

Future Growth in Agriculture and Impacts on Carbon Sequestration: Application of Global Forestry and Agricultural Model

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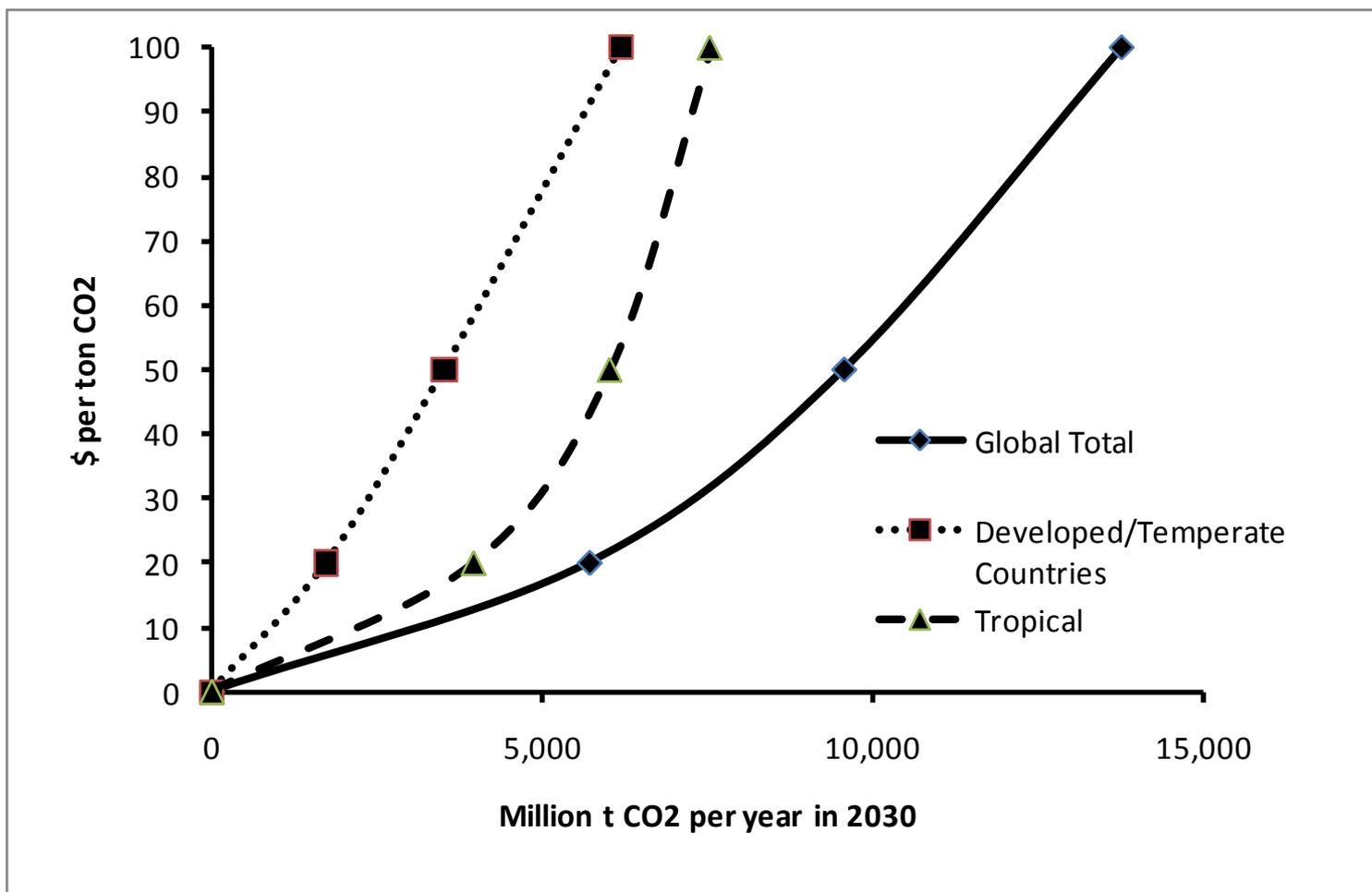
Agricultural change since 1960s

- Tech Change:
 - Crop yields increasing 1.1-2.0%/yr since 1960s for major crops (Tweeten and Thompson, 2008).
 - Total Factor Productivity increasing 0.5-1.1%/yr for crops and 0.4-2.7%/yr for livestock since 1960s (Ludena et al.).
- Land devoted to agriculture increasing 9.5 million ha's/yr

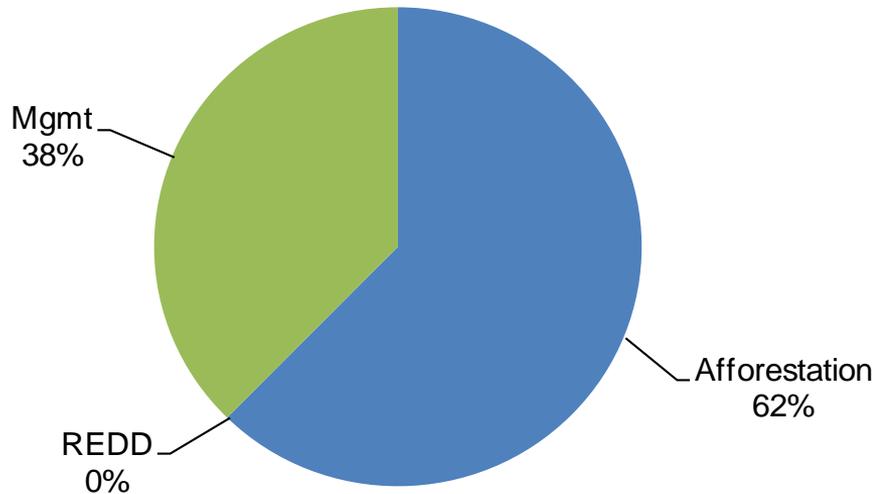
Million ha's/yr (Source: FAO)	Arable Land & Permanent Crops	Pasture
World	3.4	6.1
Temperate	-2.1	-6.6
Tropics + Asia	5.5	12.7

- Net deforestation proceeding at 8-12 million ha's per year, depending on source

How important is technical change for carbon sequestration/emission reduction costs?



What actions provide forest carbon? How might these change?

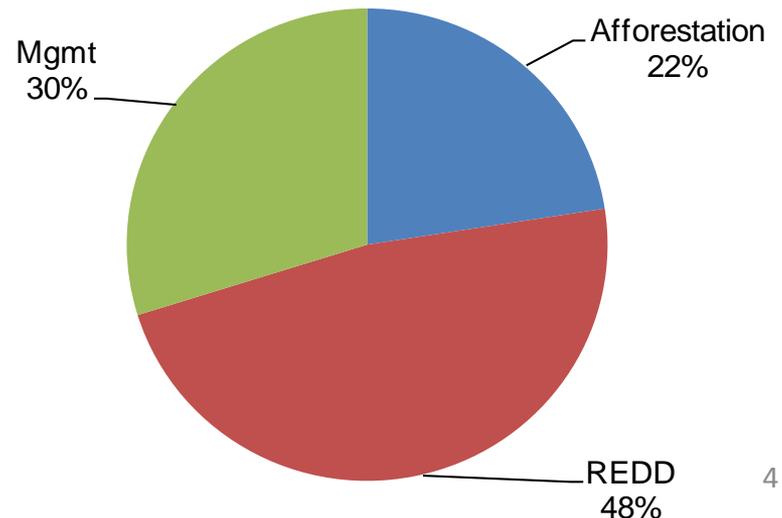


US: Management and Afforestation



Sohngen and Mendelsohn, 2008

World: Mostly REDD, management,
and afforestation



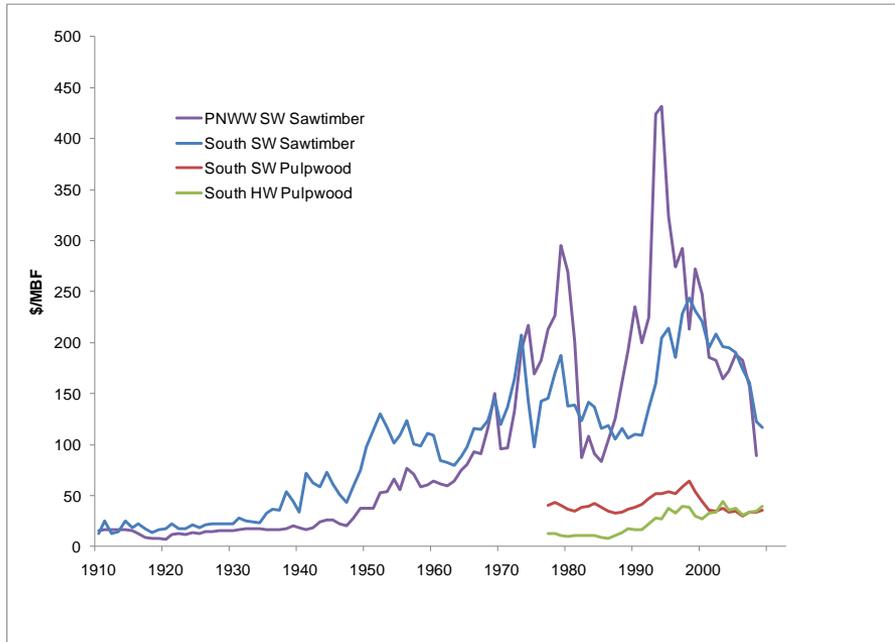
Methods

- Dynamic model of forest and agriculture.
 - Forest component optimizes
 - Forest age classes (timber harvest)
 - Forest management (investments in stocks)
 - Land area (maintain as forest or convert to something else)
 - Crop component optimizes
 - Land area and investments in L & K (although P_K and P_L are fixed)
 - Livestock component optimizes
 - Land area, feed input, investments in L & K (fixed P_K and P_L)
- Project under alternative technology assumptions (partial factor productivity)
 - Assess carbon implications.

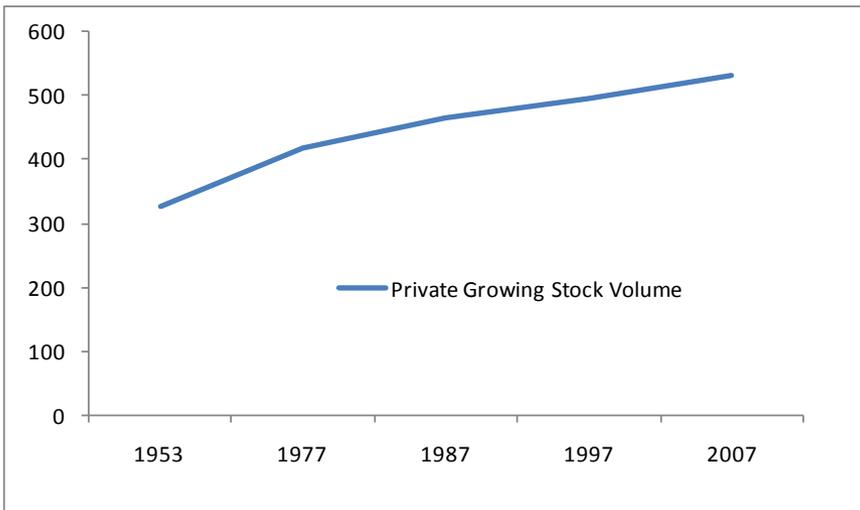
Model and Data

- Forestry components built from Sohngen and Mendelsohn (2003,2007); Sedjo and Lyon (1990).
- Agricultural components built from GTAP data (Hertel et al., 2007).
 - CES production structure
 - $Q_{crop} = f(\text{Land}, \text{Labor}, K)$
 - $Q_{livestock} = f(\text{land}, \text{feed}, \text{labor}, K)$
- Forestland database built from our own data
- Agricultural land database built on GTAP land database
 - Land heterogeneity due to AEZs.
- Competition for land via CET functions

Why dynamic forestry?

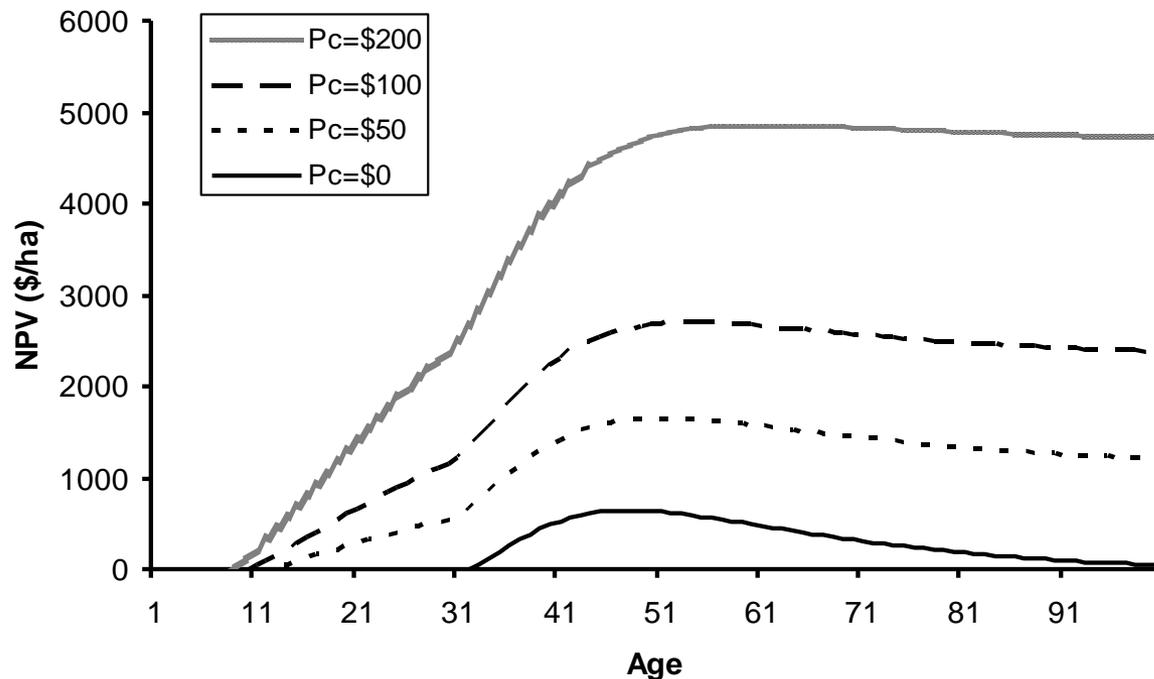


- Timber prices have risen 3-4% per year since early 1900's [various sources]
- Timber stocks have also risen.
- Why have we held timber off markets while prices have risen?
 - Rise of environmental values?
 - Some old growth left in west before 1990's, so Hotelling dynamics at play?
 - Stocks have been too young to harvest, e.g., opportunity cost of waiting is smaller than marginal benefit.



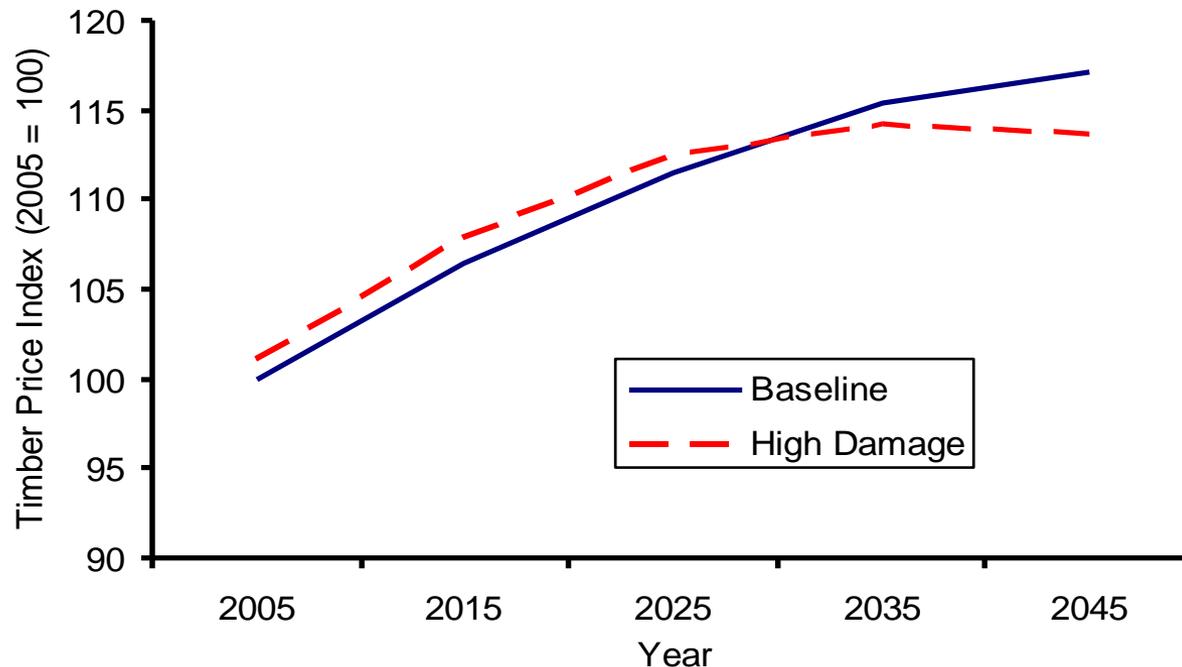
Why a forward looking dynamic model for forests?

- Carbon is becoming a valuable commodity.
- Investments require some assessment of the future.
- Main point is: forest owners might never plant trees if they didn't look toward the future. They would never wait until trees are mature to harvest them.



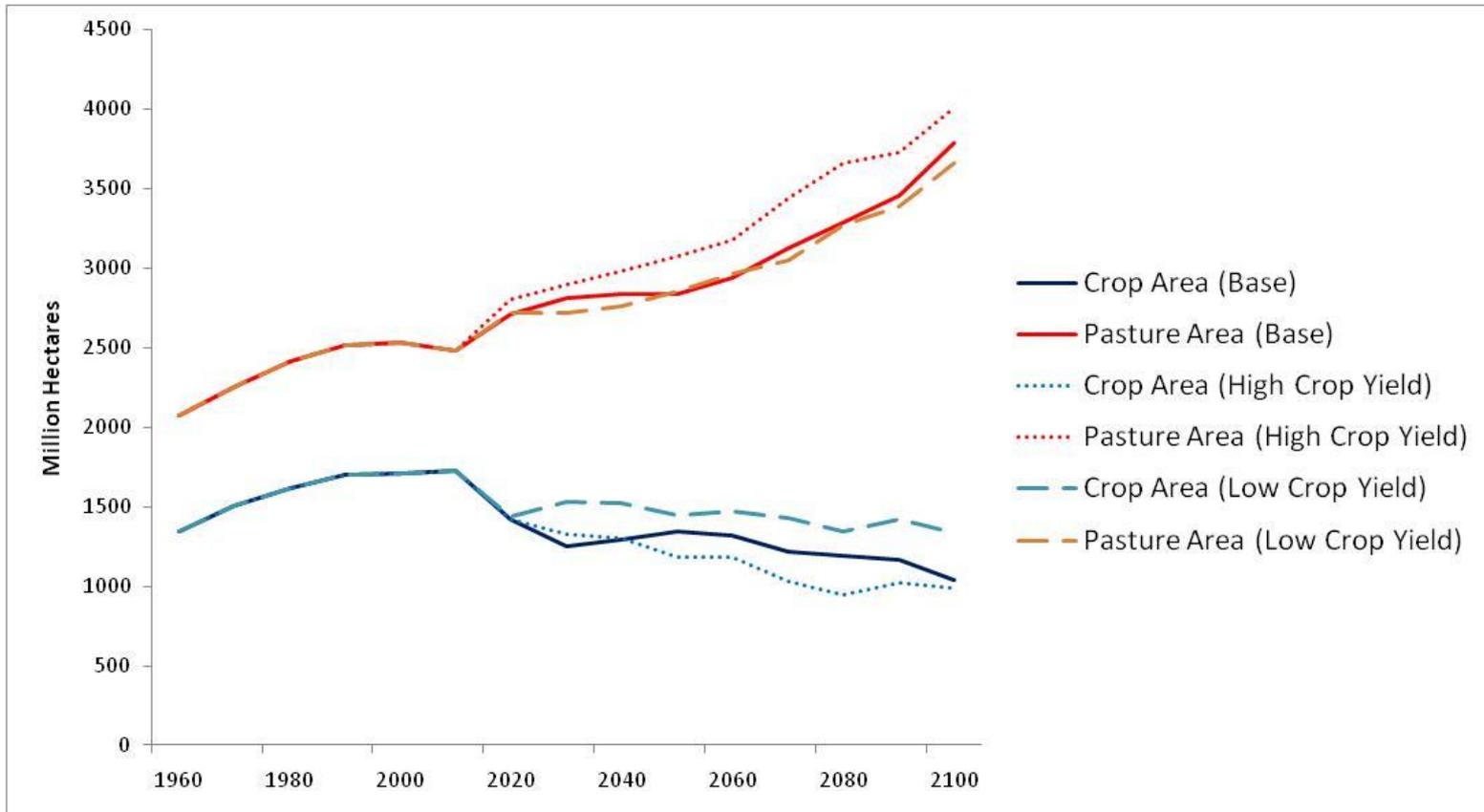
Note on implications of forward looking models for carbon...

- Complex set of price adjustments
- Dynamic models will give completely different price adjustment paths than static CGE approaches.
- EX: C policy that allows timber harvesting increases timber supply by increasing land in forestry. Higher supply means lower prices in SR, leading to higher supply & older trees in LR

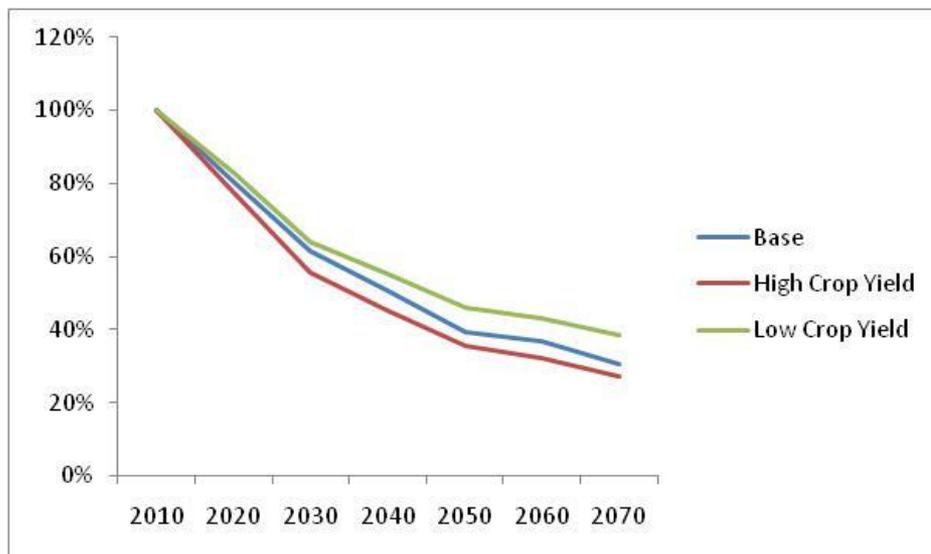


Results: Crop and livestock areas

- **Base Case (Neutral Tech):** 1.5%/yr increase in crop yields.
 - Follows trend on crops, reverses trend on pasture.
- **High Crop Yield Case (via land factor):** 2.1%/yr increase in crop yields
 - Strengthens both trends: less cropland and more pasture.
- **Low Crop Yield Case (via land factor):** 0.9%/yr increase in crop yields
 - More cropland and less pasture.



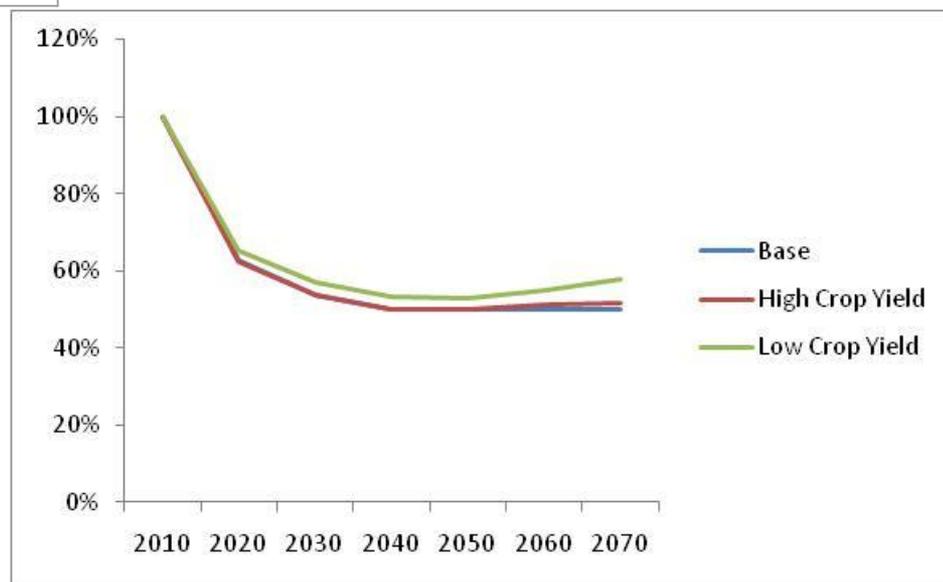
Results: Crop and livestock price trends



Higher crop yields reduces crop prices by around 18%, lower yields increases by 26%. Lower crop yields increases livestock prices by 15%.

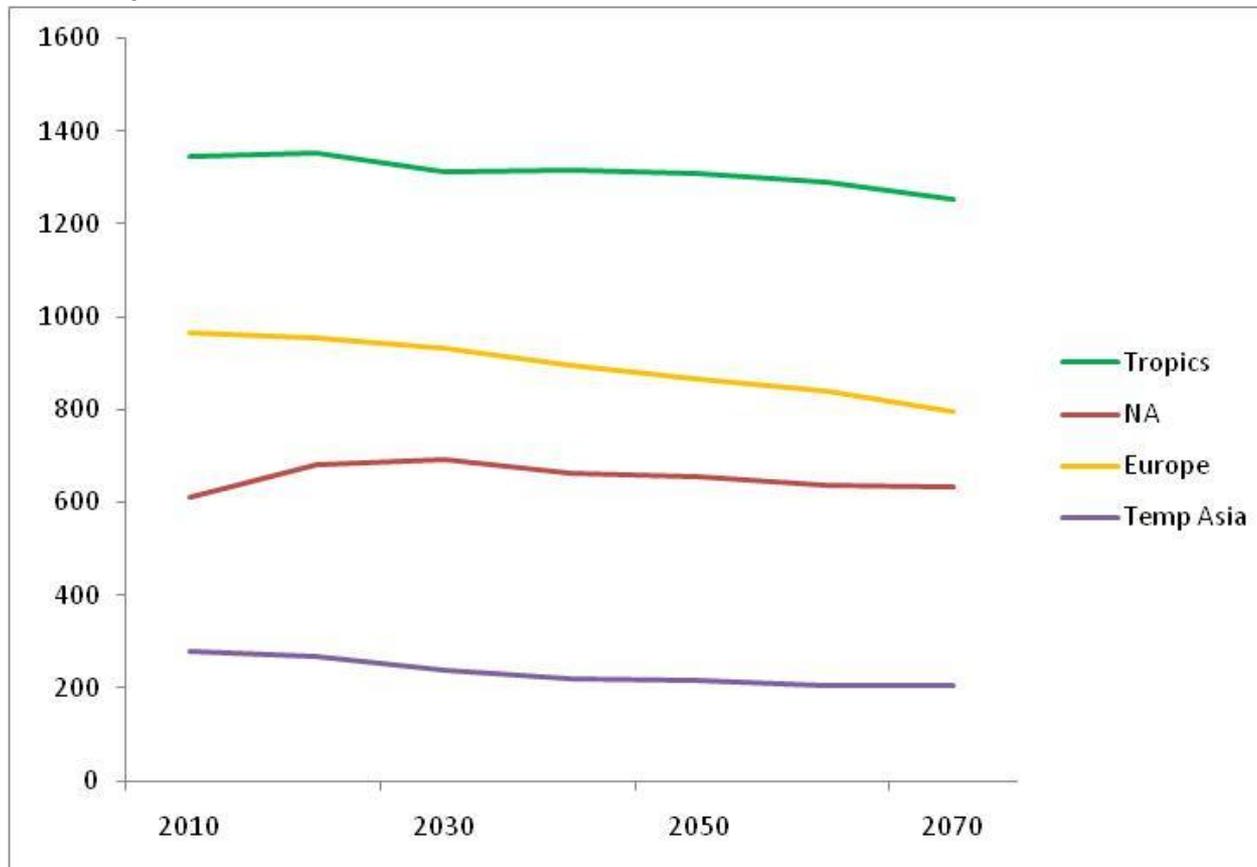
Income elasticity of crops
= 0.18 and falling

Income elasticity of Livestock
= 0.62 and rising



Forest area declines globally

- Base case trends in forest areas globally
- Most other studies that suggest rising forest area in temperate zones...



Area Change by 2070

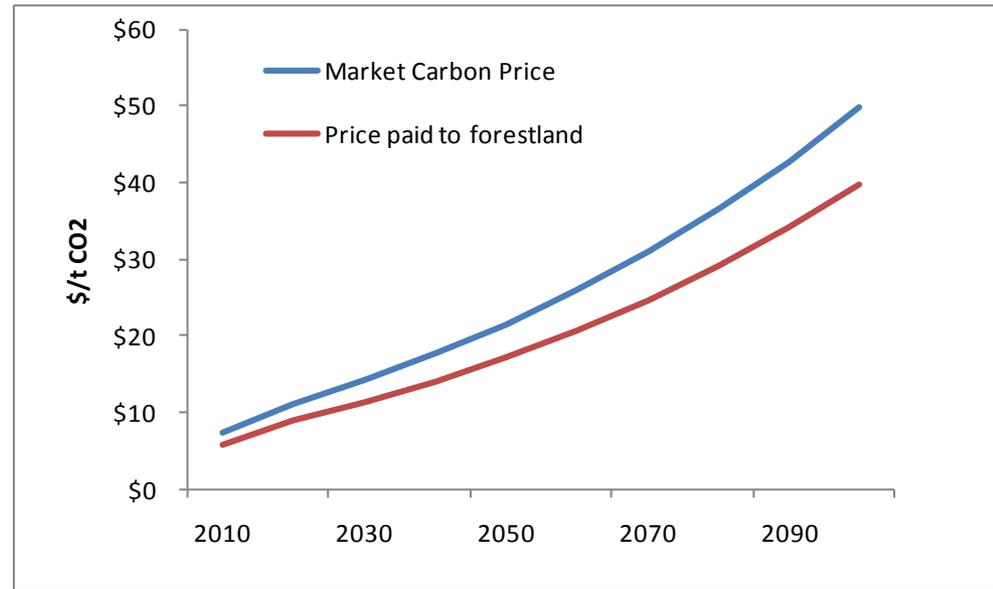
	Base	Higher Crop Yield	Lower Crop Yield
Tropics	-211.59	-198.26	-254.2
NA	-94.94	-75.41	-101.97
Europe	-183.83	-185.89	-142.58
Asia	-88.57	-71.79	-89.53
Global	-595.52	-547.01	-606.8

Carbon Emission by 2070 (Billion tons of CO₂)

	Base	High Yield	Low Yield
Tropics	-46.3	-51.8	-45.5
NA	-2.7	-2.3	-4.6
Europe	-8.5	-8.1	-4.5
Asia	-13.1	-11.0	-7.4
Global	-71.0	-68.7	-65.3
Total Pg CO ₂ /yr	-1.18	-1.15	-1.09

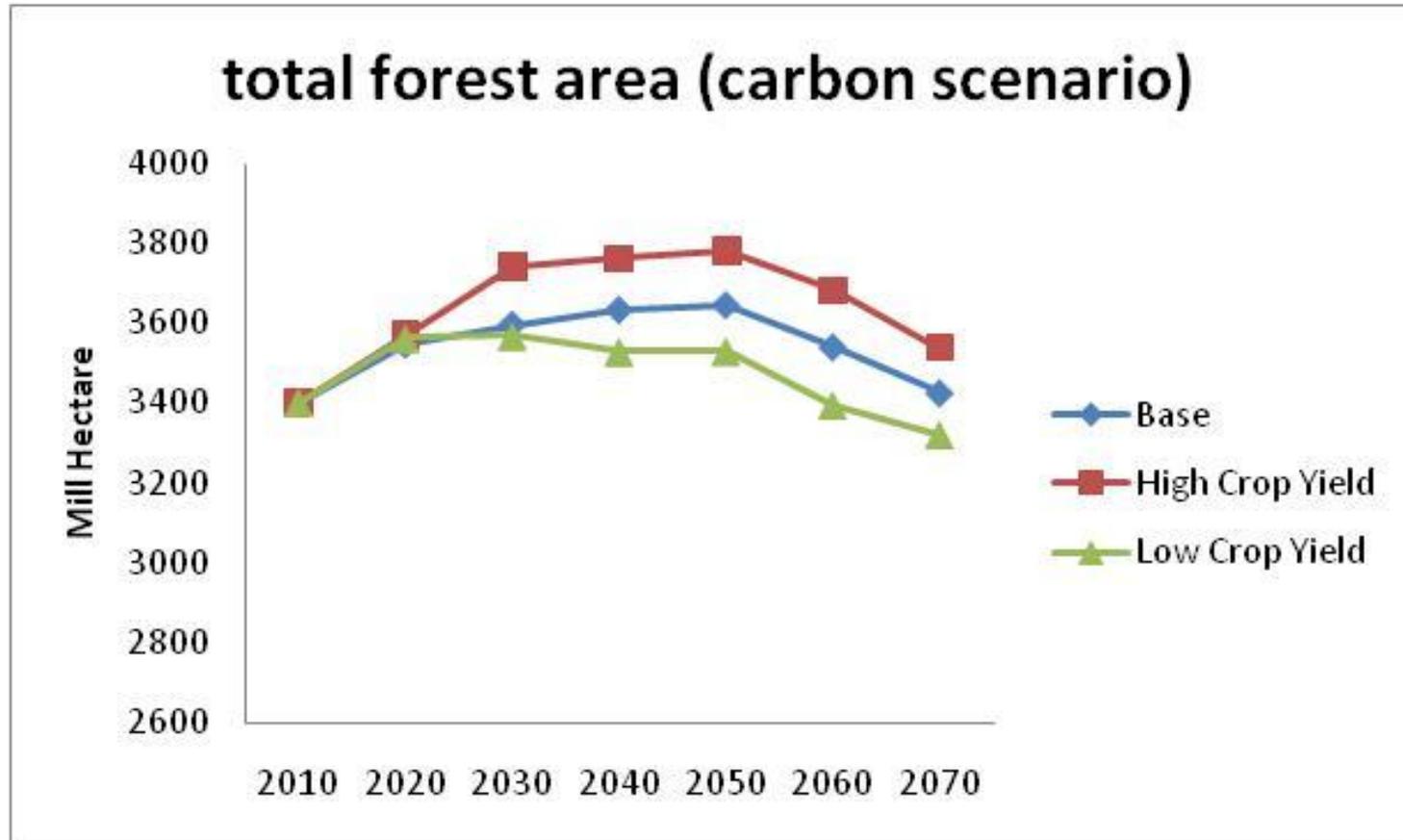
Carbon Mitigation Analysis

- Optimize benefits and costs:
 - Optimal control model of carbon stocks and abatement activities, including forestry.
 - Allows temperature to rise to 3.5 °C above current levels.
 - Incorporate 20% transaction cost
 - See Sohngen (2010)
- Effects captured by link between forest/land use model and **DICE model** (Nordhaus, 2008)
- Function: Rent carbon gains relative to the baseline, and pay for carbon stored in wood products.
 - No payments or taxes in agriculture.



Sequestration t/CO ₂	
2010	\$7.23
2020	\$11.07
2030	\$14.09
2040	\$17.54
2050	\$21.45
2060	\$25.87

Forest Area by DICE Carbon Payment

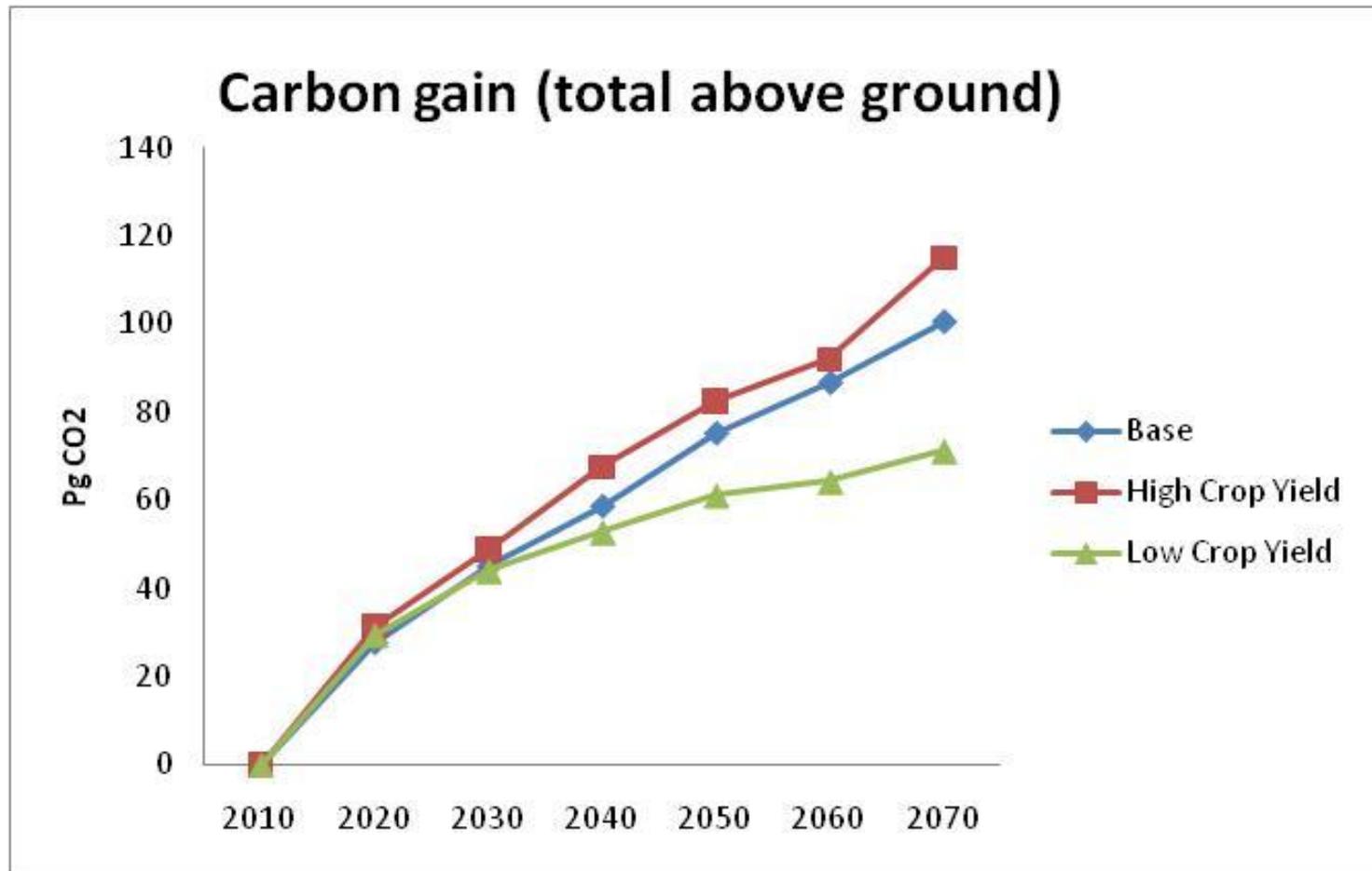


Forest Area Change

Cumulative area change by 2070

	Base	Dice Base	Gain	High Yield	DICE H	Gain	Low Yield	DICE L	Gain
Tropics	-211.6	-81.5	130.1	-198.3	-58.8	139.5	-254.2	-144.8	109.4
NA	-94.9	-52.8	42.1	-75.4	-39.5	35.9	-102.0	-103.2	-1.2
Europe	-183.8	-133.8	50.0	-185.9	-88.6	97.3	-142.6	-117.5	25.1
Asia	-88.6	-63.6	24.9	-71.8	-58.6	13.2	-89.5	-90.4	-0.9
Global	-595.5	-347.4	248.1	-547.0	-260.7	286.3	-606.8	-474.6	132.2

Total Carbon Gain



Cumulative Carbon gain by 2070 (Billion tons of CO2)

	Base	Dice Base	Gain	High Yield	DICE H	Gain	Low Yield	DICE L	Gain
Tropics	-46.3	-2.6	43.7	-51.8	1.5	53.3	-45.5	-10.9	34.7
NA	-2.7	17.5	20.2	-2.3	19.7	22.1	-4.6	1.2	5.8
Europe	-8.5	5.6	14.1	-8.1	11.2	19.4	-4.5	4.6	9.2
Asia	-13.1	11.8	24.9	-11.0	26.0	37.0	-7.4	14.1	21.5
Global	-71.0	29.4	100.3	-68.7	46.3	115.0	-65.3	6.0	71.3

Conclusions

- Tech change in crop sector has important implications for ***land use***.
 - Higher yield rates in the crop sector leads to more forests and more carbon sequestration
 - Lower yield rates in the crop sector leads to less forests and less carbon sequestration and the order of difference is bigger
 - Lower yield in crop does not affect much on pasture land
- Technology change has important implications for estimates of ***baseline quantity of carbon emissions from deforestation***, and ***the costs of carbon sequestration***.
 - Largest effects in the tropics: Improved crop productivity reduces deforestation and related emissions by leaving more land untouched in that region in the base case.
 - Different tech assumption provides different regional carbon potential

Future development

- Conversion factor for physical hectares
 - Tyner et al, 2010 (ratio of NPP)
- Disaggregate sectors
 - Several crop types
 - Ruminants and Non-ruminants in livestock
- Update to GTAP 7