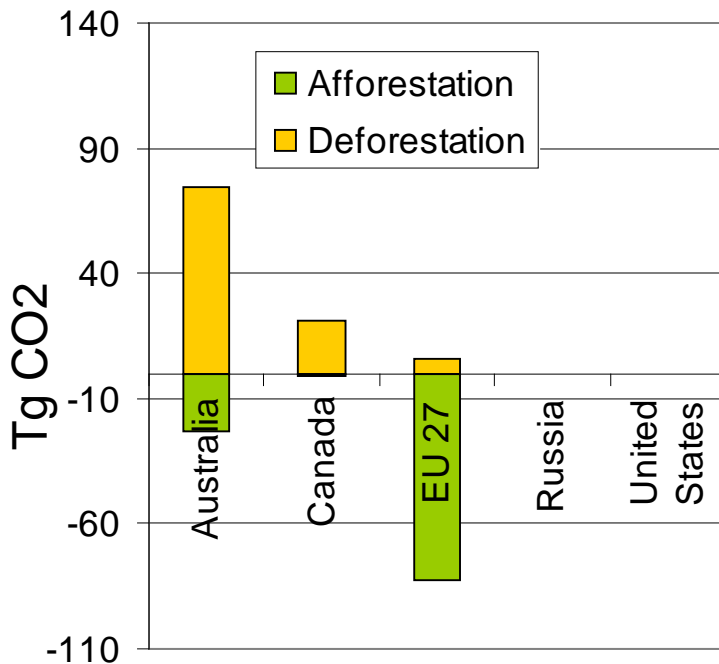
# G4M: Modeling Approach



# Baseline construction and calibration e.g. afforestation, deforestation



Reported 2005



UNFCCC 2008

Adjust country specific

- *Hurdles* (multiplier of *Forestry NPV<sub>i</sub>*)
- *DeforRateCoef* (multiplier of *Defor Rate<sub>i</sub>*)
- *AfforRateCoef* (multiplier of *Affor Rate<sub>i</sub>*)

to match (average 2000-2005)

- global FAO *Defor* and *Affor Rates*
- non-Annex 1: FAO *Net Forest Area Change*
- Annex 1: UNFCCC reported values on *Defor* and *Affor Rates*

# GLOBIOM: Model description

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## Global Biomass Optimisation Model

**Coverage:** global - 27 world regions

### 3 land based sectors:

Forestry: traditional forests for sawnwood, and pulp and paper production

Agriculture: major agricultural crops

Bioenergy: conventional crops, forest, and dedicated short rotation plantations

## Economic optimization model (FASOM structure)

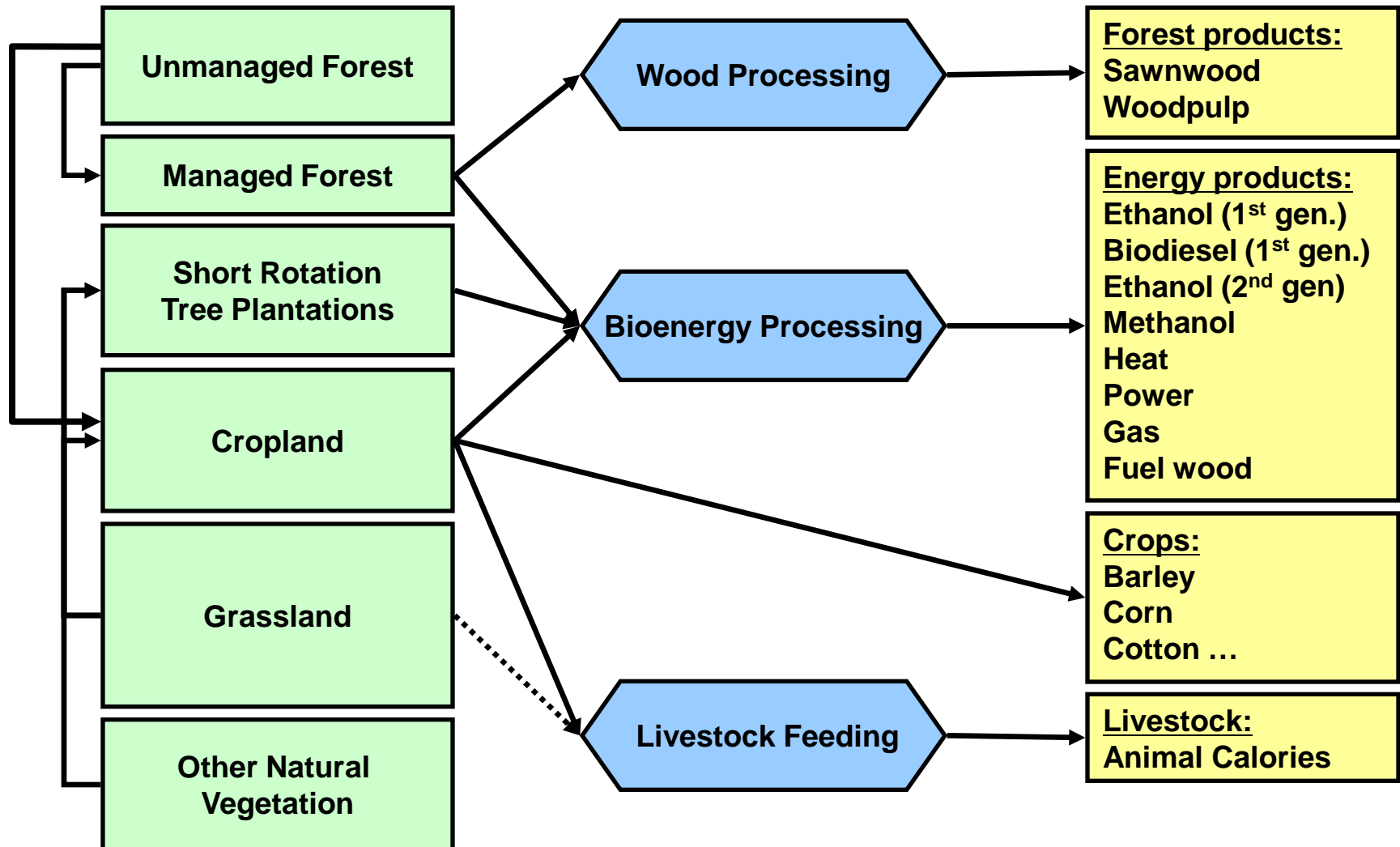
### Output

Production

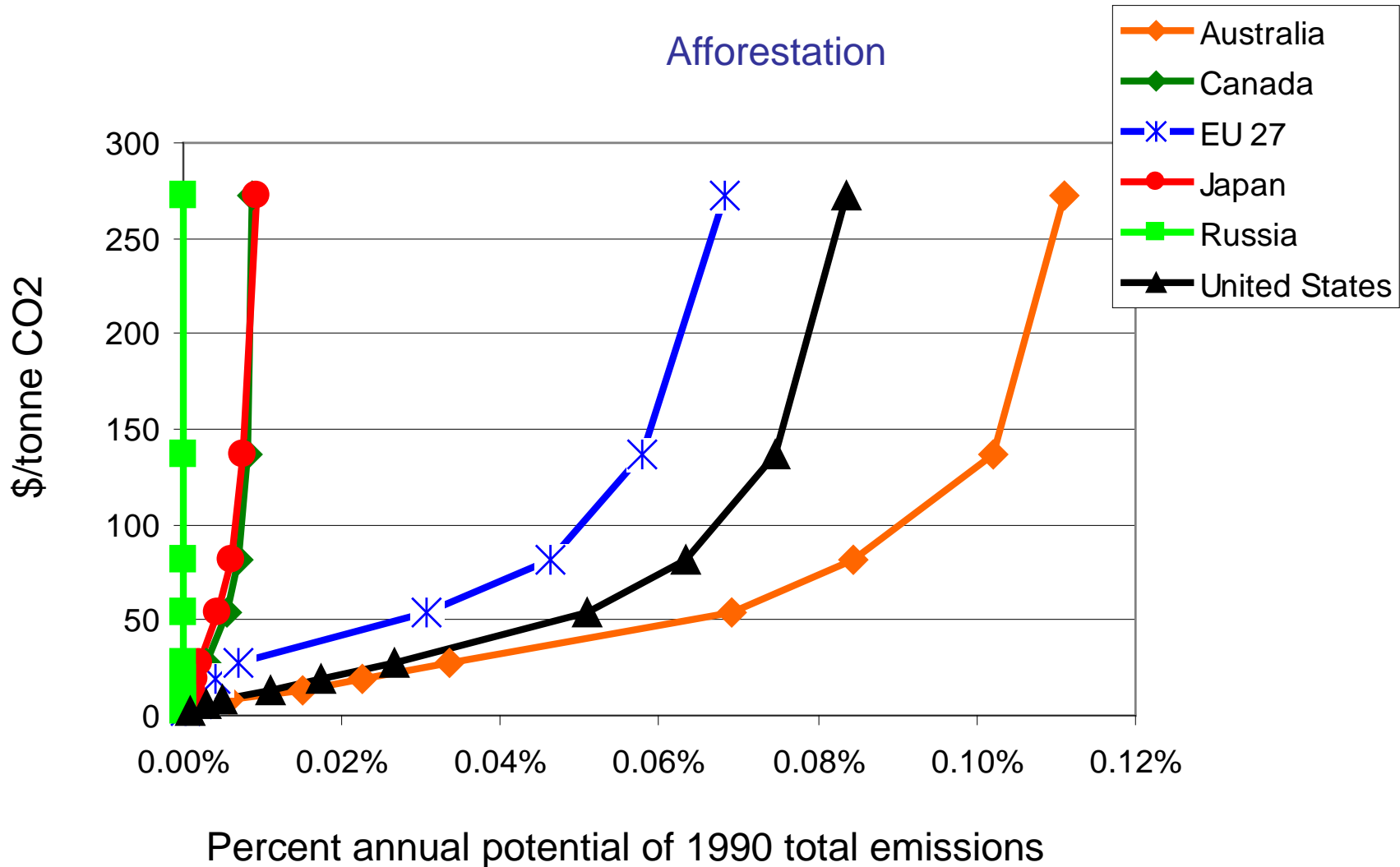
Consumption

Prices, trade flows, etc.

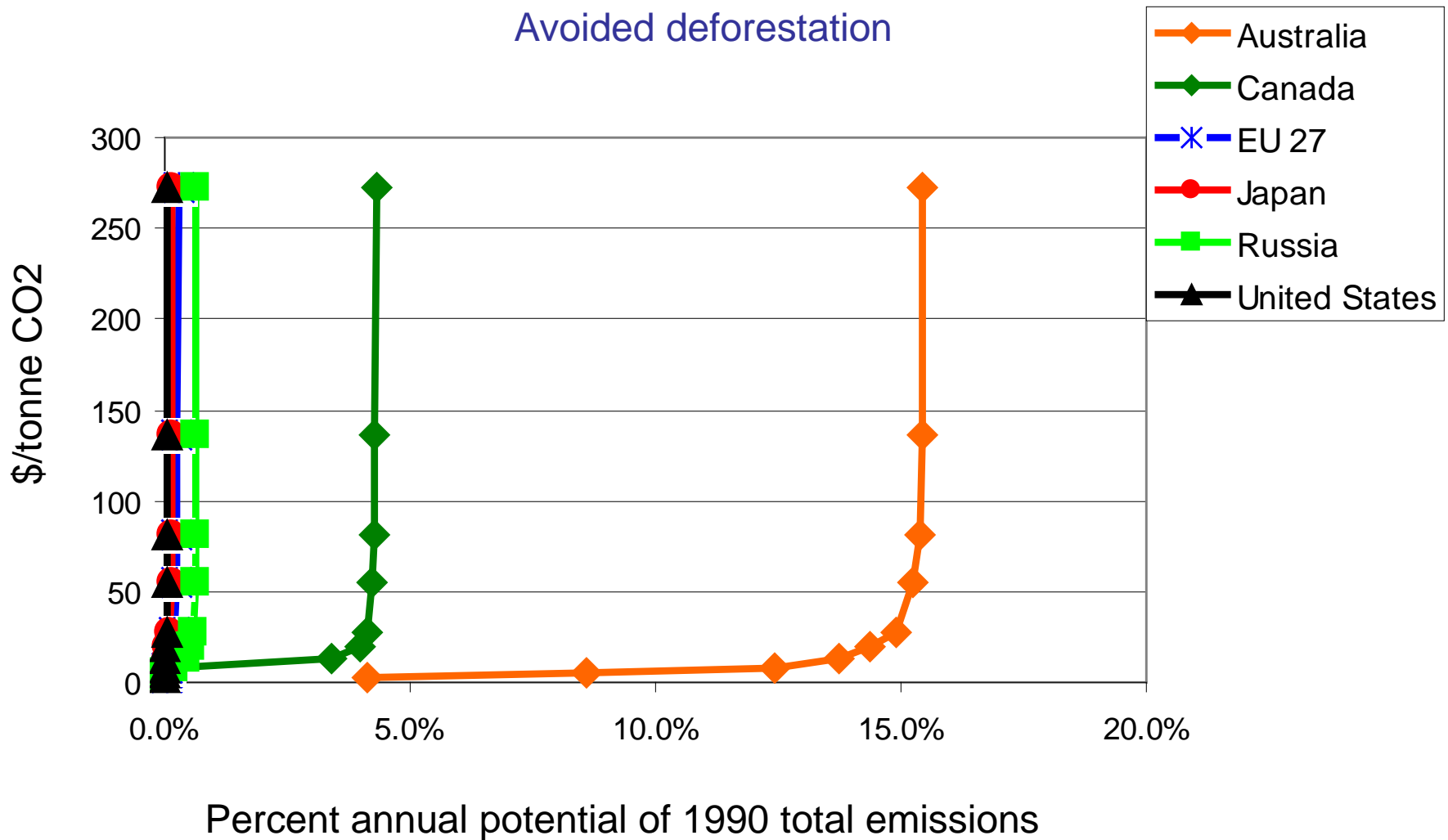
# GLOBIOM: Modeling Approach



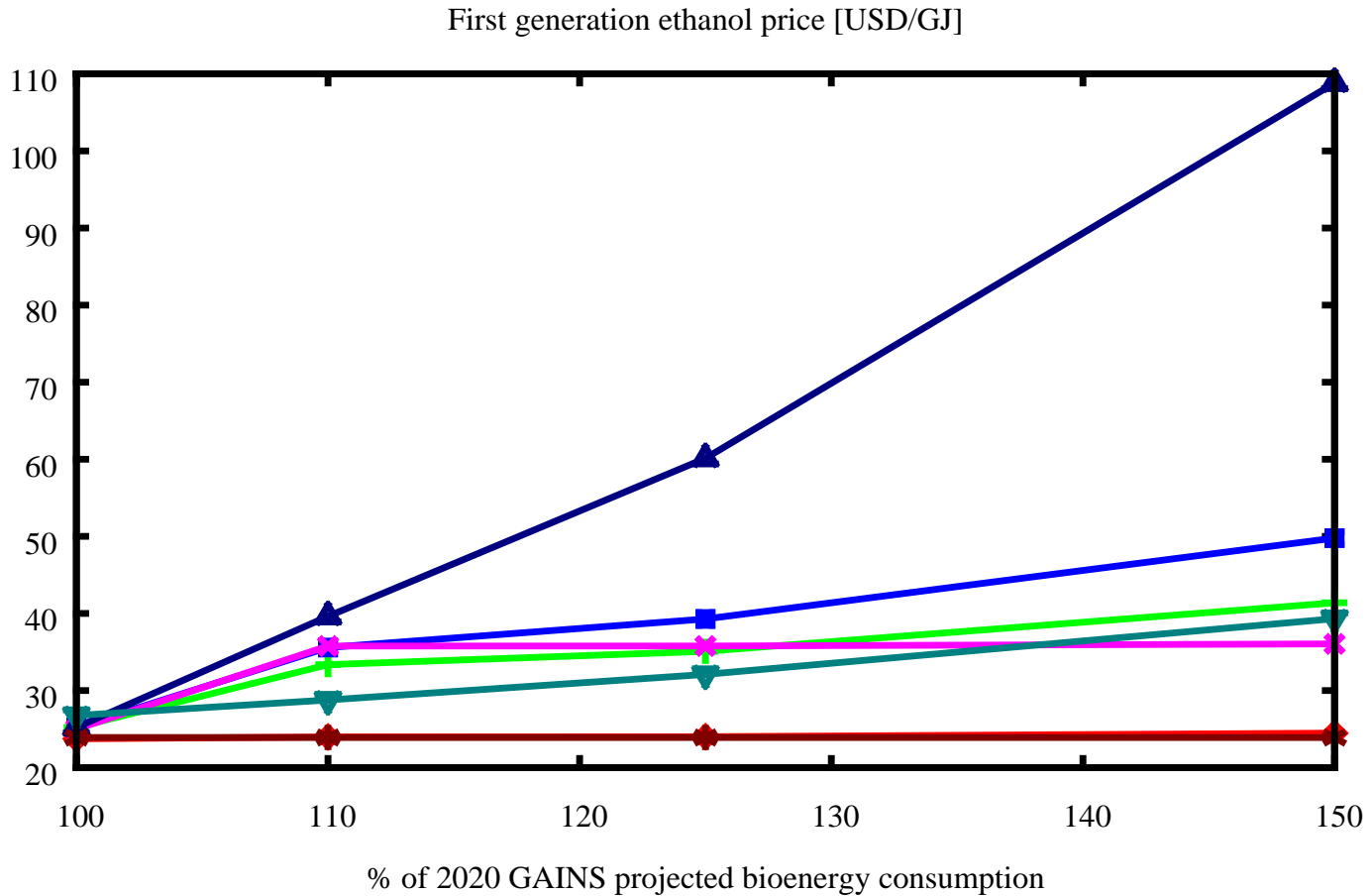
# Marginal abatement cost curves: Afforestation until 2020




# Marginal abatement cost curves: Avoided deforestation until 2020



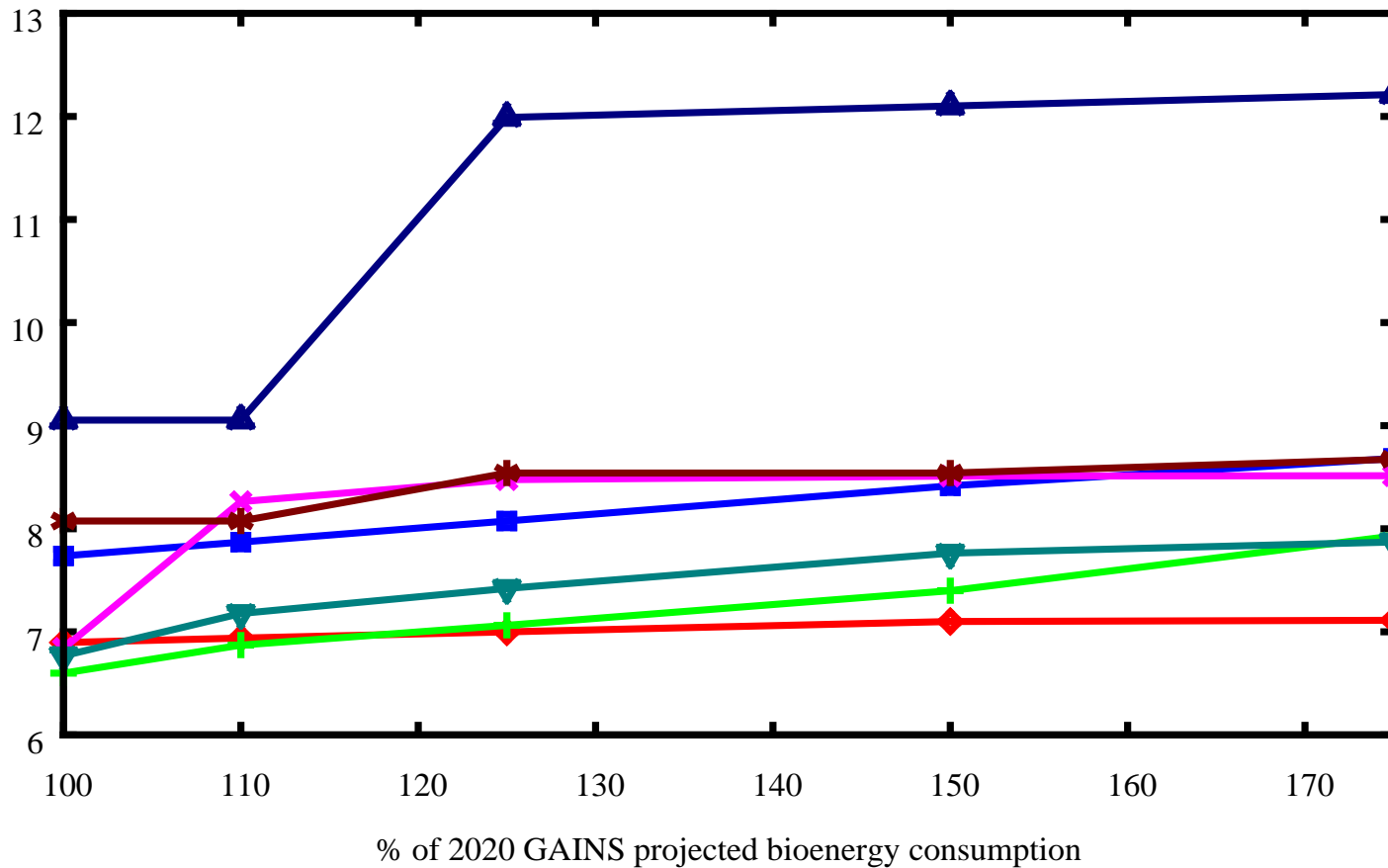
# Bioenergy supply curves in 2020: First Generation Ethanol







ANewZ  EU\_27  JapReg  USReg   
CanReg  X\_USSR  SwiNor 

# Bioenergy supply curves in 2020: Cogeneration of Heat and Power

Cogeneration heat and power price [USD/GJ]



ANewZ  EU\_27  JapReg  USReg   
CanReg  X\_USSR  SwiNor 

# Comparison to other studies: e.g. US



Comparison of USEPA (2009) versus GAINS estimates at about 10 US\$ per t CO<sub>2</sub> (MtCO<sub>2</sub>/yr)

	Afforestation	Avoided deforestation	Forest management
USEPA	7.4	-	75
our study	<1	<1	65

- Afforestation to begin later in our model
- Baseline for afforestation is similar (USEPA 19, GAINS 12 MtCO<sub>2</sub>/yr)
- Forest management of our study does not (yet) take market feedbacks into account
- FM results from us preliminary

# G4M sensitivity study

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## Sensitivities to wood price, % / \$/m<sup>3</sup>

Year	2005	2020
Deforestation Rate	-5.39	1.96
Afforestation Rate	1.81	0.30

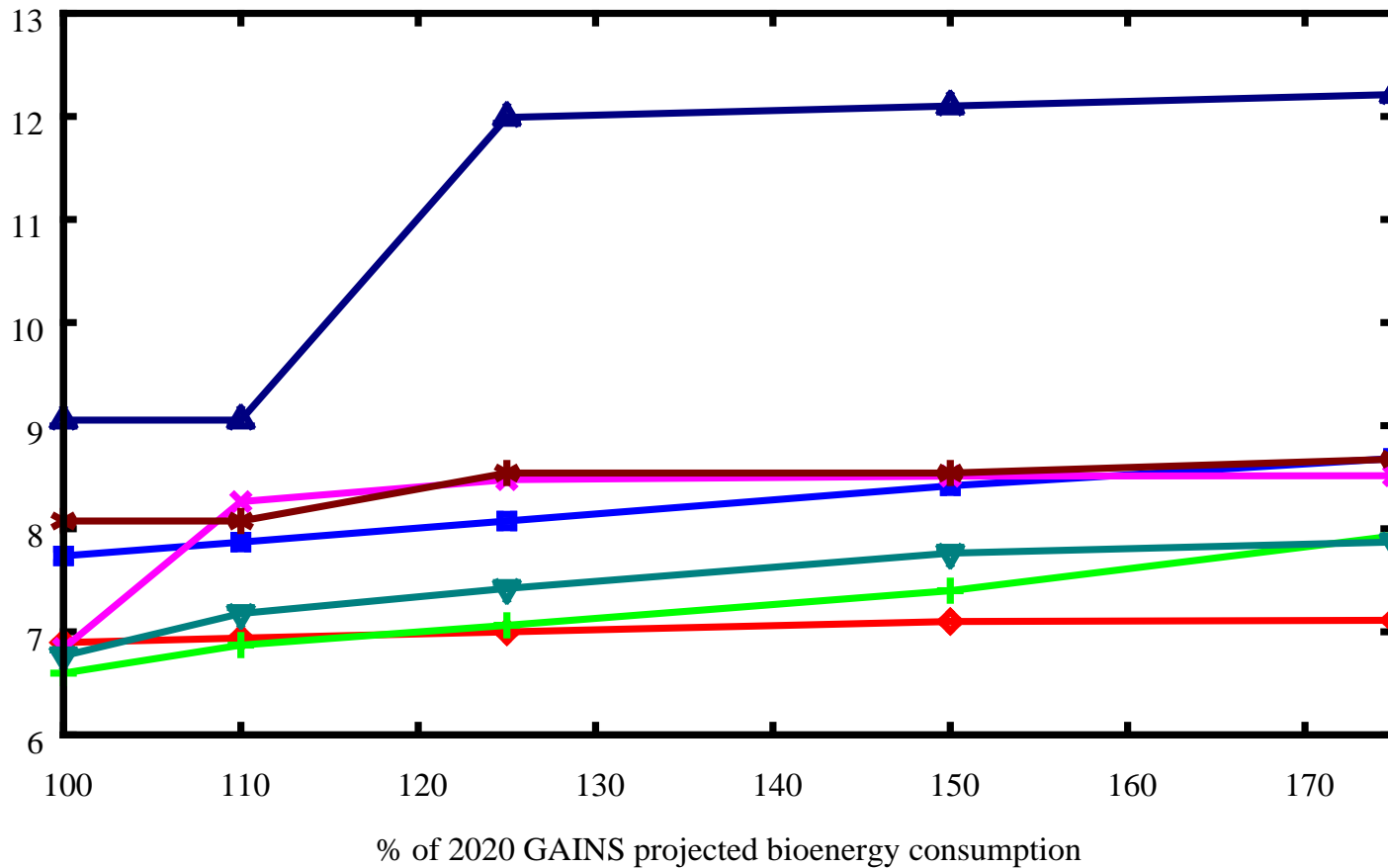
## Sensitivities to agriculture land price, % / \$/ha

Year	2005	2020
Deforestation Rate	0.02	0.01
Afforestation Rate	-0.04	-0.01

# GLOBIOM sensitivity: CHP with grasslands



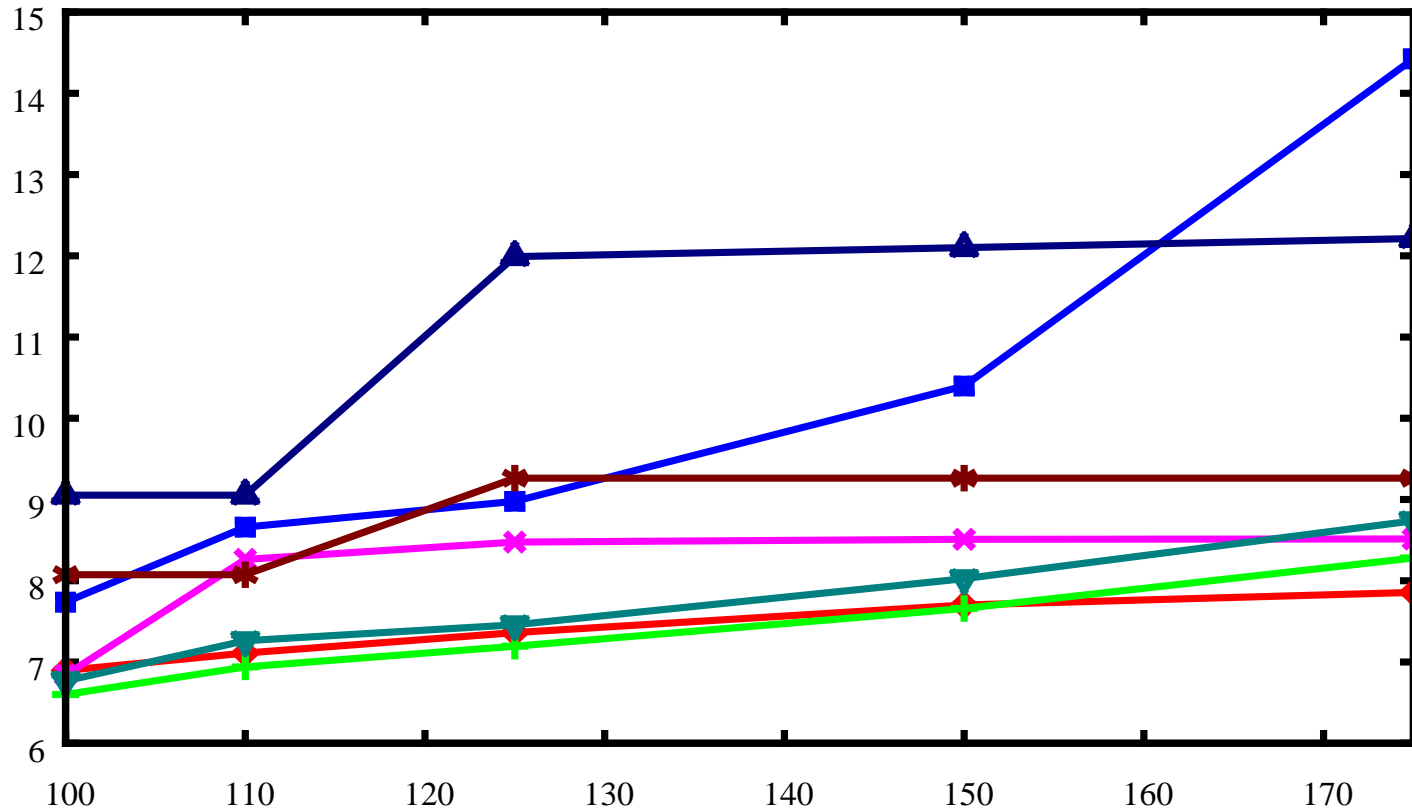
Cogeneration heat and power price [USD/GJ]



# GLOBIOM sensitivity: CHP without grasslands



Cogeneration heat and power price[USD/GJ]



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# Limitations and caveats

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- Baseline assumptions
  - Forest management, deforestation
  - Not all countries reporting
  - Future crop yields
- Data issues
  - Global land cover, NPP, climate change
  - Forest inventories
  - Countries' reports to the UNFCCC
  - Global statistics on forests, products, etc.
  - System switch cost
- Market
  - Market feedbacks are included for Afforestation & Deforestation
  - Forest management: costs expected to rise in case of timber shortage
- .....

# Conclusions

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- Integrated LULUCF Model cluster is developed
- Mitigation potentials for Annex-I comp. to 1990
  - Avoided deforestation < 1% (for some countries up to 15%)
  - Afforestation < 1%
  - Afforestation is expected to increase substantially after 2020
- Bioenergy potential
  - Agricultural crop biofuels – 25% above baseline
  - Wood-based bioenergy – 75% above baseline
- Large uncertainties specific to the biosphere

# Additional information

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# References

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- Benitez P, McCallum I, Obersteiner M, Yamagata Y, 2004: Global Supply for Carbon Sequestration: Identifying Least-Cost Afforestation Sites Under Country Risk Consideration. Interim Report IR-04-022, International Institute for Applied System Analysis.
- Benitez PC, Obersteiner M, 2006: Site identification for carbon sequestration in Latin America: A grid-based economic approach. *Forest Policy and Economics*, 8:636–651.
- Kindermann G., Obersteiner M., Rametsteiner E. and McCallum I., 2006: Predicting the Deforestation–Trend under Different Carbon–Prices. *Carbon Balance and Management*, 1:15; doi:10.1186/1750-0680-1-15
- Kindermann G, McCallum I, Fritz S, Obersteiner M., 2008: A global forest growing stock, biomass and carbon map based on FAO statistics. *Silva Fennica*. Vol.42(3), pp.387-396
- Nijnik M. and Bizikova L., 2008: Responding to the Kyoto Protocol through forestry: A comparison of opportunities for several countries in Europe. *Forest Policy and Economics* 10, p. 257–269
- Rokityanskiy D., Benítez P., Kraxner F., et al., 2007: Geographically explicit global modeling of land-use change, carbon sequestration, and biomass supply. *Technological Forecasting and Social Change*, Volume 74, Issue 7, September 2007, P. 1057-1082

# G4M: Carbon pools and fluxes

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## Pools:

- Aboveground biomass Kindermann et al., 2006  
based on FAO data OR
- Belowground biomass =  $f(Ab, E, (NPP), A)$

- Litter
  - SOC
  - Dead trees
- Kindermann et al., 2008 based on  
FAO data
- 
- Three black arrows originate from the right side of the words 'Litter', 'SOC', and 'Dead trees' and converge towards the text 'Kindermann et al., 2008 based on FAO data'.

# G4M: Carbon pools and fluxes

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## Emissions and sinks:

- Burning of slash, dead trees and coarse roots
- Loosing and accumulation of litter (0.5tC/ha)
- Changes in SOC ( $\pm 40\%$ )
- Changes in products
- Ab and BI Biomass increase

# Comparison to other studies: Projections for Ukraine

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## Forest area change projections for 2010-2050 at C price 0 \$/tC, th.ha

Nijnik and Bizikova, 2008	G4M
2 289	2 588

## Forest area change projections for 2010-2015 at C price 0 \$/tC, th.ha

SP "Forests of Ukraine" in 2002-2015	G4M
300	500

# G4M: Carbon value mechanisms

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- **Carbon "Tax"**
  - **Pay money for lost C due to deforestation**
  - **Get money for accumulated C due to a/re-forestation**
- Regular incentive payments
  - Get money every e.g. 5 years for C in forest phytomass

Kindermann et al. 2006

# G4M: Calibration

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## Adjust country specific

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## Optimization Model (FASOM structure)

Recursive dynamic spatial equilibrium model

Maximization of the social welfare (Producer plus consumer surplus)

**Partial equilibrium model (land use sector only):** endogenous prices

## Output

Production

Consumption

Prices, trade flows, etc.

# EPIC: Model description

Crop related parameters: SimU → EPIC (Schmid, E.)

## Major inputs:

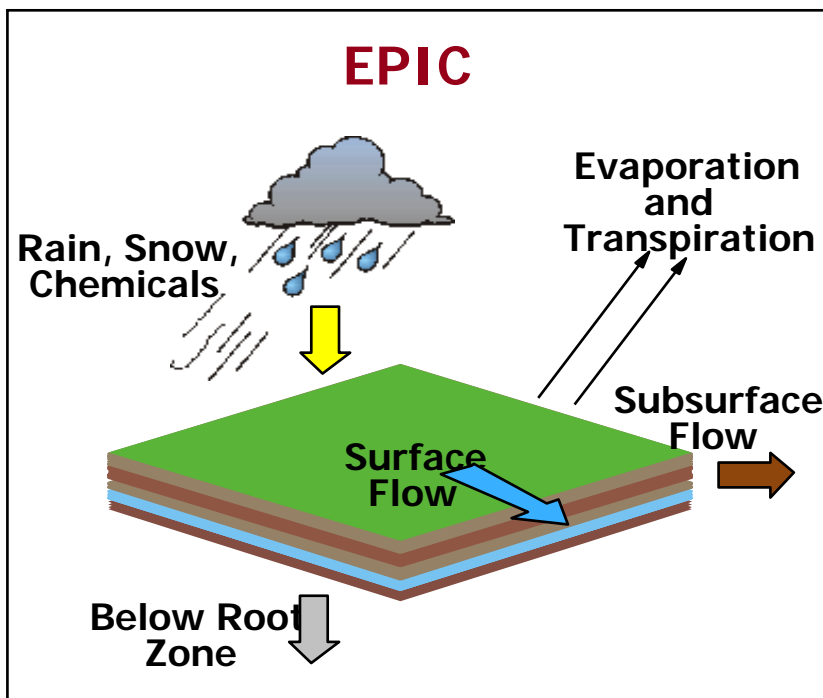
Weather  
Soil  
Topography  
Land management

## Major outputs:

Yields  
Environmental variables

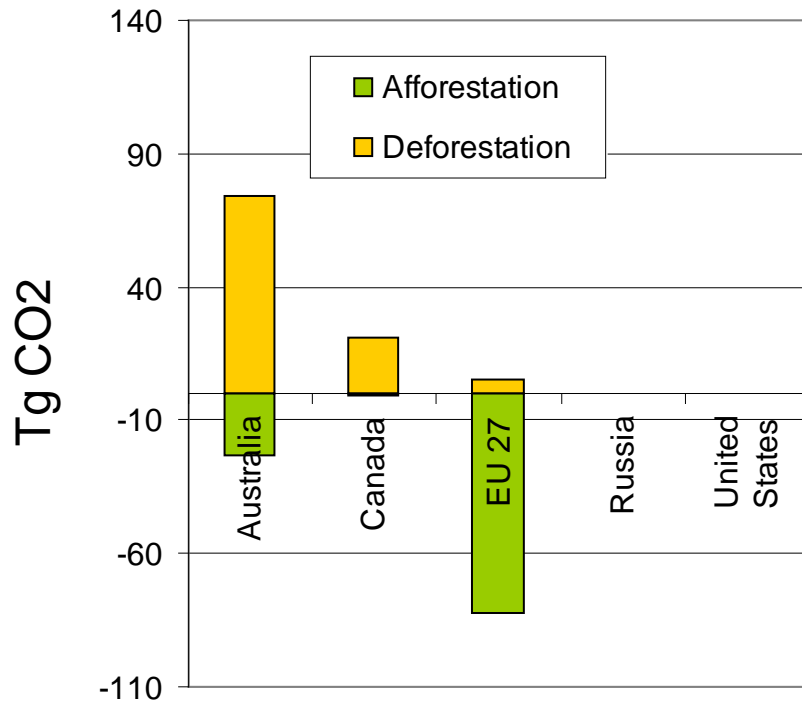
## 4 management systems:

High input, Low input, Irrigated, Subsistence



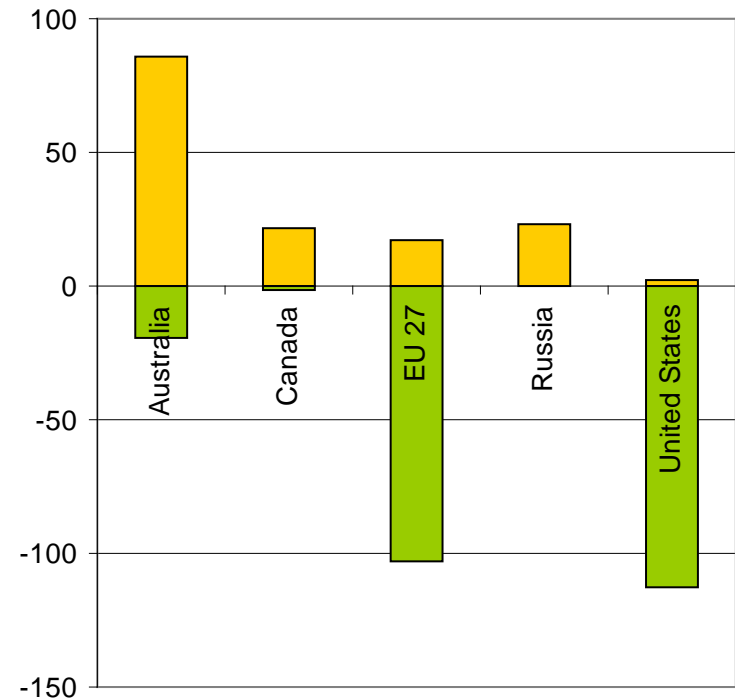
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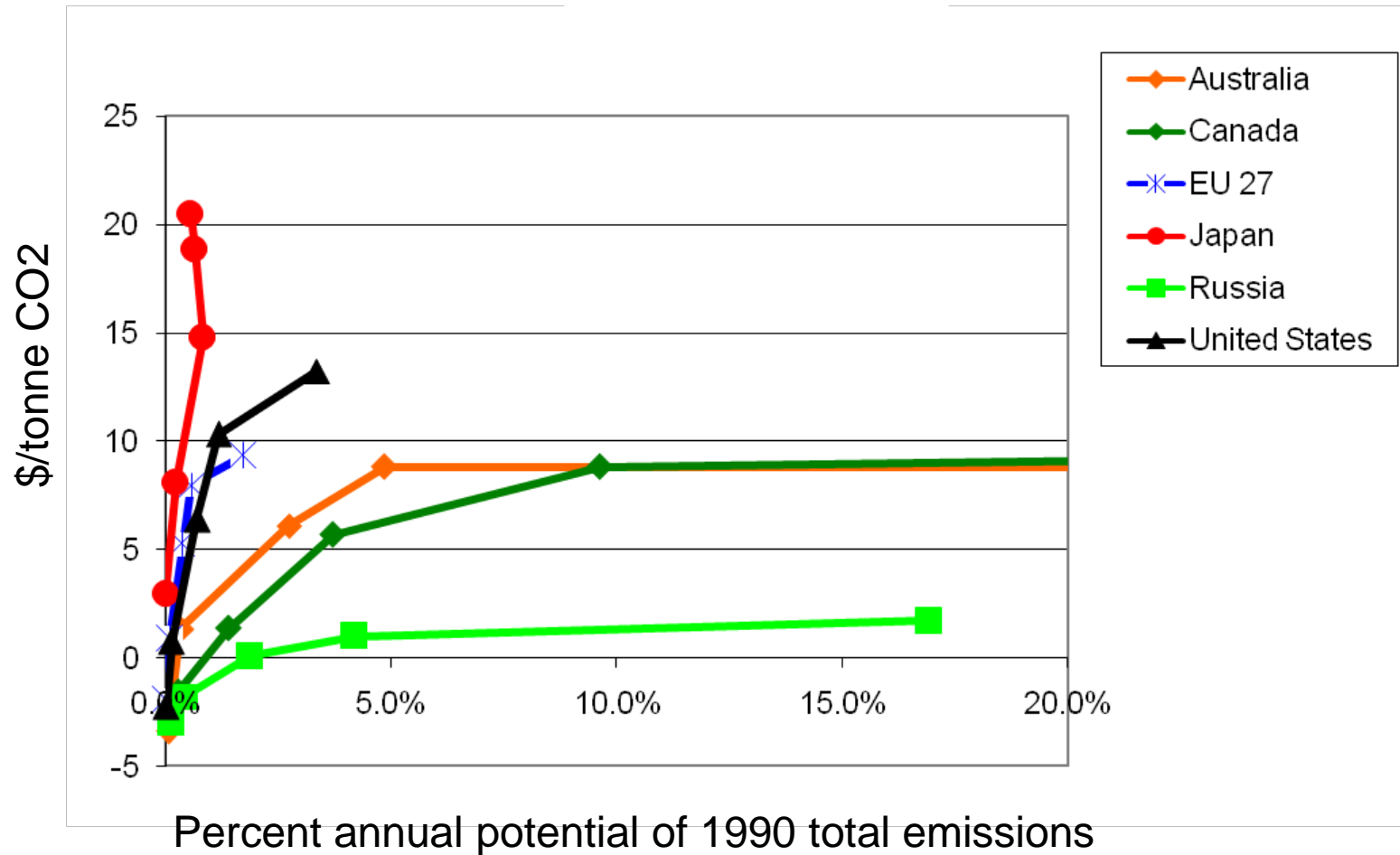


UNFCCC 2008

## Baseline in 2020 (G4M)



# Marginal abatement cost curve: Forest management until 2020



# G4M sensitivity study

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## Sensitivities to wood price, ha/year/\$/m3

Year	2005	2010	2015	2020
Deforestation Rate	-755,124	-353,742	-187,405	134,413
Afforestation Rate	104,637	92,027	61,707	16,020

# G4M sensitivity study

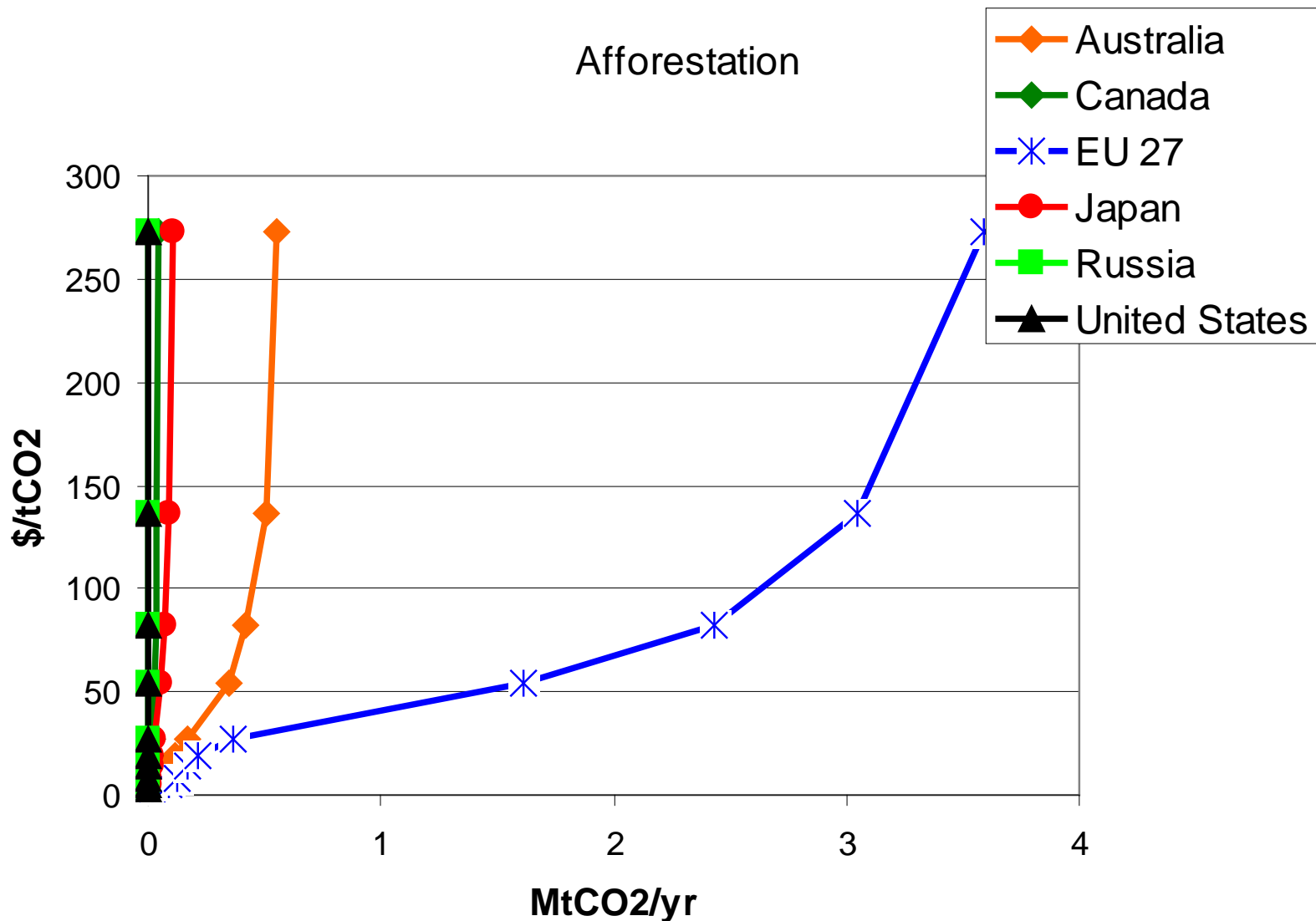
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## Sensitivities to agriculture land price, ha/year/\$/ha

Year	2005	2010	2015	2020
Deforestation Rate	3,378	914	1,119	375
Afforestation Rate	-2,061	-1,190	-1,549	-696

# Marginal abatement cost curves: Afforestation until 2020



# Marginal abatement cost curves: Avoided deforestation until 2020

