Tools for Estimating the Costs of Carbon Sequestration through Avoided Deforestation: Global Land Use Modeling

Brent Sohngen
Ohio State University

World Bank Workshop on "The Costs of Reducing Carbon Emissions from Deforestation and Forest Degradation"
May 27, 2008

Acknowledgements:
Ken Andrasko, Sandra Brown, Brian Murray, Michael Obersteiner, Jayant Sathaye Bin Sun,
US Department of Energy, US Environmental Protection Agency,
Ohio State University Climate Water and Carbon Initiative.

Global Forest and Land Use Model

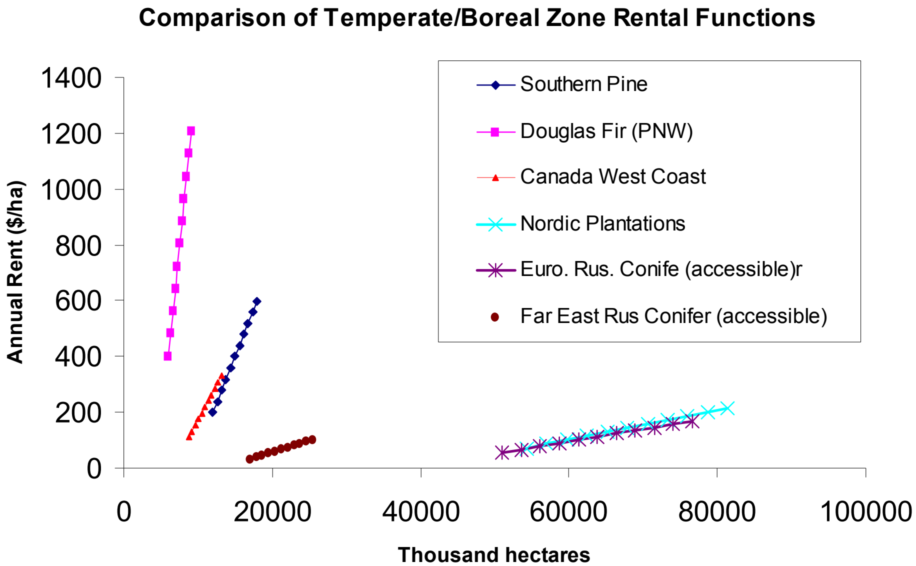
Approach…

- Maximize welfare in timber markets
  - Max NPV(CS - Costs + Annual Carbon Rent)
  - 200 year time horizon in 10 year increments.
  - Costs = production costs, access costs, land rental costs.

- 250 Ecosystem and Management Classes:
  - *Aggregated into 13 larger regions.*
  - *Range of species*
    - Intensive plantations (10 – 12 m^3/ha/yr)
    - Slow growing boreal forests (0.5 – 2 m^3/ha/yr)
  - *Range of management intensity from $0/ha to >$1000/ha*
  - *Range of access costs from $0/ha to $6000/ha*

- Use rental functions to account for land use change
  - Initial elasticity is 0.25
    - Many of the rental functions are linear so this changes with actual land use.
  - Shift the rental functions in some regions to simulate land use change
    - Tropical regions especially.

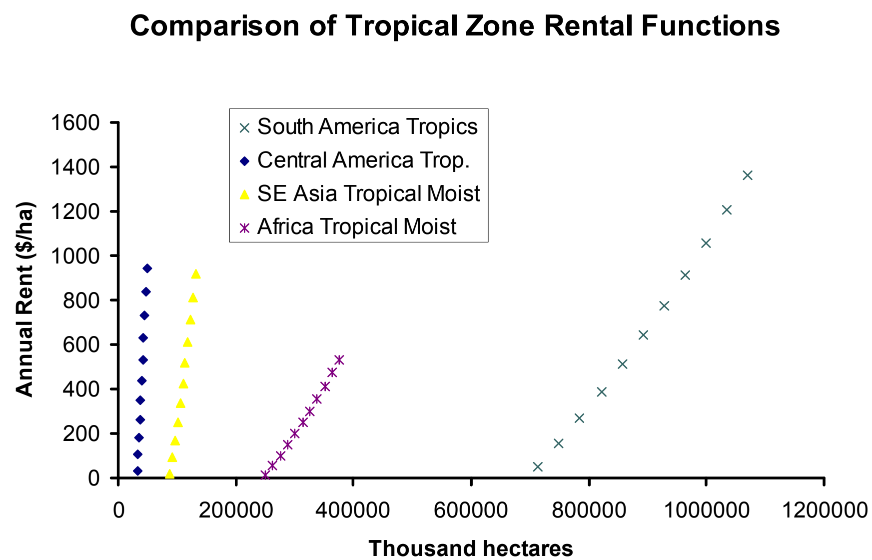
Rental Functions



Total Rent = $R(X) = \alpha(t)X + \beta(t)X^2$

Rental functions in tropical
Zones are shifting inward
Over time to simulate LUC

Total Rent = $R(X) = \alpha(t)X^2 + \beta(t)X^3$



Other Model Parameters

- Initial stocks:
  - Initial stocks in other regions are either country level data or FAO data.
  - Tropics are from FAO (except plantation data)

- Biomass growth parameters developed from literature.

- Demand:
  - GWP: 1.7%/yr
  - Population: 0.4%/yr
  - Income elasticity: 0.86
  - Timber price elasticity: 1.10

- Inventory and Economic Data available on web
  - http://aede.osu.edu/people/sohngen.1/forests/GTM/index.htm

Actions That Affect Carbon in Model

- Land Use
  - Reduce deforestation or increase afforestation
  - Change inaccessible margin in temp. & boreal forests.
- Forest Stand Management
  - Replant rather than naturally regenerate
  - Enhance stocking density: fertilize, chemical weed suppression, thinning (remove dead or slow growing stock and replace with faster growing stock).
- Rotation ages
  - Generally, longer rotations enhance carbon storage.
- Harvest Quantity (storage in markets)

Summary of Major Assumptions

- Single global demand for forest products
  - Price elasticity = -1.0
- Supply of land assumed, not modeled or estimated
  - Rental elasticity ~ 0.25
- Optimal behavior
- Many estimates made for US and applied elsewhere.
- Biomass growth functions assumed for some regions.

SOME RESULTS….

Reductions in Deforestation are Largest Potential Carbon Source in the Near Term.

Constant Carbon Prices, AEA, **20 yrs**, r=5%

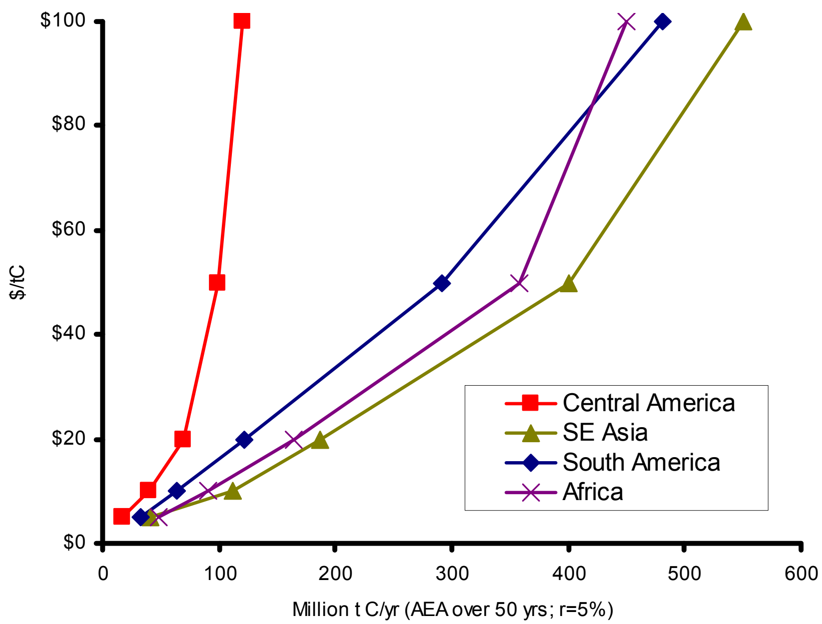
- **For $100/t C ($27/t CO2), over next 20 years…**

Action	Gt (Pg) C/yr	Gt (Pg) CO_2/yr
Reduce Deforestation	1.0 – 1.2	3.7 – 4.4
Aging, Mgmt, Set-Asides	0.4 – 0.5	1.4 – 1.8
Afforestation	0.1 – 0.3	0.4 – 1.1

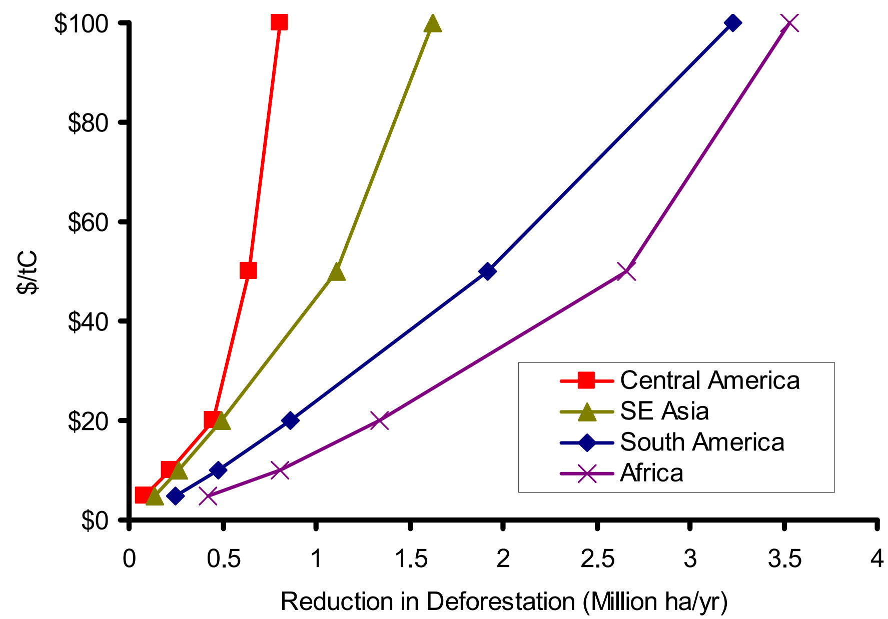
Carbon and land supply potential from reducing deforestation

(2005 – 2055)

Carbon Supply
(AEA - Million t C/yr)

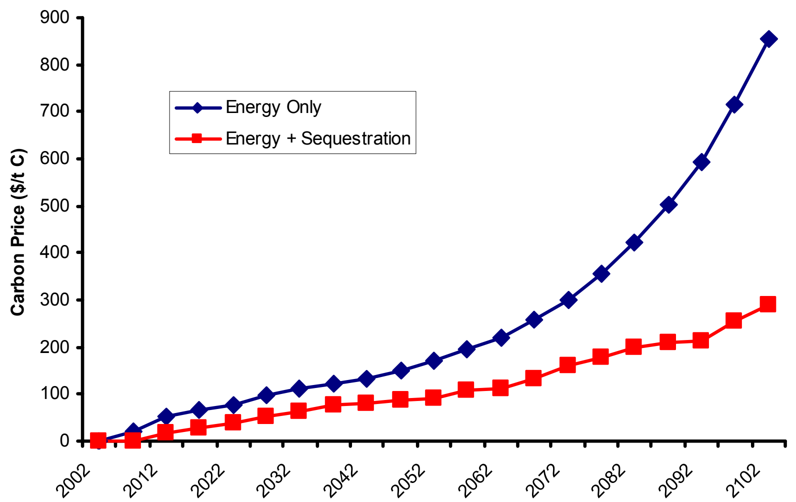


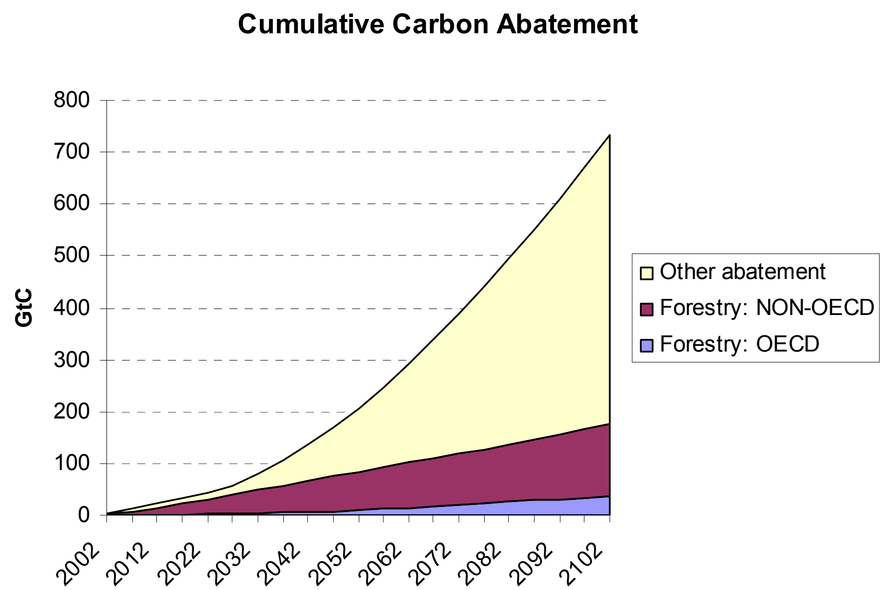
Land Supply (Million ha/yr)



Land Use/Forestry can have important economic effects on global stabilization policy

(Analyze 550 ppmv CO_2 target; optimal economic modeling)





- Forestry reduces C prices 40-50%
- Forestry is roughly 30% of the “solution” over the century
- BCA ratio = 3:1
- If REDD is cheaper, then the price effects will be bigger and costs smaller

Tavoni, Sohngen, and Bosetti (2007)

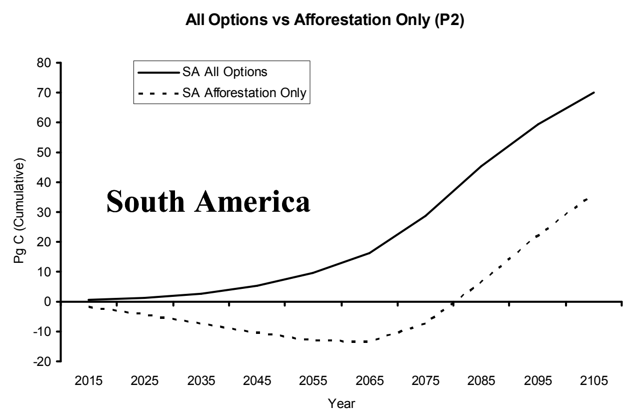
Net effects/Leakage

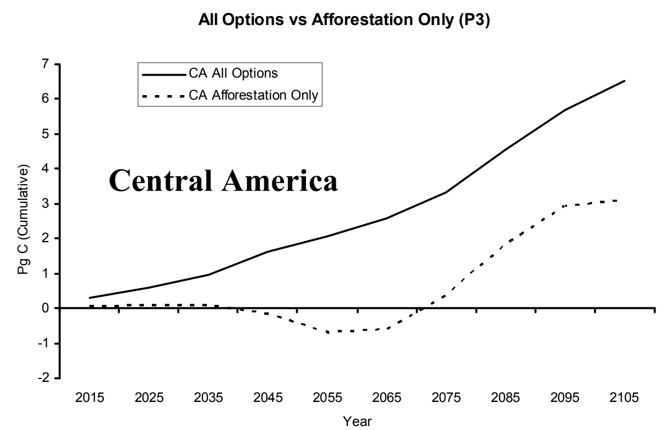
Afforestation only vs. comprehensive approach

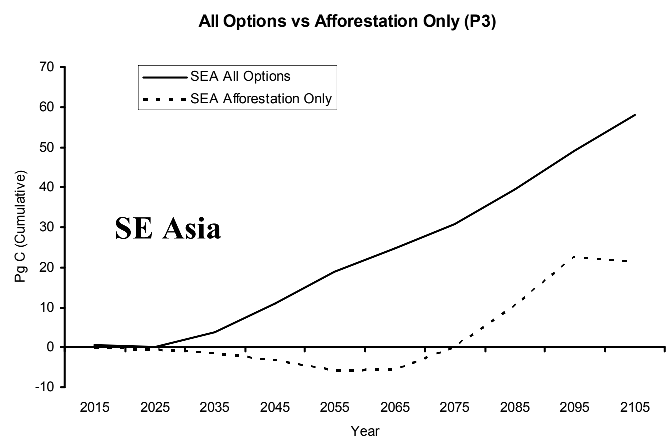
P^C_0 = $18/t C
Rises to $916 by 2100

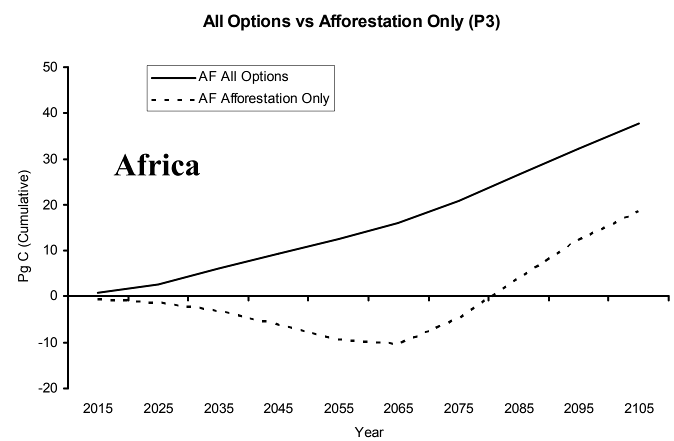
Afforestation scenario generates little net carbon In tropics (and globally) in the near-term, suggesting large potential leakage.

Over longer-run gains are 30-50% lower than if all options included.









Pros and Cons (current analysis)

- Pros:
  - Capture important timber management responses.
  - Timber prices endogenous
  - Global coverage – Net Effects
  - Efficient market response
  - Rigorous definition of baseline
- Cons:
  - Land prices not endogenous
    - e.g., no agricultural markets
  - Highly aggregated.
    - Resolution limited for considering particular ecosystems or timber types.
  - Focus on “Long run”.
  - Parameter assumptions

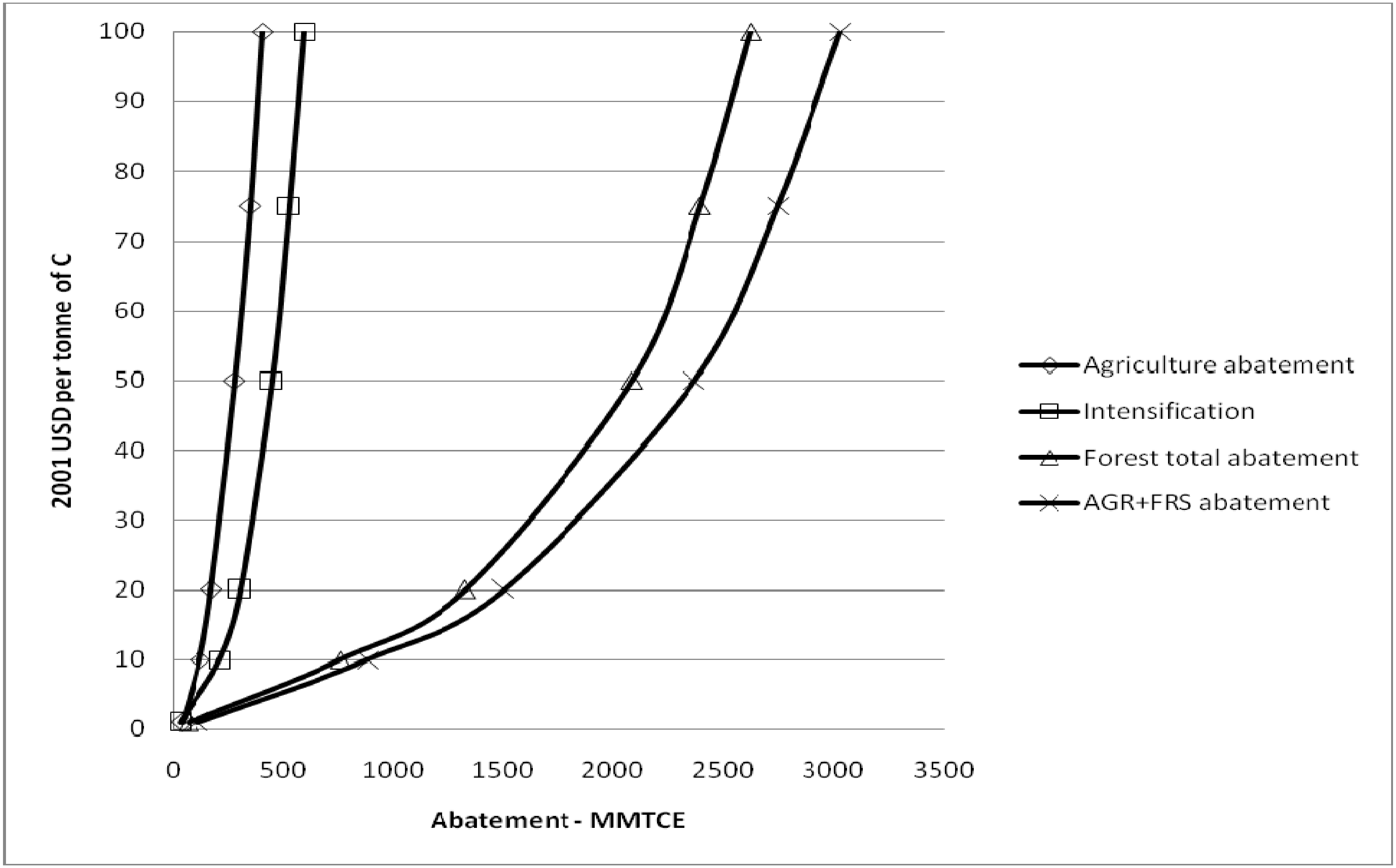
Other issues…

- What costs included?
  - Opportunity costs
- Sensitivities:
  - Elasticity parameter is important
  - Alternative baselines important (e.g., biofuels, technology change in agriculture).
  - Carbon price path (faster price growth, higher marginal costs).
  - Marginal access cost functions

CGE Approaches

- Emerging methods to assess land use change with static and recursive dynamic CGE approaches.
  - Hertel et al. (2008)
  - Calibrate a CGE model with MACs from forestry model, and agricultural abatement models.
  - Conduct analysis of implications of carbon policies:
    - marginal costs; imports/exports; employment; etc.

CGE Approach:
Global Marginal Costs



CGE Approach:
Factors of production and net exports

		Factor of Production		
	Output	Land	Labor	Fertilizer
ROW				
Paddy Rice	-4	-17	13	-5
Other Grains	-4	-16	10	-15
Other Crops	-3	-16	8	-14
Ruminants	-6	-20	7	

% change in input intensities and Output for $100/t C carbon policy.

Change in net exports for $100/t C carbon policy

	Net Exports ($/year)		
Sector		CHN	ROW
Rice	594	16	-619
Other Grains	2,263	101	-2,279
Other Crops	2,066	1,041	-2,833
Ruminants	3,686	-545	-2,997
Non-Ruminants	1,627	-707	-852
Other Foods	1,642	-633	-498
Other Sectors	-10,378	2,539	6,767
Total	1,499	1,812	-3,311

Additional Alternatives

- PE model of the forest and agricultural sectors
  - Model land competition directly via CET function or some other approach.
  - Model development at the “frontier” via estimates of the costs of access.
  - Can easily adjust elasticity parameters, depending on empirical estimates or other local information.

- Ultimately, any “modeling” approach at any level of aggregation relies on empirical estimates from other sources.

Conclusions

- Modeling approaches
  - Account for within-sector and cross-sector interactions, which can have implications for costs. May also account for international activity.
  - Parameters often derived from empirical estimates from the literature, some of which may come from far away .
  - Can be adjusted for analysis in other regions.
  - Suggest large potential for REDD activities currently.