Forestry Climate Mitigation Potential and Costs: GCOMAP Model Results

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Sino-US-Korea
Economic and Environmental Modeling Workshop
Beijing, China 20-21 May 2004

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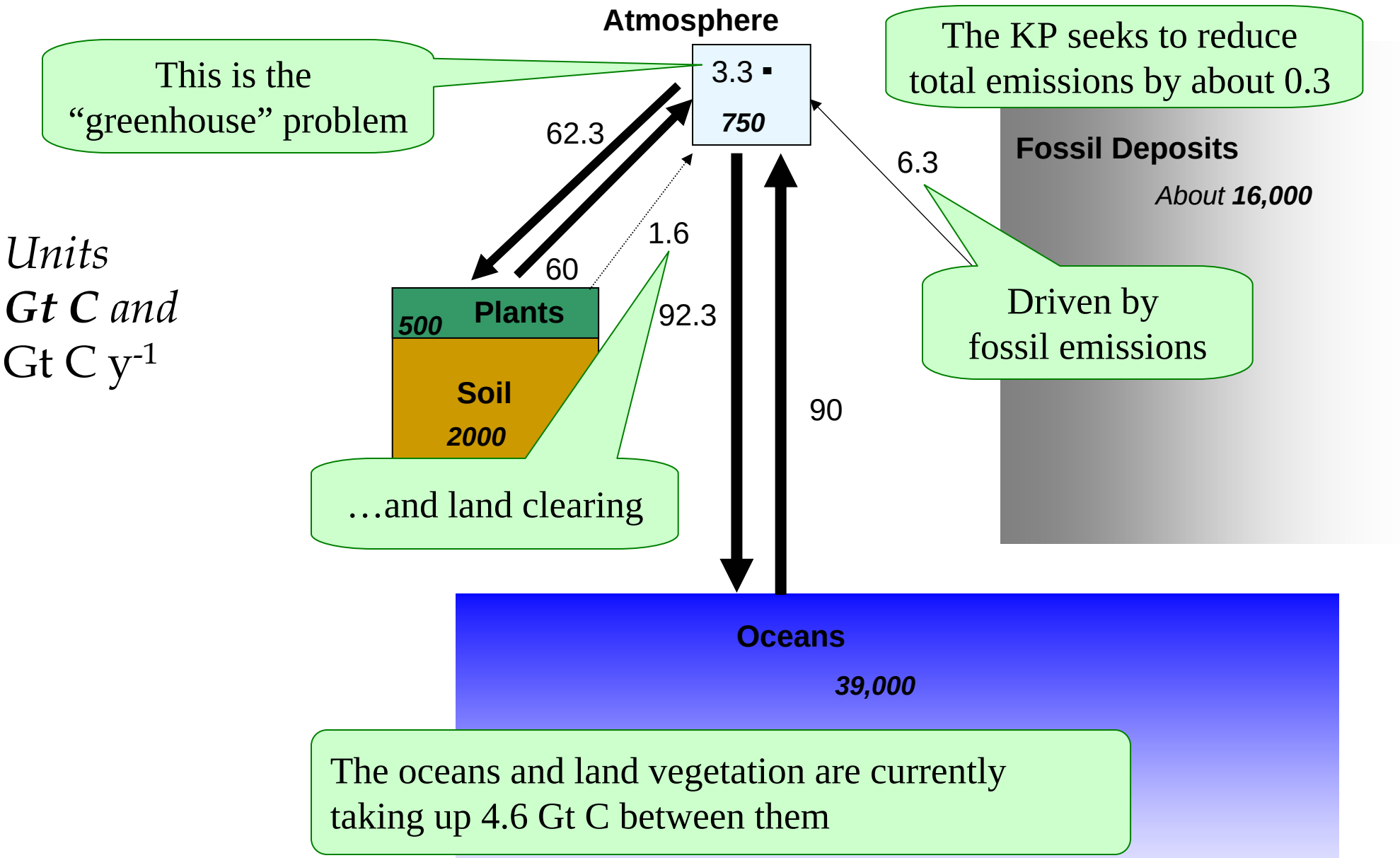


Human Activities are Perturbing the Carbon Cycle: Potential and costs to increase sequestration and reduce emissions from land-use change and forestry?

Carbon Accounting and Mitigation Options in Land-use Change and Forestry

- **Carbon:**
  - Carbon stored in many pools --- above and below ground vegetation, soils, products, litter, post-harvest waste
  - Store carbon today, gone tomorrow?
    - » Harvests, and disturbances can release stored carbon
- **Mitigation Options:**
  - Short and long-run forestry
    - » With biofuels
    - » Without biofuels
  - Avoiding deforestation
  - Forest management

Modeling Analysis: Goal and Approach

- **Goal:**
  - Assess the potential for carbon sequestration and avoidance of carbon emissions for alternative future carbon price paths
- **Approach:**
  - Base or reference case extrapolates ongoing implementation of mitigation options to 2100
  - Mitigation or policy case assesses land-use and carbon changes to the base case for a given carbon price path
- Model accounts for carbon stocks in all pools and annual changes in stocks until 2100

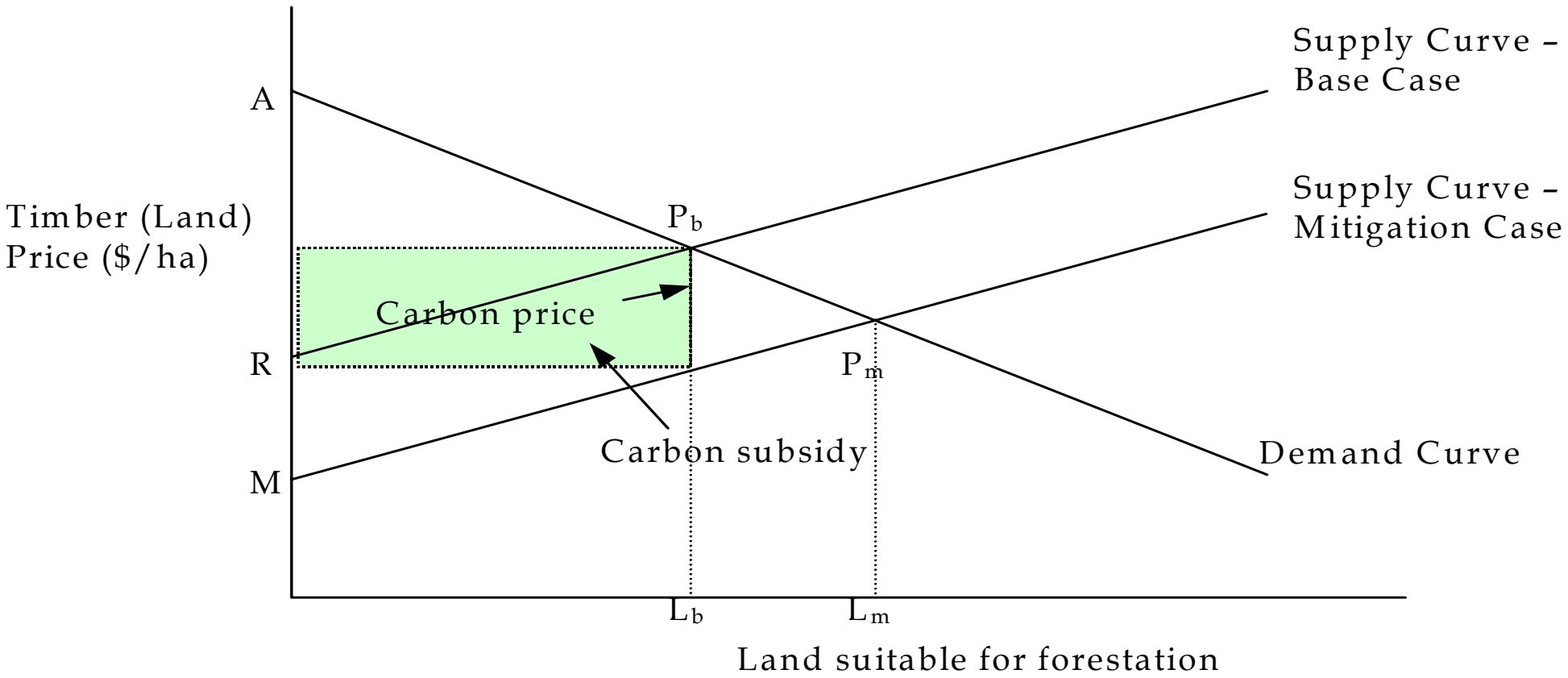
GCOMAP -- Features

Issue	*GCOMAP (Dynamic Partial Equilibrium Model)*
Temporal	• 2000 to 2100 by year
Land-use change scenarios	• Reference scenario – historical trends, modified government plans • Mitigation scenario – driven by future carbon prices
Timber and other product prices & quantities	• Use supply and demand elasticities to estimate timber price and quantity changes • Five timber and non-timber products • Separate domestic and international markets
Discount Rates	• Rate of return (ROR) remains unchanged between reference and mitigation scenarios. • ROR derived from cost, price, and yield inputs
Model mechanics	• Country- or region-specific • Perfect foresight; based on investment theory; dynamic partial equilibrium model • Permits sensitivity analysis and analysis of alternative scenarios • Software: Excel, Visual Basic

GCOMAP Current Scope

Mitigation Option	Current Geographic Coverage	Carbon Pools
Forestation – short rotation • Without biofuels • With biofuels	North America South / Central America Europe Russia (not FSU) China India Australia/NZ Asia-Pacific Africa	• Above/below ground biomass • Soils • Litter • Post-harvest waste • Domestic timber products • International timber products • Fuelwood • Mill-waste products • Biofuels – used as a substitute for coal in power plants
Forestation – long rotation • Without biofuels • With biofuels		
Avoided deforestation (no biofuels)	South / Central America Asia-Pacific Africa	

Determining Mitigation Land Use Change and Associated Products Output



Rule :

Rate of return mitigation case = Rate of return reference case

(Discount rates are not exogenously assumed)

Base Case Land-use Change

- Base case projections
  - 1990-2000 forestation rates are maintained to 2100
  - Avoided deforestation rates change from 2000 to 2100
- Cumulative land planted subject to cap on the total land area
  - Degraded forest and non-forest lands, grass land, from activities prior to 2000
  - Large and rapid planting in base case means less land available for mitigation options
- Land / other costs increase with cumulative amount of planted land
  - Costs are offset by productivity gains in the base case

GCOMAP Deforestation Rate Assumptions: Historical and Projected

- Global deforestation currently about 17 Mha/yr (FAO)
  - India and China deforestation has declined to almost zero now
  - Brazil has constant or accelerating deforestation
- Africa 1990-00 deforestation rate increased, unlike in other regions
  - Deforestation rate is projected to increase to 2020 before declining
- Rest of tropics: Deforestation rates are projected to continue declining

Region	**Change in Deforestation Rate (%/yr)**	**Deforestation Rates (% / year)**				
	1990 –00	**2000**	**2020**	**2040**	**2050**	**2100**
Africa	+ 0.026	0.80	1.29	0.78	0.65	0.26
Rest of Asia	- 0.005	1.03	0.82	0.60	0.52	0.12
Central America	- 0.011	1.19	0.97	0.75	0.65	0.37
South America	- 0.030	0.40	0.26	0.21	0.20	0.13

The deforestation rate gives the percent decline in the forest area per year
(-) rate is an annual decline in the deforestation rate
Based on FAO, 2000 data.

GOCMAP Data Table (Example)
Cost, Price and Yield Data for Long Rotation Forestry Option, China

Item	Value	Explanation/Source
COST: Initial Cost ($/ha) Recurrent Cost ($/ha/yr) Monitoring Cost ($/ha/yr) Harvesting and Transport Cost ($/m^3)	 **245** **3** **3** **40**	Initial costs are incurred largely in the first year with some costs carried over to the second and third years. Recurrent and monitoring costs are incurred annually. 40% of the product price goes towards harvesting and transport. Weighted average for NE, SE, and SW regions. Data from Xu and Zhang (2001, and 2002).
PRICE: Timber domestic market price ($/m^3) Timber international market price ($/m^3)	 **200** **450**	Xu et al. 2001, and FAO Forest Products Yearbook, 2000.
ELASTICITY: Timber supply price elasticity Timber domestic demand price elasticity Timber international demand price elasticity	 **0.49** **-1.0** **30**	Adams, MacCarl, Farouk et al, 1988. McKillop, 1977, Robinson, 1976. Makundi, 1990
YIELD: Base-year carbon stock (t C/ha) Mean annual increment (t biomass/ha/yr) Rotation Period (Yrs) % of carbon in biomass	**25** **6.5** **42** **50%**	Current stated planting rate adjusted for survival rate (Zhang, 2001)
TIMBER TRADE: % of timber exported	 **1%**	
TIMBER PRODUCT % of timber assumed lost during harvest % of timber in products after harvest Domestic & international product life (Yrs)	**50%** **30**% **30**	
LAND AREA CAP: Max area dedicated to LR afforestation (Mha) Planting rate in base year (kha/yr)	 **27** **614**	Long term plans to add 117 mi ha to Chinas Forestry, of which 63 Mha will be for timber production. (PEER – Long term nationwide environmental restoration).

Results – Global land area and carbon gain across scenarios*

Mitigation Options : Long and short rotation forestry, and avoided deforestation

Scenario*	Carbon Price ($/ t C)		Land Area Gained (Mha)		Carbon Gained (Mt C)	
2010 Carbon Price + Increase	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
1. $5 + 5% / year	**35**	**404**	**150**	**547**	**11,224**	**62,951**
Forestation			68	163	5,554	33,162
Avoided Deforestation			83	384	5,670	29,789
2. $10 + 5% / year	**70**	**807**	**263**	**742**	**20,983**	**87,839**
Forestation			108	231	10,123	47,849
Avoided Deforestation			155	511	10,860	39,990
3. $10 + 3% / year	**33**	**143**	**162**	**429**	**12,583**	**42,854**
Forestation			52	77	4,934	16,358
Avoided Deforestation			110	352	7,649	26,496
4. $20 + 3% / year	**65**	**286**	**283**	**665**	**23,630**	**69,695**
Forestation			75	135	8,917	28,575
Avoided Deforestation			208	530	14,713	41,120
5. $100 + 0% / year	**100**	**100**	**459**	**713**	**42,367**	**69,177**
Forestation			83	56	13,587	17,245
Avoided Deforestation			376	657	28,780	51,932
6. $75 +$ 5 / year; (2050 cap)	**275**	**275**	**615**	**952**	**58,415**	**103,415**
Forestation			192	146	25,675	38,422
Avoided Deforestation			423	806	32,740	64,993

* Gained amount refers to the difference between mitigation (policy) and base or reference scenarios

GCOMAP – Global land area and carbon gain* across scenarios

Mitigation Options : Long and short r forestation

Higher the carbon price, larger the gained land and carbon amount, but …

Scenario*	Carbon Price ($/ t C)		ed (Mt C)			
2010 Carbon Price + Increase	2050	2100			0	2100
1. $5 + 5% / year	**35**	**404**	**150**	**547**	224	**62,951**
Forestation			68	163	1	33,162
Avoided Deforestation			83	384	5,67	29,789
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* Gained amount refers to the difference between mitigation (policy) and base or reference scenarios

GCOMAP – Global lar … across scenarios

Mitigation Options : Long a … ided deforestation

Higher the carbon price, larger the gained carbon amount, but paths starting low and rising produce majority of carbon after 2050 and vice versa

Scenario*	Carbon Pr				rbon Gained (Mt C)	
2010 Carbon Price + Increase	205				2050	2100
1. $5 + 5% / year	3				11,224	62,951
Forestation					5,554	33,162
Avoided Deforestation					5,670	29,789
2. $10 + 5% / year	70	807	263	742	20,983	87,839
Forestation			108	231	10,123	47,849
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* Gained amount refers to the difference between mitigation (policy) and base or reference scenarios

GCOMAP – Global land [illegible] cross scenarios

Mitigation Options : Long and [illegible] ded deforestation

Avoided deforestation accounts from 45% to 75% of gained 2100 carbon depending on the carbon price and path.

Scenario*	Carbon Price (				on Gained (Mt C)	
2010 Carbon Price + Increase	**2050**				**2050**	**2100**
1. $5 + 5% / year	**35**				**11,224**	**62,951**
Forestation			68	163	5,554	33,162
Avoided Deforestation			83	384	5,670	29,789
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Avoided Deforestation			208	530	14,713	41,120
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Forestation			83	56	13,587	17,245
Avoided Deforestation			376	657	28,780	51,932
6. $75 +$ 5 / year; (2050 cap)	**275**	**275**	**615**	**952**	**58,415**	**103,415**
Forestation			192	146	25,675	38,422
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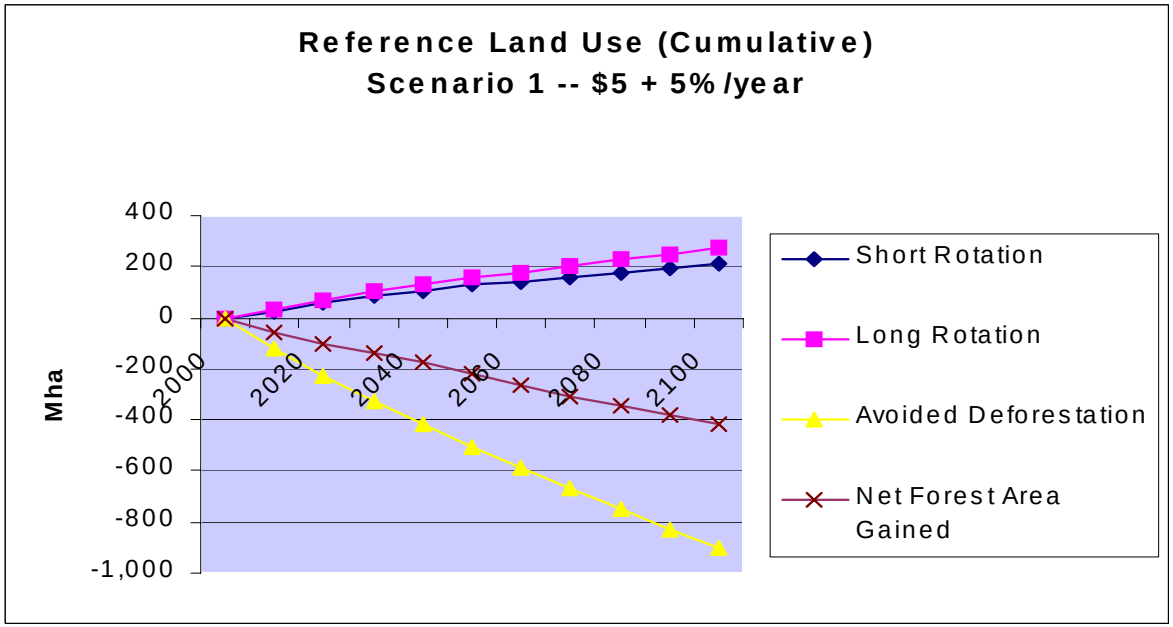
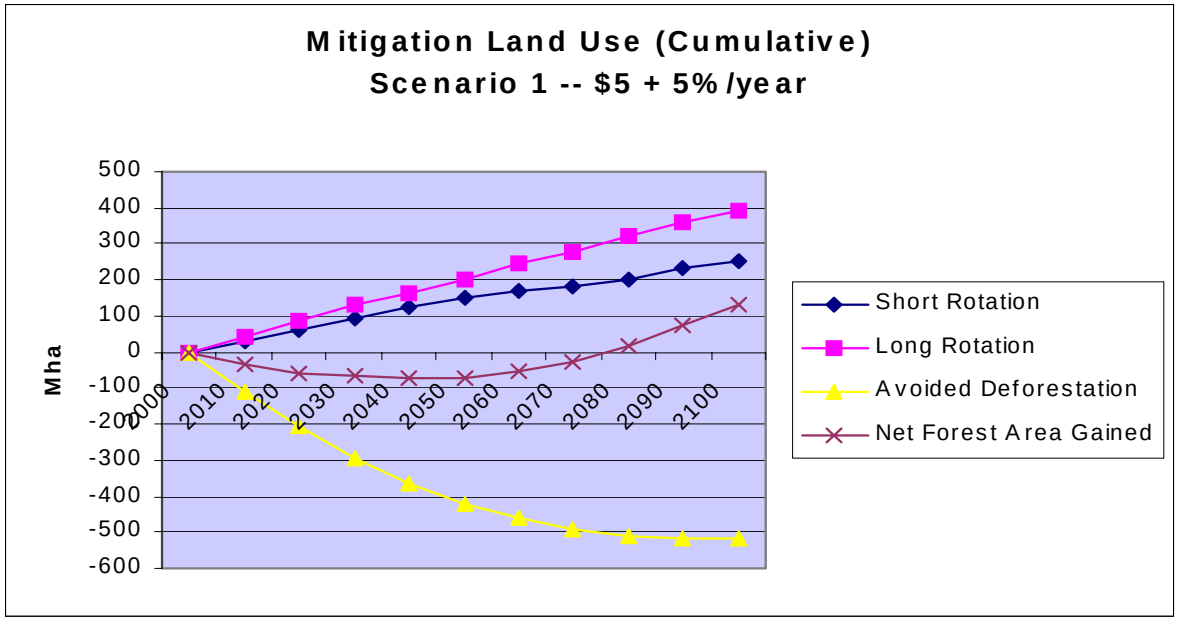
* Gained amount refers to the difference between mitigation (policy) and base or reference scenarios



***Reference:* Net forest area declines through 2100**



***Mitigation:* Decline is halted in 2080. Paths and dates vary by scenario.**

Carbon price to virtually stop deforestation (i.e., C price > opportunity cost) varies across the tropics

- Carbon price to halt deforestation depends on opportunity cost of land and products
  - Timber products fetch higher prices than land or other products
  - Higher the timber revenue higher the carbon price required to slow or avoid deforestation
- Feasibility of stopping deforestation complicated by many barriers.

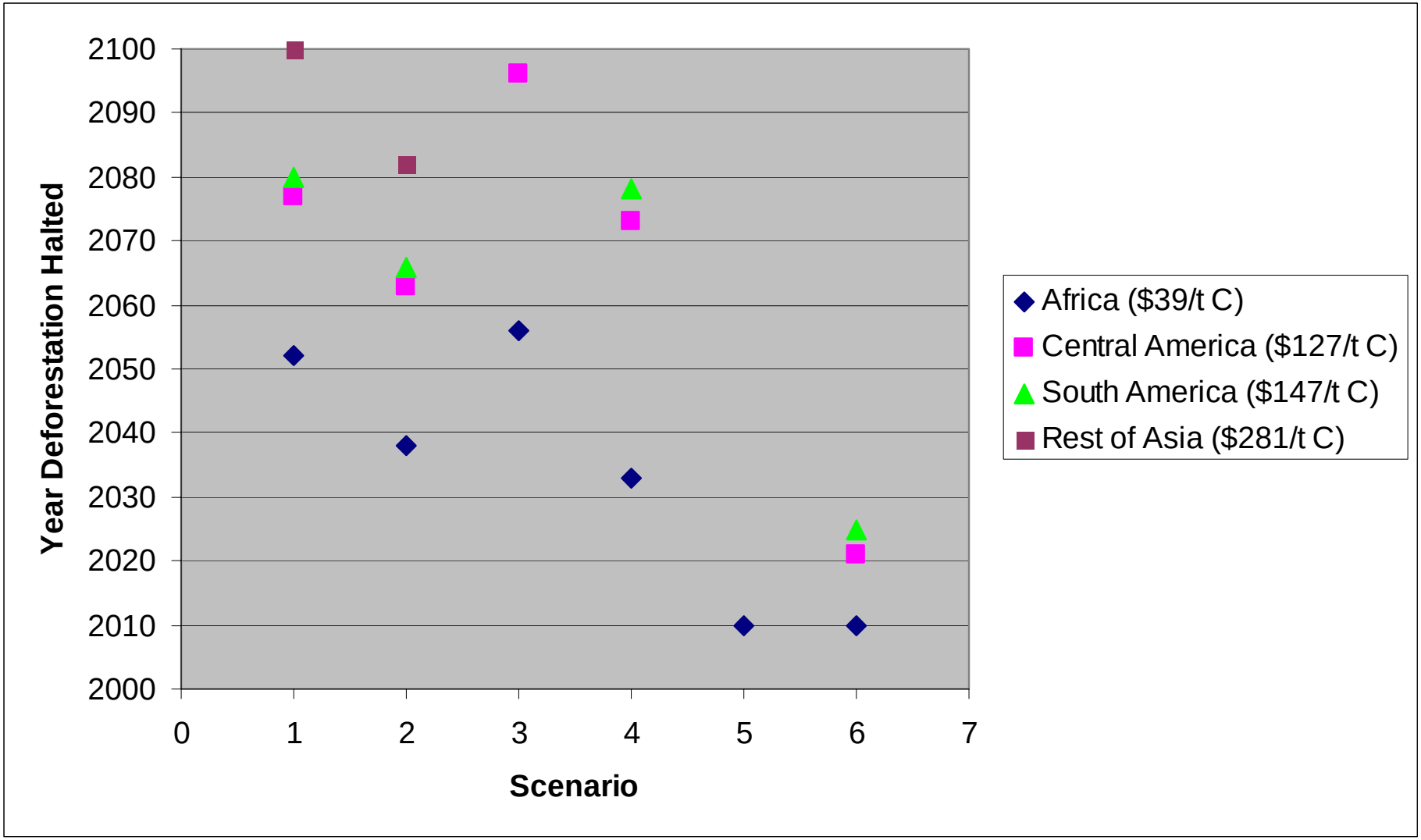
Region	Carbon price to virtually stop deforestation ($/ t C)
Africa	$ 39
Central America	$ 127
South America	$ 147
Rest of Asia (Asia without China and India)	$ 281

South and Central America and Africa account for bulk of carbon avoided from deforestation

		Scenario 2 -- $10 + 5% /year				
	2050	2100	2050	2100	2050	2100
	(Mt C)	(Mt C)	(%)	(%)	(%)	(%)
Africa	6,806	16,222	63%	41%	42%	100%
China						
India						
Russia						
Rest of Asia	400	3,001	4%	8%	13%	100%
Central America	350	1,639	3%	4%	21%	100%
South America	3,305	19,130	30%	48%	17%	100%
USA						
EU						
Oceania						
WORLD TOTAL	10,862	39,992	10,862	39,992	27%	100%

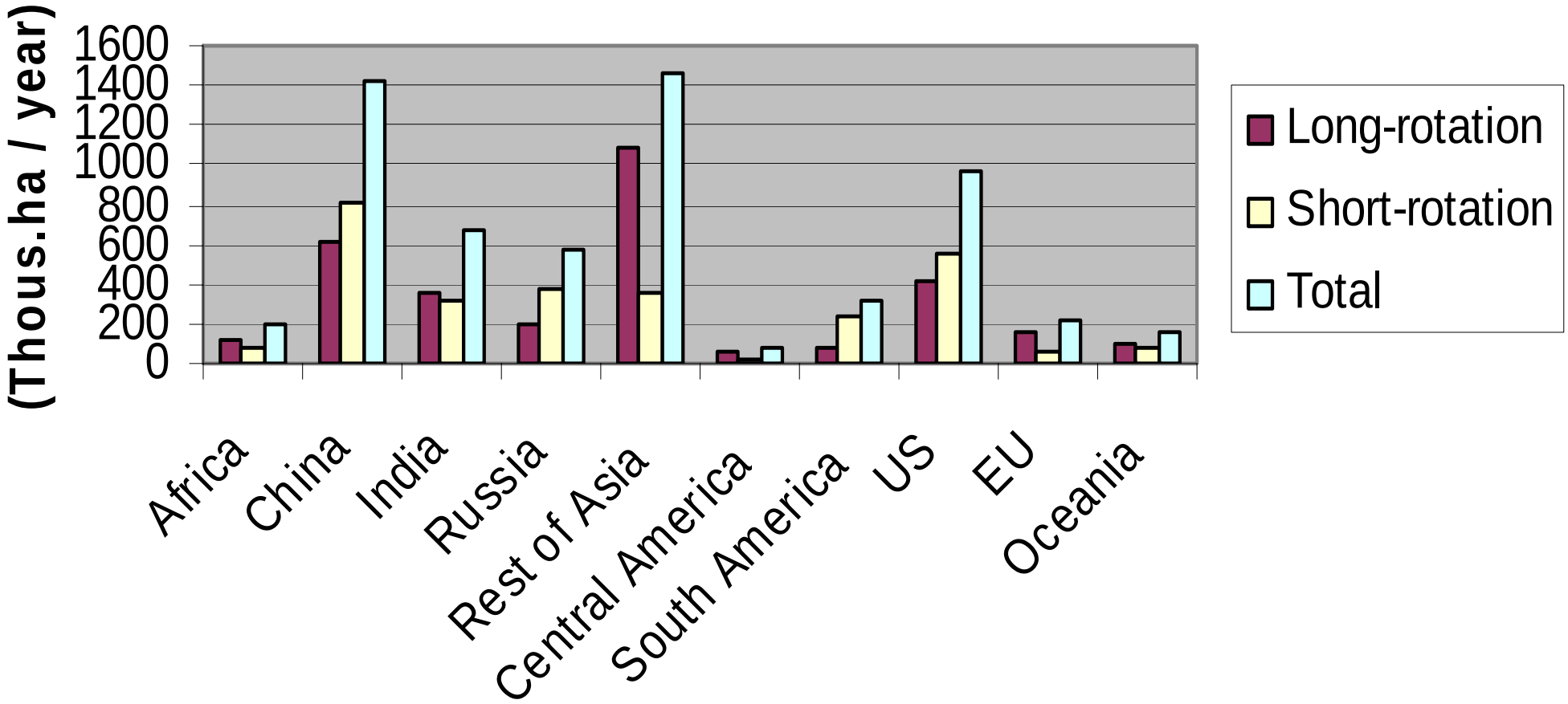
		Scenario 5 -- $100 /t C Constant				
	2050	2100	2050	2100	2050	2100
	(Mt C)	(Mt C)	(%)	(%)	(%)	(%)
Africa	12,923	22,360	45%	43%	58%	100%
China						
India						
Russia						
Rest of Asia	1,650	2,877	6%	6%	57%	100%
Central America	1,455	2,406	5%	5%	60%	100%
South America	12,753	24,289	44%	47%	53%	100%
USA						
EU						
Oceania						
WORLD TOTAL	28,780	51,932	28,780	51,932	55%	100%

Deforestation virtually halted – Dates by 4 regions and 6 scenarios



Historical Afforestation Rates

(Data for each region for periods varying from 1975 to 2000)



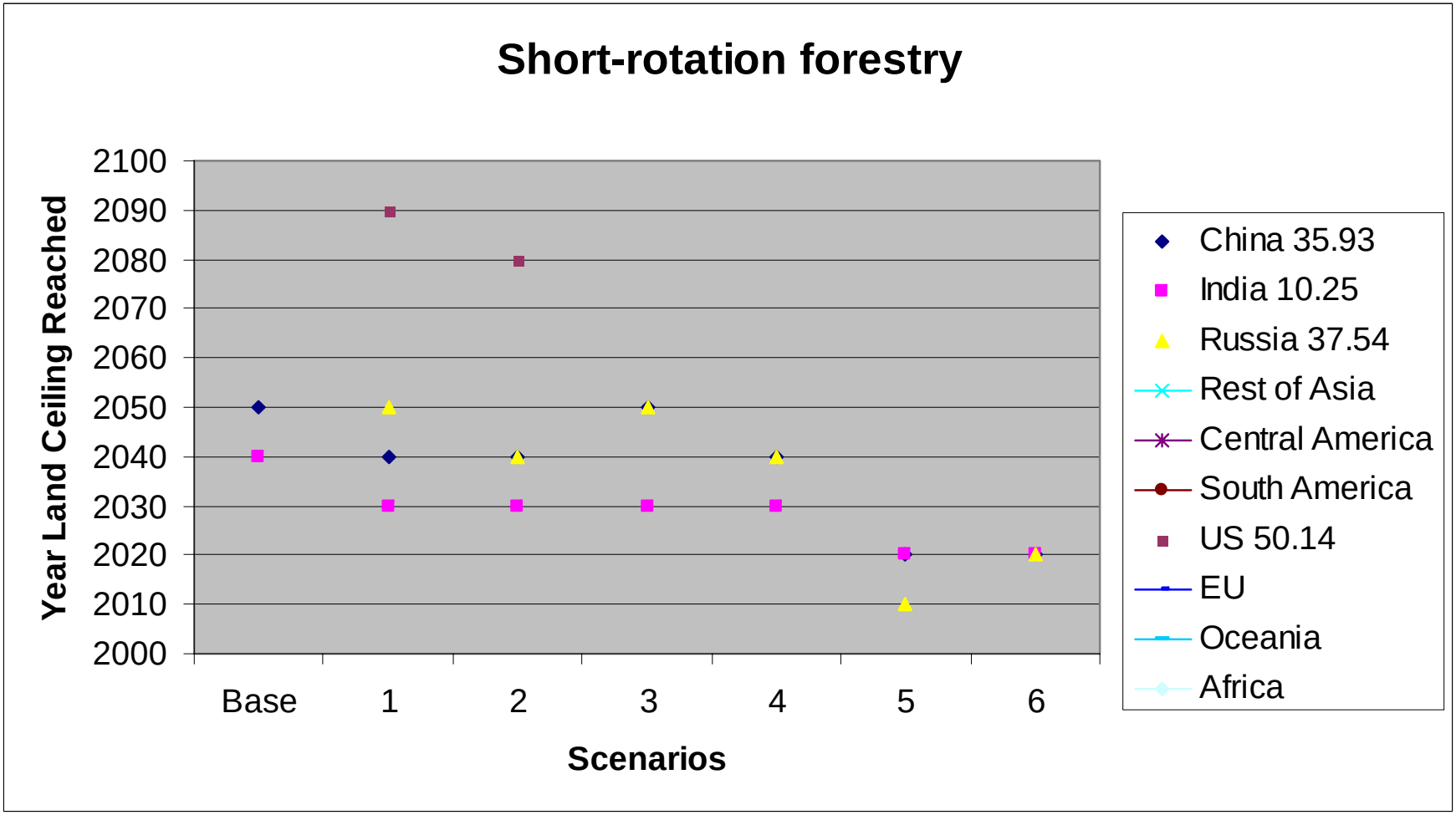
Caps on land suitable for forestation limits the full benefit of the carbon price in several regions

Land availability for forestation varies by region and option

Regions	Short-rotation Mha	Long-rotation Mha	Comments
Africa	80.0	120.0	Grassland, abandoned ag. land, and some deforested land.
China	35.9	27.1	Based on China's short, medium, an d long-term expansion plans
India	10.2	11.5	Government forestry plans to 2020
Russia	37.5	20.2	Doubled current afforestation rate-- half the available land
Rest of Asia	50.0	150.0	Degraded forest land and waste land.
Central America	6.5	15.0	Degraded forest land and waste land.
South America	50.0	150.0	Degraded forest land and waste land.
United States	50.1	65.9	Dry and wet soil pasture and cropland and non-grazing forest by 9 US regions
European Union	40.0	50.0	Forestry, cropland and agricultural land
Oceania	28.0	42.0	Australia plans, New Zealand FAO 2050 scenario, and Japan and PNG estimated areas
TOTAL	388.3	651.7	

Yellow highlighted figures show regions where land cap was reached in at least one scenario

Carbon price effect is mitigated since land area ceiling is reached before 2100 in a few regions

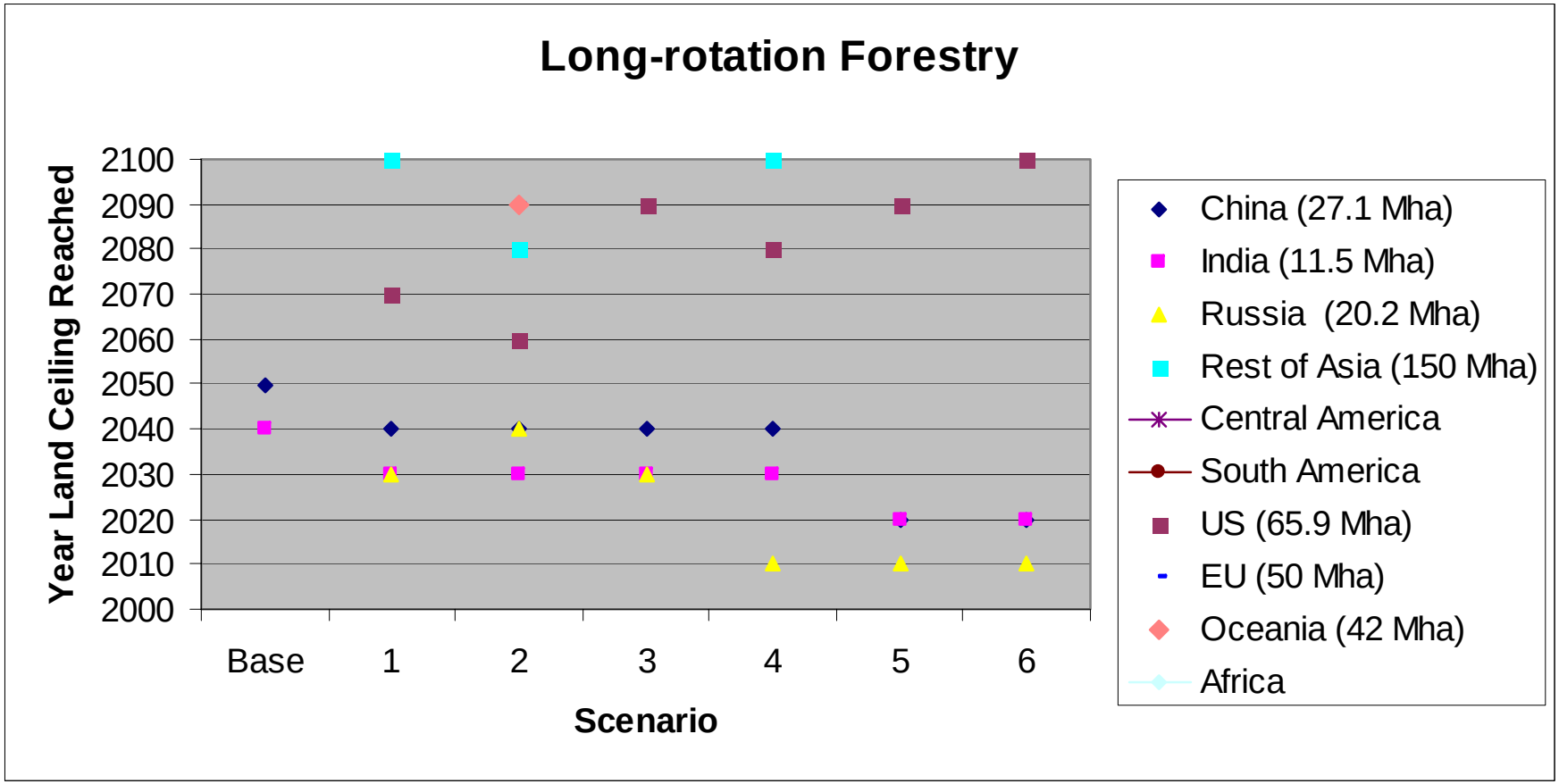


Short-rotation: Russia C gain important up to 2050, other regions by 2100

	Scenario 2 -- $10 + 5% /year					
	2050 (Mt C)	2100 (Mt C)	2050 (%)	2100 (%)	2050 (%)	2100 (%)
Africa	55	686	3%	8%	8%	100%
China	121	-38	6%	0%	-323%	100%
India	16	-15	1%	0%	-109%	100%
Russia	880	165	45%	2%	533%	100%
Rest of Asia	210	2,444	11%	27%	9%	100%
Central America	1	13	0%	0%	5%	100%
South America	196	1,548	10%	17%	13%	100%
USA	278	1,703	14%	19%	16%	100%
EU	102	1,226	5%	14%	8%	100%
Oceania	101	1,262	5%	14%	8%	100%
WORLD TOTAL	1,960	8,994	1,960	8,994	22%	100%

	Scenario 5 -- $100 /t C Constant					
	2050 (Mt C)	2100 (Mt C)	2050 (%)	2100 (%)	2050 (%)	2100 (%)
Africa	156	187	4%	6%	83%	100%
China	140	-56	3%	-2%	-249%	100%
India	7	7	0%	0%	101%	100%
Russia	1,906	536	45%	16%	356%	100%
Rest of Asi	454	469	11%	14%	97%	100%
Central Am	1	5	0%	0%	27%	100%
South Ame	340	593	8%	18%	57%	100%
USA	825	957	19%	29%	86%	100%
EU	299	321	7%	10%	93%	100%
Oceania	139	260	3%	8%	54%	100%
WORLD TOT	4,268	3,278	4,268	3,278	130%	100%

Carbon price benefit is mitigated since land area ceiling is reached before 2100 in some regions

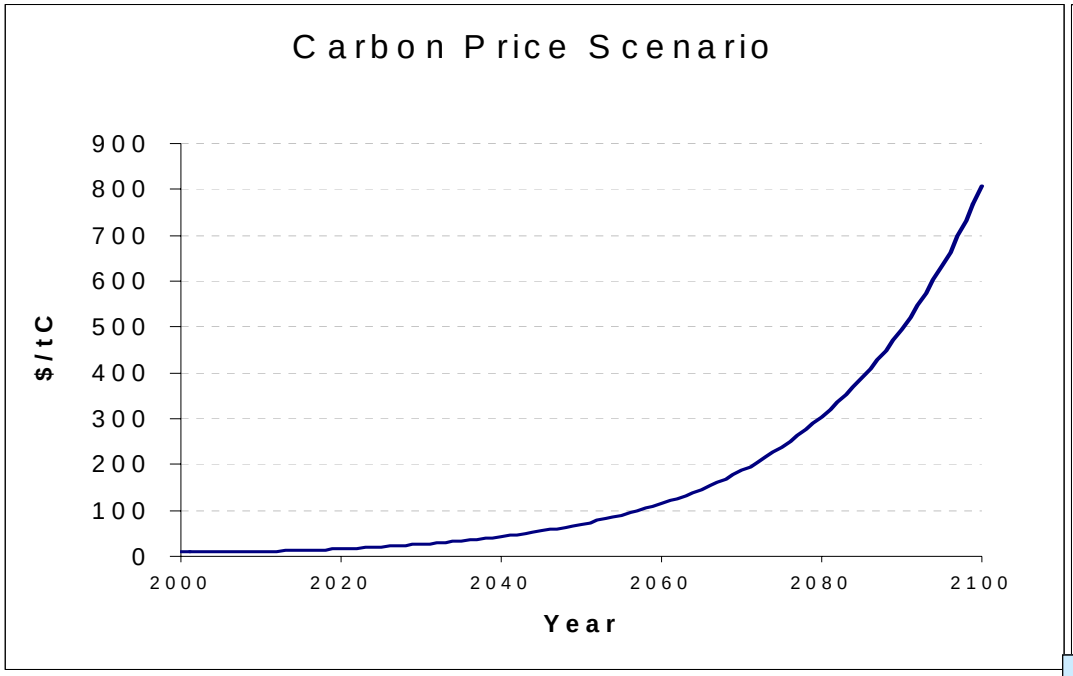


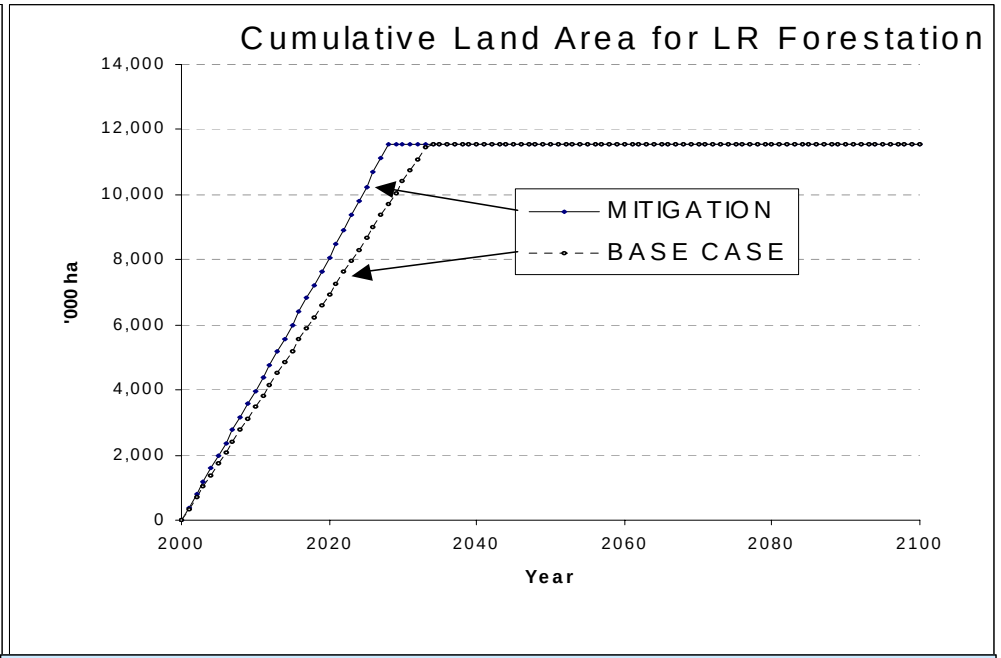
Base Case 1990-2000 – All planting Rates (thousands ha/yr) :
India – 350; China – 615; Rest of Asia – 1,100; Africa – 115;
Central America – 60; S America – 80

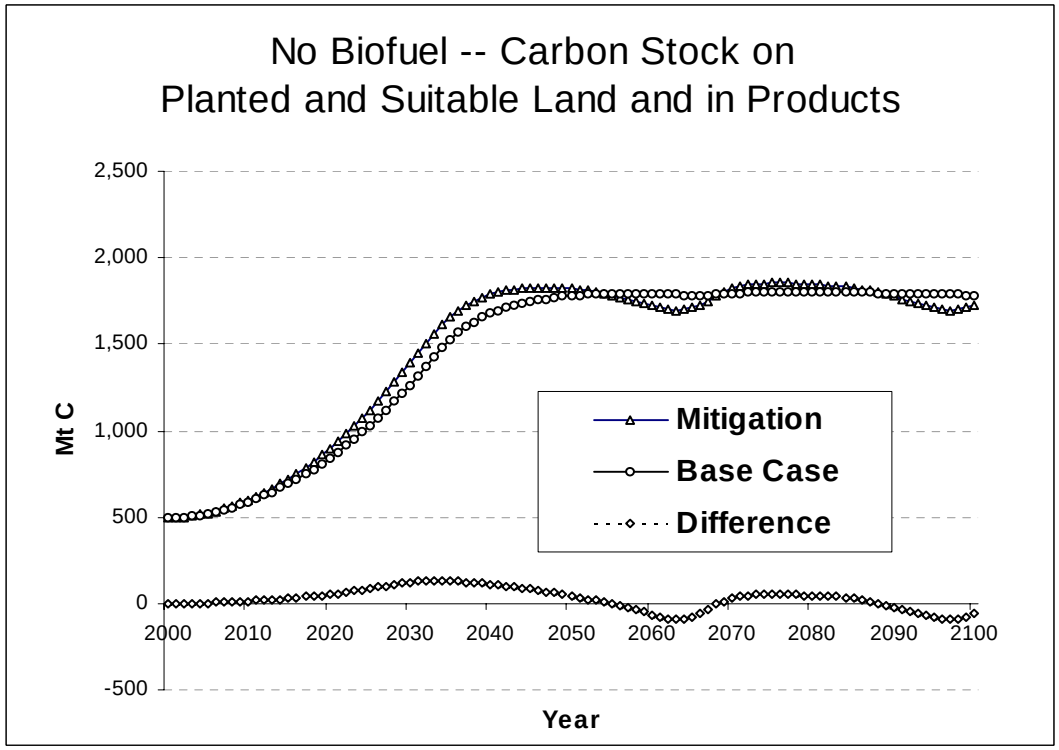
Long rotation: Russia, ROA, US and Oceania carbon gains important by 2050, ROA, US, EU, and Oceania by 2100

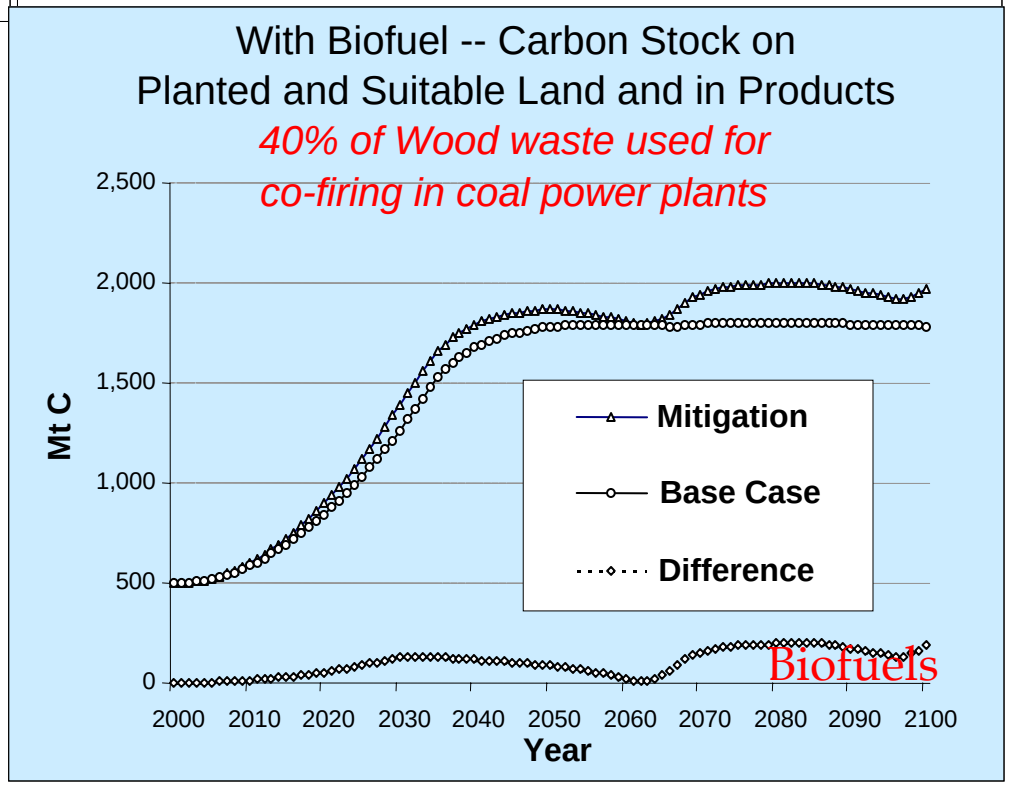
	Scenario 2 -- $10 + 5% /year					
	2050 (Mt C)	2100 (Mt C)	2050 (%)	2100 (%)	2050 (%)	2100 (%)
Africa	143	1,862	2%	4%	8%	100%
China	502	218	6%	0%	230%	100%
India	44	-57	0%	0%	-77%	100%
Russia	1,273	1,932	14%	4%	66%	100%
Rest of Asia	3,418	18,436	38%	37%	19%	100%
Central America	29	455	0%	1%	6%	100%
South America	51	638	1%	1%	8%	100%
USA	2,272	9,770	25%	20%	23%	100%
EU	748	8590	8%	17%	9%	100%
Oceania	618	7566	7%	15%	8%	100%
WORLD TOTAL	9099	49411	9,099	49,411	18%	100%

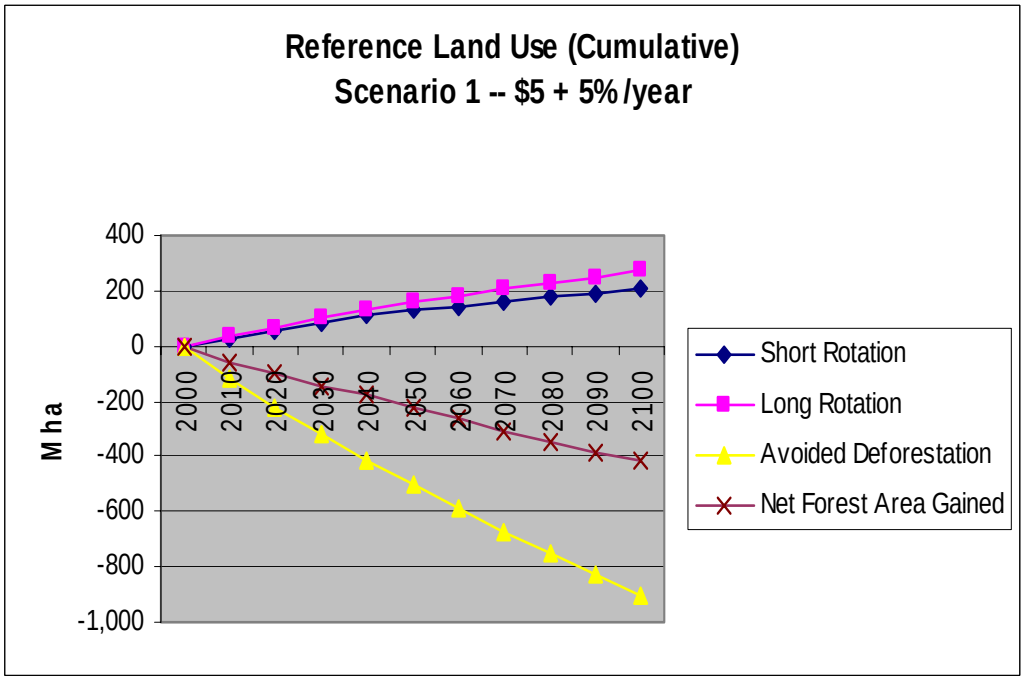
	Scenario 5 -- $100 /t C Constant					
	2050 (Mt C)	2100 (Mt C)	2050 (%)	2100 (%)	2050 (%)	2100 (%)
Africa	386	476	2%	2%	81%	100%
China	603	-555	3%	-2%	-109%	100%
India	-173	136	-1%	0%	-127%	100%
Russia	1,473	2,132	8%	7%	69%	100%
Rest of Asi	5,695	6,545	29%	22%	87%	100%
Central Am	53	57	0%	0%	93%	100%
South Ame	120	137	1%	0%	88%	100%
USA	4,685	10,683	24%	35%	44%	100%
EU	1586	3744	8%	12%	42%	100%
Oceania	5125	6756	26%	22%	76%	100%
WORLD TOT	19553	30110	19,553	30,110	65%	100%

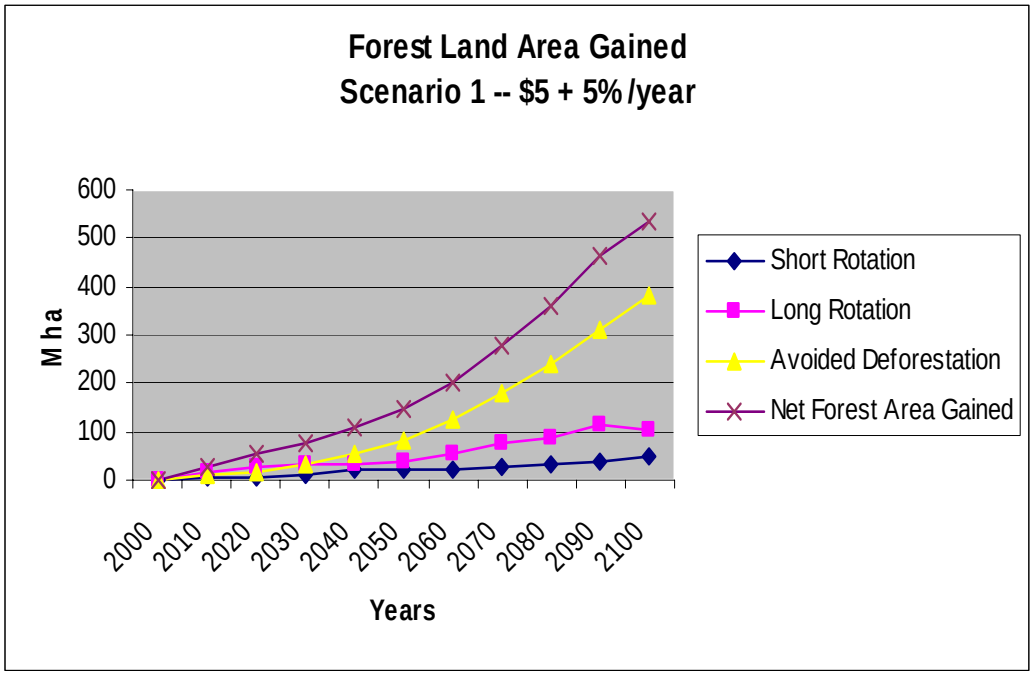

Carbon Price Scenario
$ / t C
900
800
700
600
500
400
300
200
100
0
2000
2020
2040
2060
2080
2100
Year

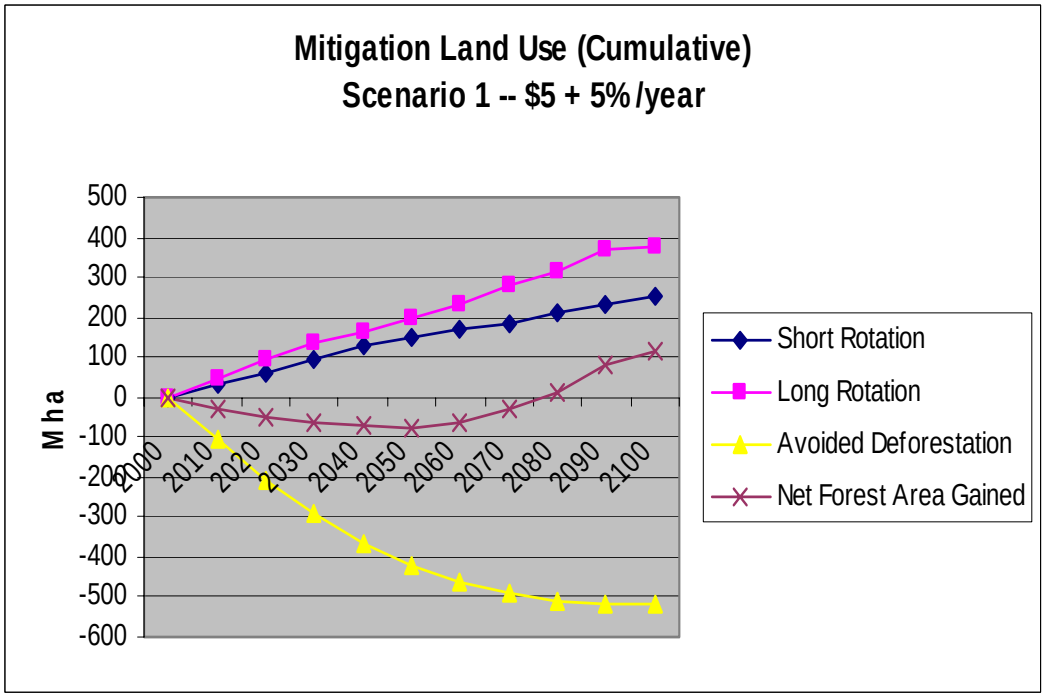

Cumulative Land Area for LR Forestation
'000 ha
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
2000
2020
2040
2060
2080
2100
Year
MITIGATION
BASE CASE

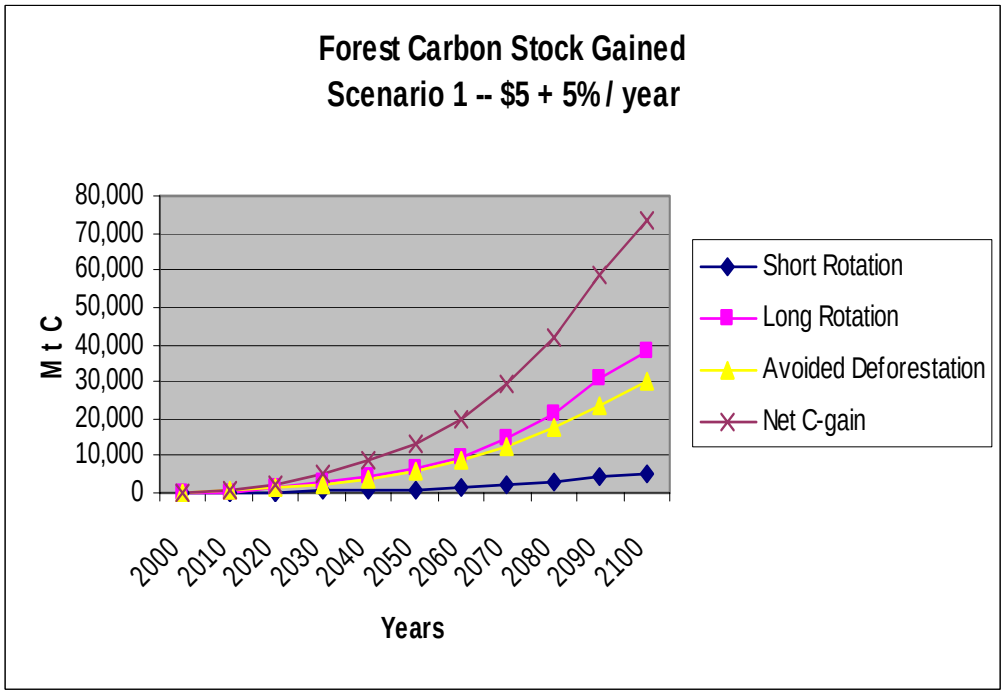

No Biofuel -- Carbon Stock on
Planted and Suitable Land and in Products
Mt C
2,500
2,000
1,500
1,000
500
0
-500
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
Mitigation
Base Case
Difference


With Biofuel -- Carbon Stock on
Planted and Suitable Land and in Products
40% of Wood waste used for
co-firing in coal power plants
Mt C
2,500
2,000
1,500
1,000
500
0
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
Mitigation
Base Case
Difference
Biofuels


Reference Land Use (Cumulative)
Scenario 1 -- $5 + 5% /year
M ha
400
200
0
-200
-400
-600
-800
-1,000
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Short Rotation
Long Rotation
Avoided Deforestation
Net Forest Area Gained


Forest Land Area Gained
Scenario 1 -- $5 + 5% /year
M ha
600
500
400
300
200
100
0
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Years
Short Rotation
Long Rotation
Avoided Deforestation
Net Forest Area Gained


Mitigation Land Use (Cumulative)
Scenario 1 -- $5 + 5% /year
M ha
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Short Rotation
Long Rotation
Avoided Deforestation
Net Forest Area Gained


Forest Carbon Stock Gained
Scenario 1 -- $5 + 5% / year
M t C
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Years
Short Rotation
Long Rotation
Avoided Deforestation
Net C-gain

Summary and Conclusions

- **Sequestered carbon and avoided emissions:**
  - IPCC SAR estimate: 60 – 80 Gt C
  - This study: 11 – 58 Gt C by 2050, and 43 – 103 Gt C by 2100
  - Quantity depends on reference case forestation and deforestation and on carbon price and path
  - Land availability limits planting in China, India, Russia, and US in many scenarios, and in Oceania and Rest of Asia in some scenarios
  - Biofuels could significantly increase the above values

- Carbon price could virtually halt deforestation in Africa and Latin America in all scenarios, and in Asia in the high priced scenarios

Thank you