LBNL / EPA Cooperation on Forestry Climate Mitigation Potential and Costs:

GCOMAP Model

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Mexico City, July 11-12, 2005

Contents

GCOMAP Model

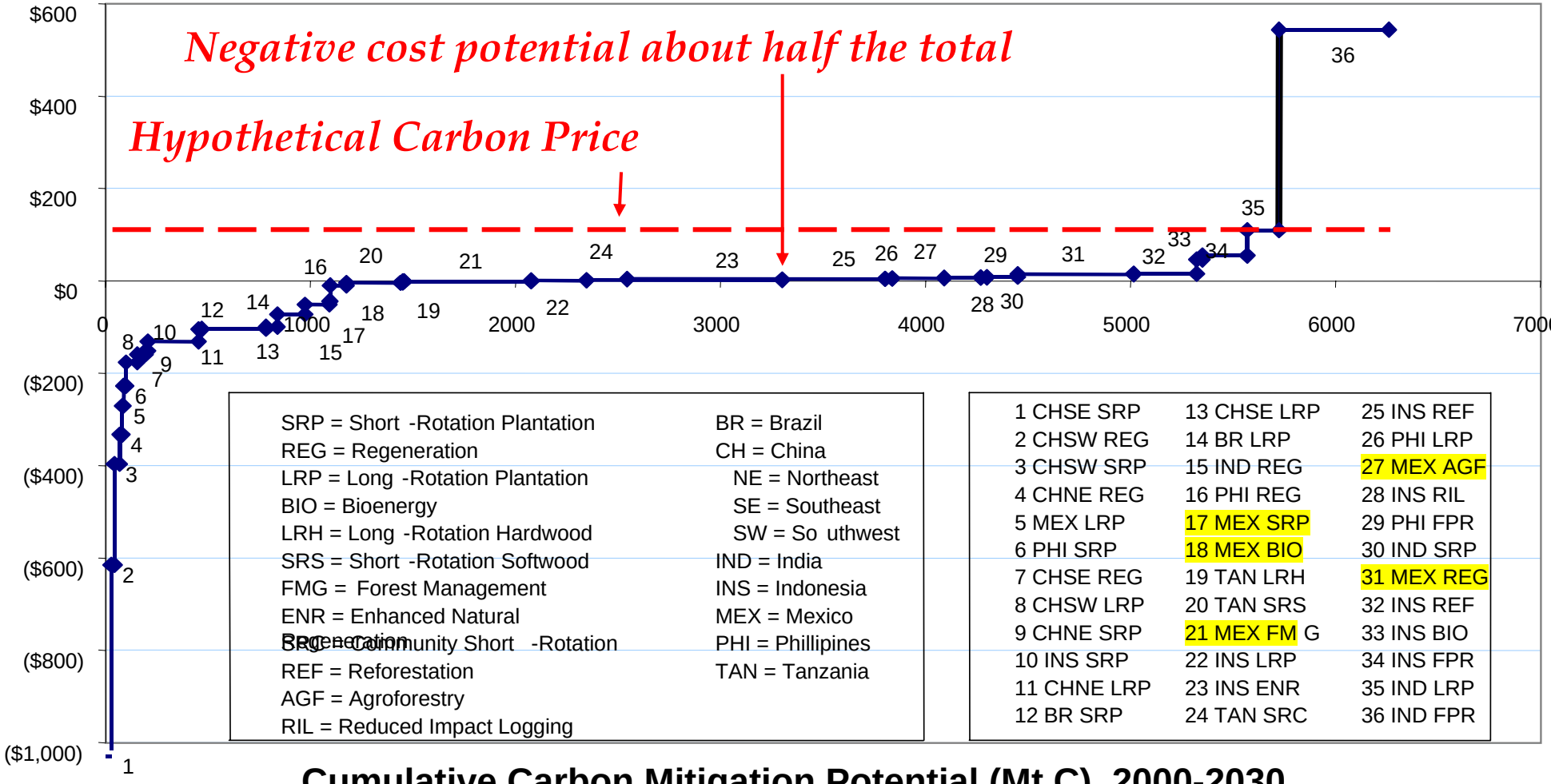
(Generalized Comprehensive Mitigation Assessment Process)

- GCOMAP Model Structure:
  - Dynamic partial equilibrium model
- Key Input Data -- Tropics & Reference Case
- Results for six EMF 21 carbon price scenarios
- Deforestation
- Reforestation
- Effect of biofuels

Earlier LBNL/EPA Studies of Forestry in the Tropics: COMAP -- Forestry Mitigation Potential

(Brazil, China, India, Indonesia, Mexico, Philippines and Tanzania)

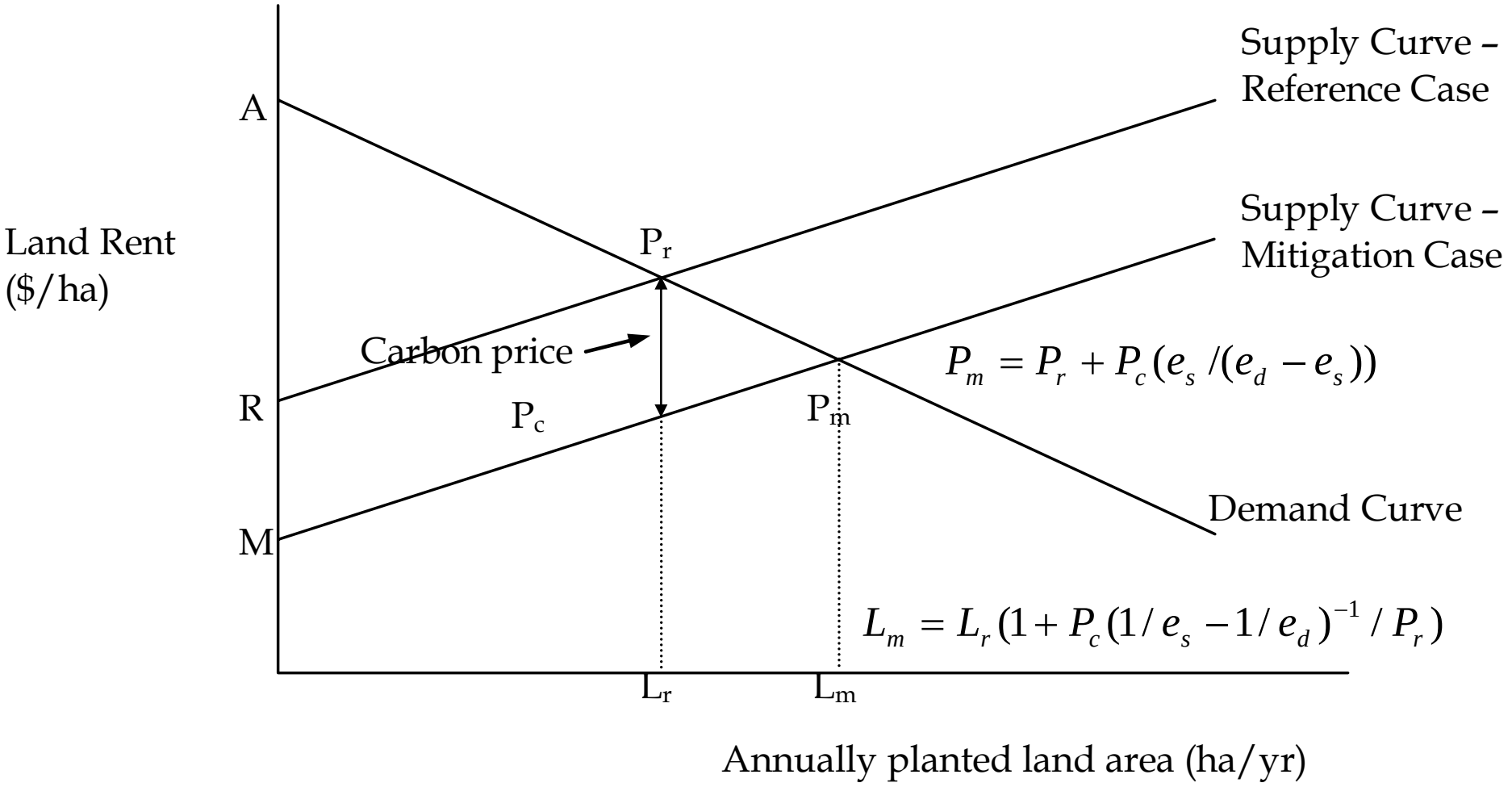
Cost ($/ t C) DR = 8-12%



Cumulative Carbon Mitigation Potential (Mt C), 2000-2030

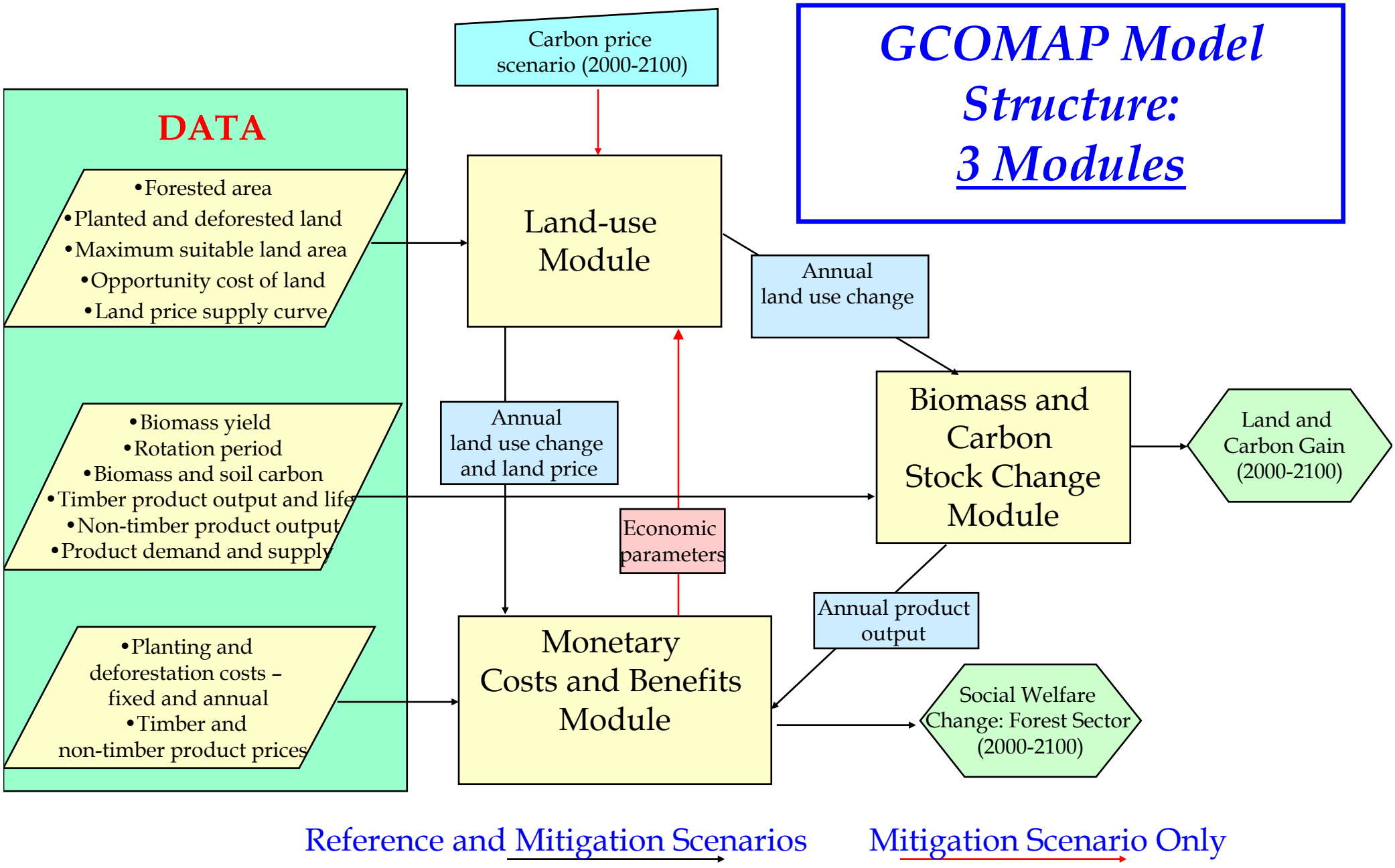
Source: 1. Sathaye J. Makundi W., Andrasko K. Boer R., Ravindranath N.H., Sudha P., Rao S., Lasco R., Pulhin F., Masera O., Ceron A., Ordonez J., Deying X., Zhang X., and Zuomin S. 2001. Carbon mitigation potential and costs of forestry options in Brazil, China, India, Indonesia, Mexico, the Philippines, and Tanzania. *Mitigation and Adaptation Strategies for Global Change,* Vol. 6. Nos. 3-4, pp. 185-211.

GCOMAP: Determining Mitigation Land Use Change and Associated Products Output: How much would forested land area change in response to a carbon price?



GCOMAP Current Scope

Mitigation Option	Current EMF 21 Geographic Regions	Carbon Pools (in all regions)
Forestation – **Short-rotation** **Long-rotation** • **Without biofuels** • **With biofuels (not analyzed yet)**	**North America** **South / Central America** **Europe** **Russia (not FSU)** **China** **India** **Australia/NZ** **Asia-Pacific** **Africa**	• **Above/below ground biomass** • **Soils** • **Litter** • **Post-harvest residue** • **Domestic timber products** • **International timber products** • **Fuelwood** • **Mill-waste products** • **Biofuels – used as a substitute for coal in power plants**
Avoided deforestation (no biofuels)	**South / Central America (incl. Mexico)** **Asia-Pacific** **Africa**	


GCOMAP Model Structure: 3 Modules
Carbon price scenario (2000-2100)
DATA
•Forested area
•Planted and deforested land
•Maximum suitable land area
•Opportunity cost of land
•Land price supply curve
Land-use Module
Annual land use change
Biomass and Carbon Stock Change Module
Land and Carbon Gain (2000-2100)
•Biomass yield
•Rotation period
•Biomass and soil carbon
•Timber product output and life
•Non-timber product output
•Product demand and supply
Annual land use change and land price
Economic parameters
Annual product output
•Planting and deforestation costs – fixed and annual
•Timber and non-timber product prices
Monetary Costs and Benefits Module
Social Welfare Change: Forest Sector (2000-2100)
Reference and Mitigation Scenarios
Mitigation Scenario Only

Key Data Inputs
Deforestation Rate: Historical and Projected

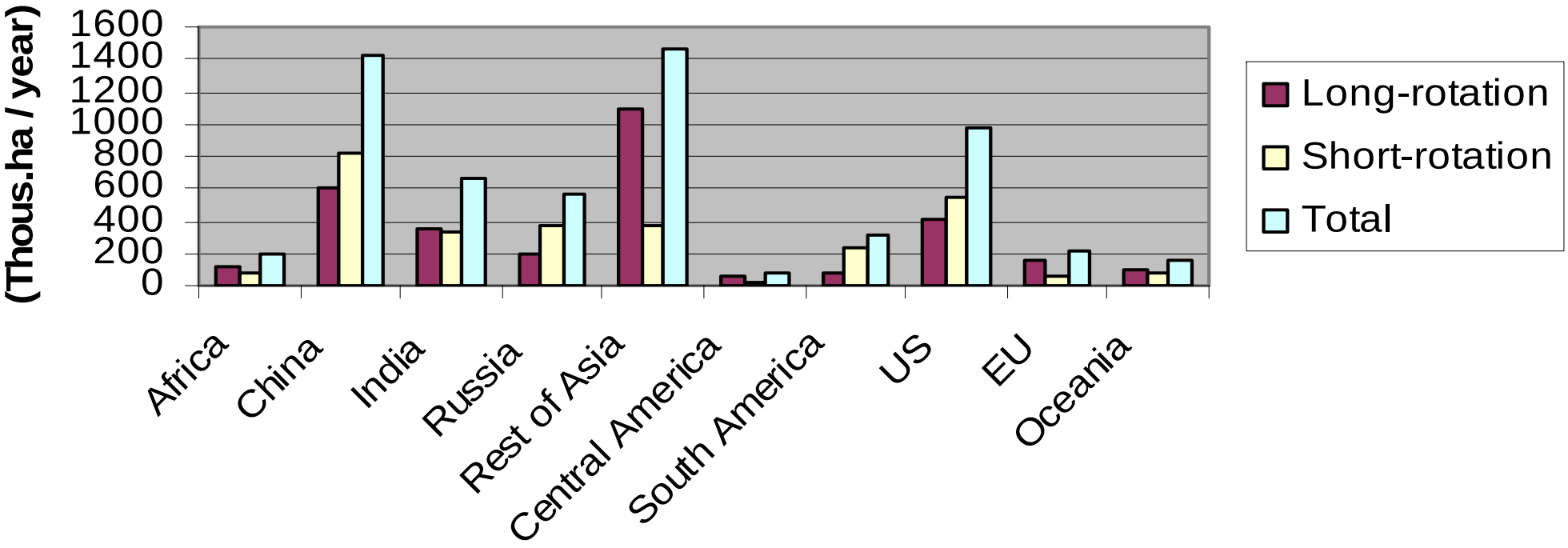
- Global deforestation currently 17 Mha/yr (FAO) or less (Houghton)
  - –India and China: deforestation declined to zero
  - –Brazil: constant or accelerating deforestation
  - –Africa 1990-00 deforestation rate increased, unlike in other regions
  - • Deforestation rate is projected to increase to 2020 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

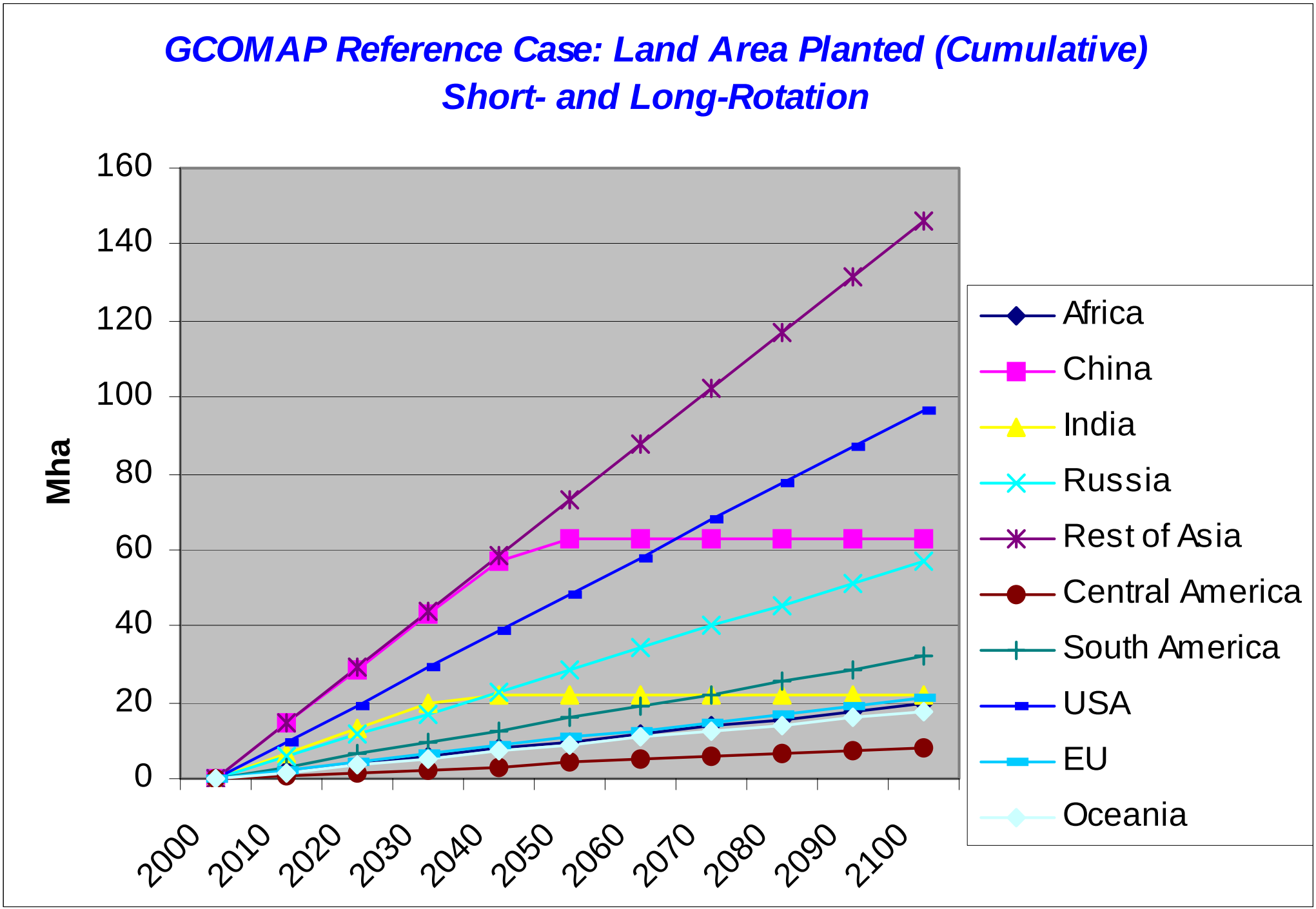
The deforestation rate gives the percent decline in the forest area per year
(-) rate is an annual decline in the deforestation rate

Based on FAO 2001 – Forest Resource Assessment-2000; Kaimovitz 1996 Livestock and deforestation in Central America in 1980s and 1990s; Barraclough and Ghimire 2000. Agricultural Expansion and Tropical Deforestation

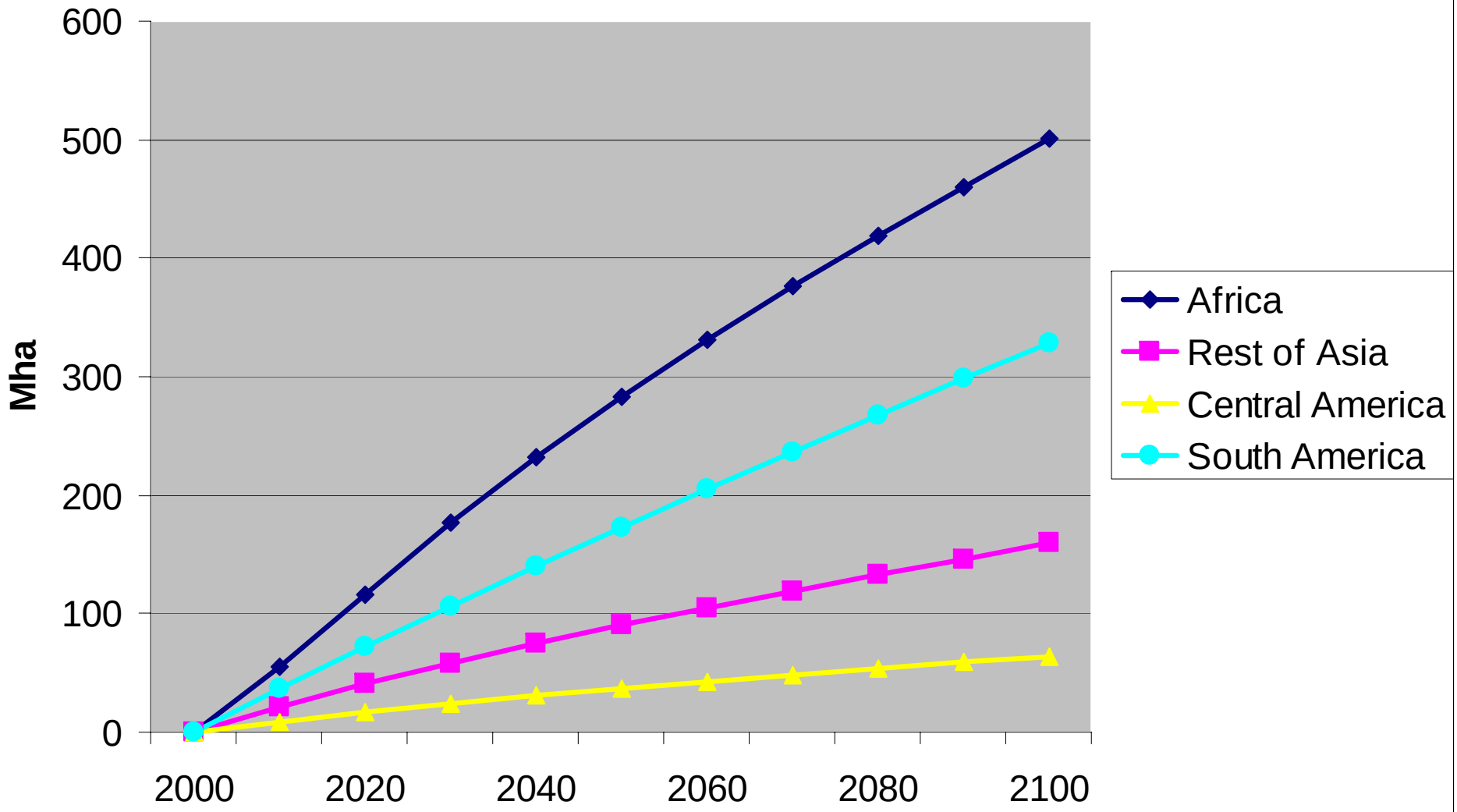
Key Data Inputs



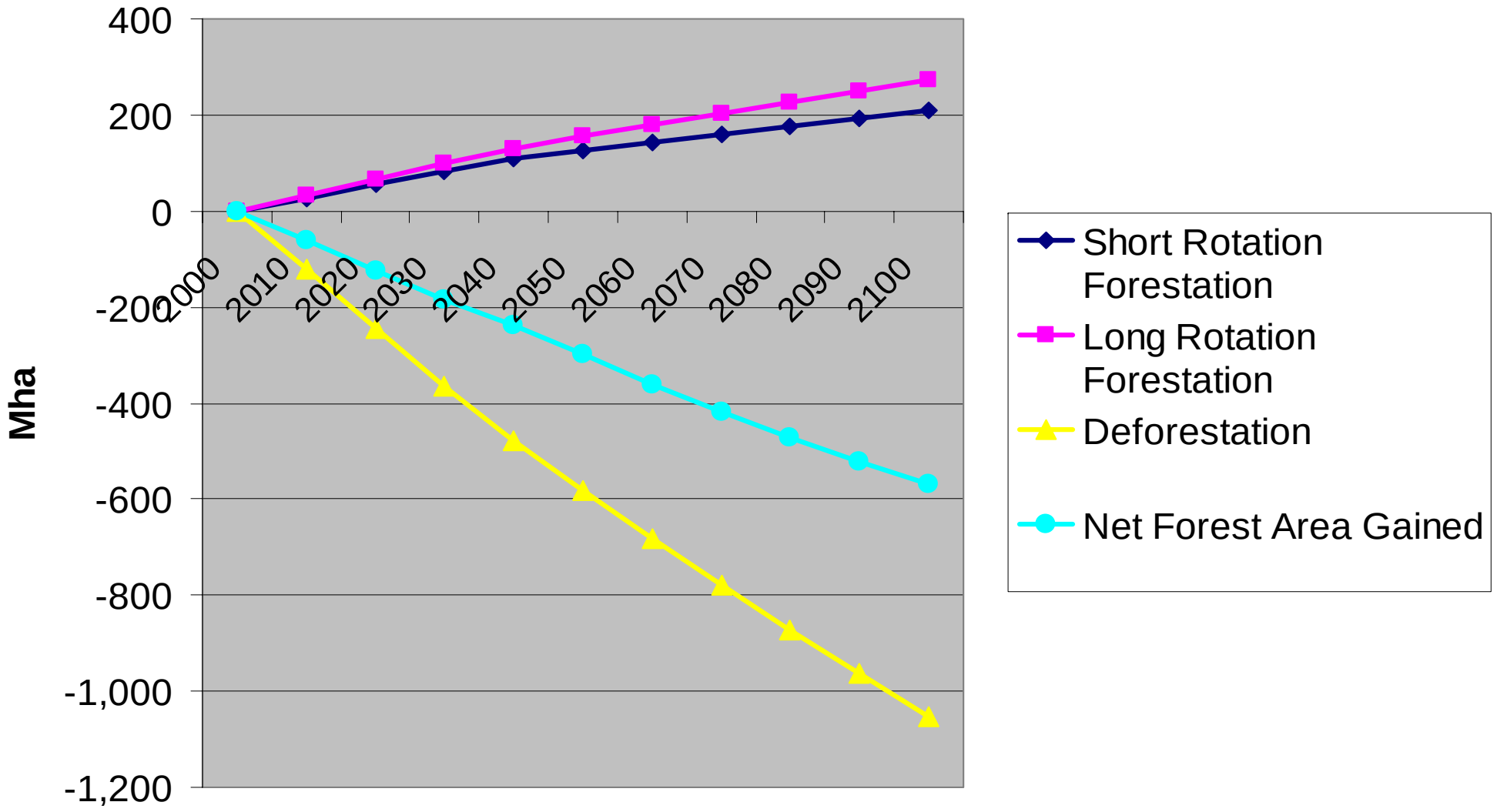
Source:
FAO 2001 – Forest Resource Assessment-2000, and
FAO 2000 – The Global Outlook for Future Wood Supply from Plantations
US – Moulton et al., 1996: Tree Planting in the United States

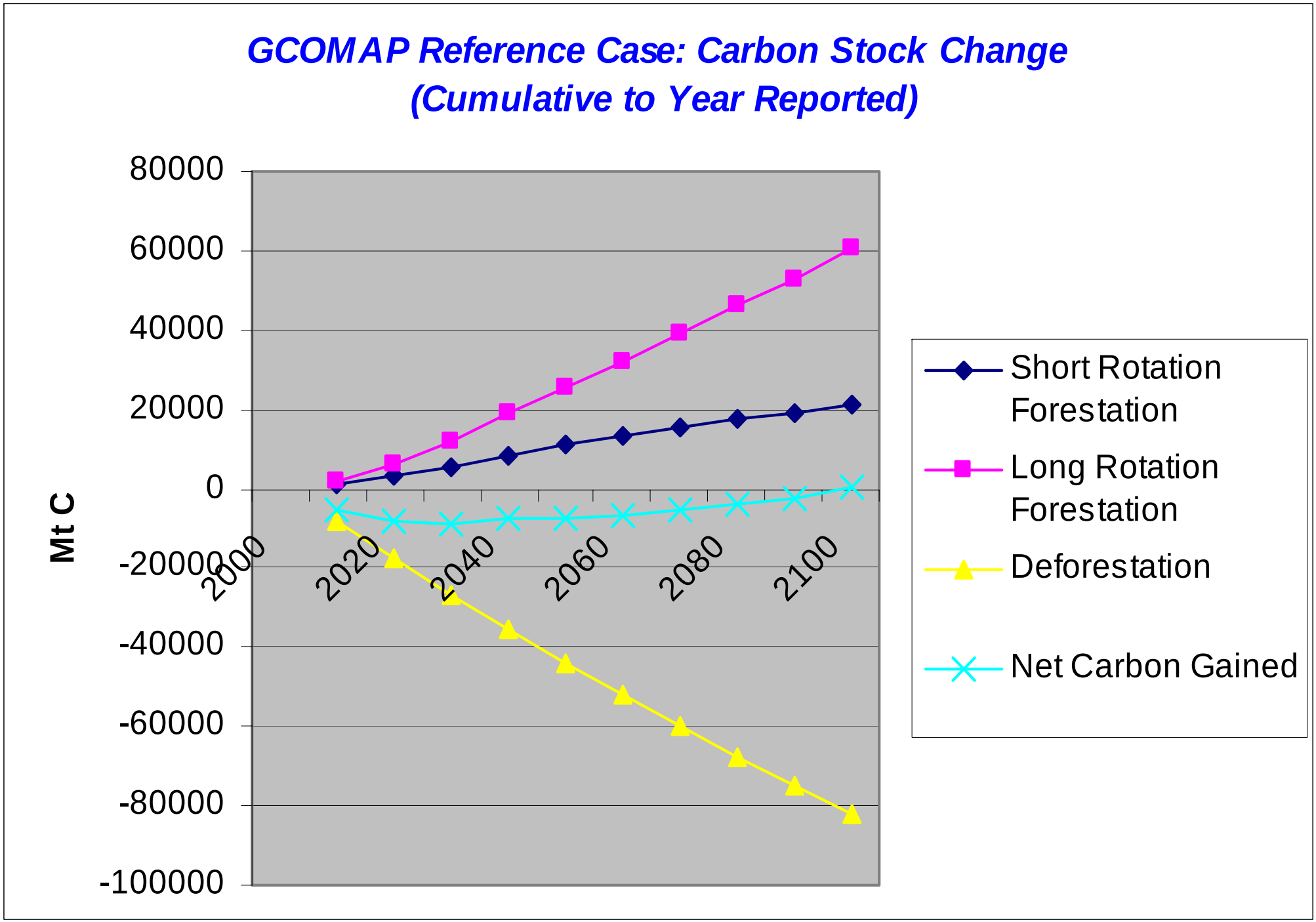

GCOMAP Reference Case: Land Area Planted (Cumulative)
Short- and Long-Rotation
Mha
160
140
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Africa
China
India
Russia
Rest of Asia
Central America
South America
USA
EU
Oceania

GCOMAP Reference Case: Land Area Deforested by Region (Cumulative to year reported)

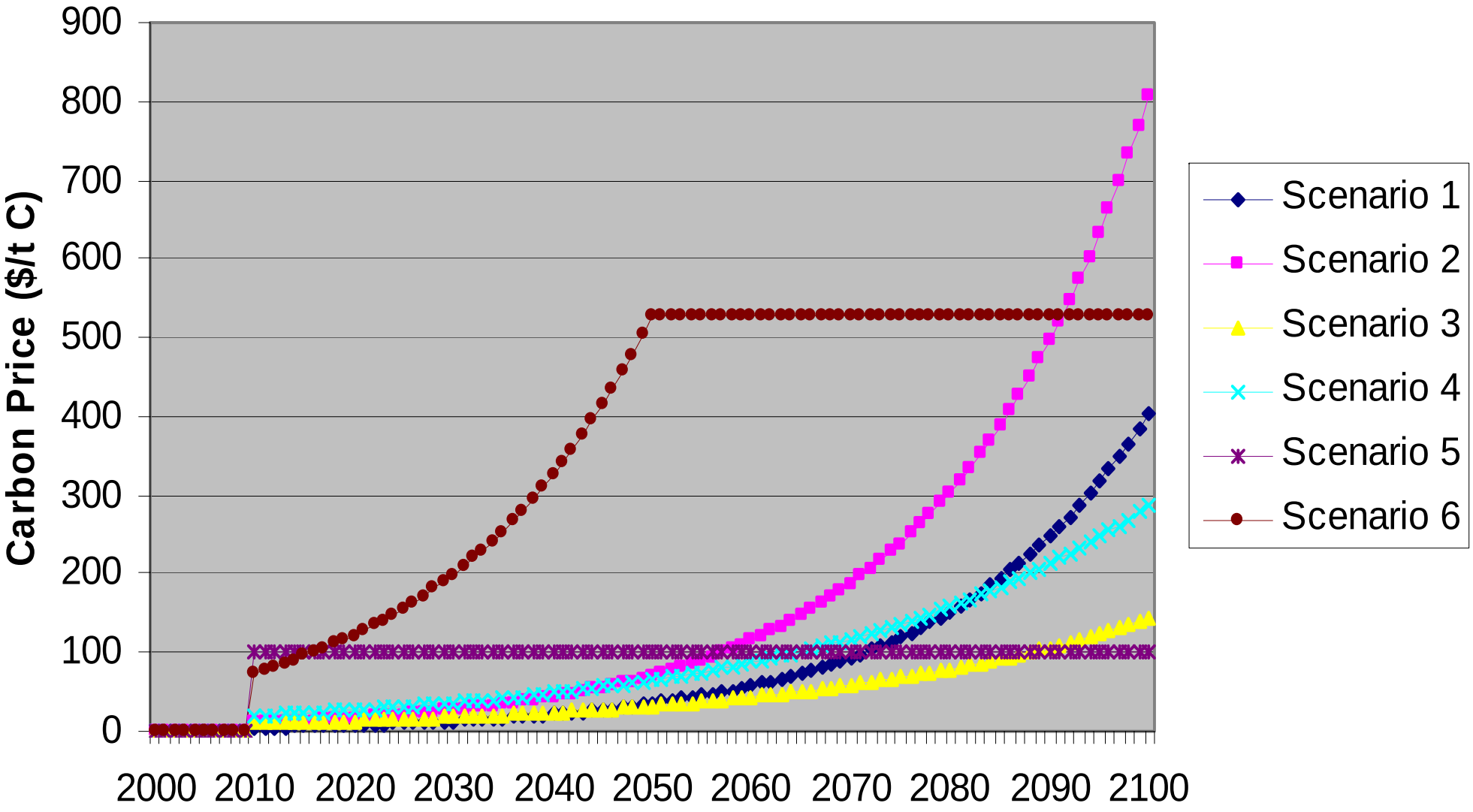


GCOMAP Reference Case: Land Use Change by Activity for All Regions (Cumulative to year reported)

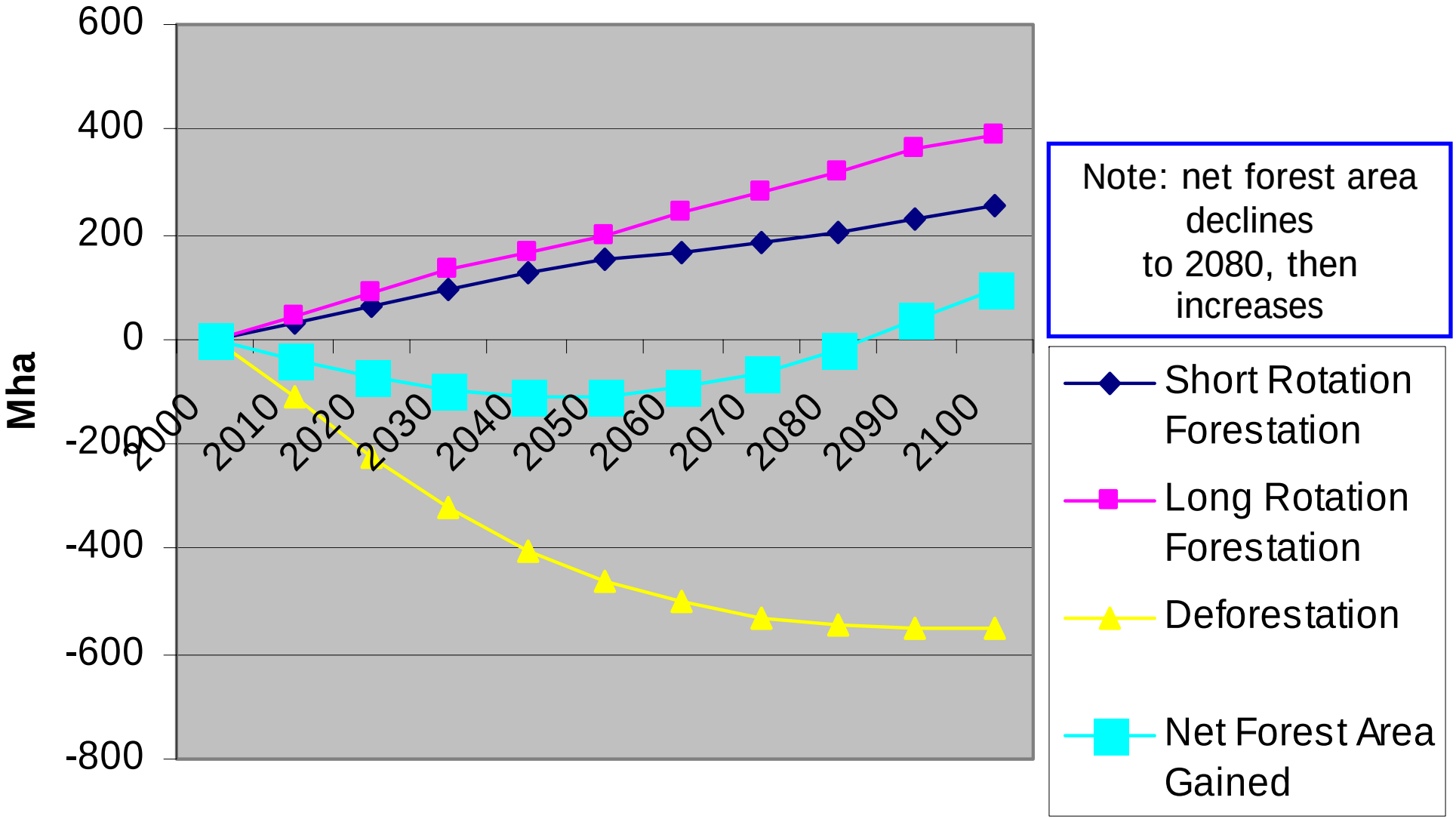



GCOMAP Reference Case: Carbon Stock Change
(Cumulative to Year Reported)
Mt C
80000
60000
40000
20000
0
-20000
-40000
-60000
-80000
-100000
2000
2020
2040
2060
2080
2100
Short Rotation Forestation
Long Rotation Forestation
Deforestation
Net Carbon Gained

Carbon Price Mitigation Scenarios



Scenario 1 ($5 + 5% /year) -- Land Use Change by Activity for All Regions (Cumulative to year reported)



Results – Global land area and carbon gain across scenarios*

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

Scenario [b]	Carbon Price ($/t C)		Land Area Gained (Mha)		Carbon Benefits Gained (Mt C)	
2010 C Price + Annual Increase	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
1. $5 + 5%	**35**	**404**	**190**	**662**	**13,570**	**70,145**
Forestation			68	163	5,554	33,162
Avoided deforestation			122	499	8,034	37,105
2. $10 + 5%	**70**	**807**	**327**	**880**	**24,917**	**96,496**
Forestation			108	231	10,123	47,849
Avoided deforestation			219	649	14,796	48,835
3. $10 + 3%	**33**	**143**	**212**	**555**	**15,628**	**50,905**
Forestation			52	77	4,934	16,358
Avoided deforestation			160	478	10,694	34,547
4. $20 + 3%	**65**	**286**	**363**	**819**	**28,582**	**79,559**
Forestation			75	135	8,917	28,575
Avoided deforestation			288	684	19,665	50,985
5. $100 + 0%	**100**	**100**	**537**	**866**	**47,252**	**78,970**
Forestation			83	56	13,587	17,245
Avoided deforestation			454	810	33,665	61,725
6. $75 + $5	**275**	**275**	**664**	**1081**	**63,300**	**113,208**
Forestation			192	146	25,675	38,422
Avoided deforestation			501	959	37,625	74,786

Notes: a) Gained amount refers to the cumulative difference between a mitigation scenario and the reference case scenario by 2050 and 2100

b) All carbon prices are zero until 2009, and begin with the stated value in 2010

Results – 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 [b]	Carbon Price ($/t C)		Land A…		…ained (Mt C)	
2010 C Price + Annual Increase	**2050**	**2100**				**2100**
1. $5 + 5%	**35**	**404**	**190**	**662**	**…570**	**70,145**
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Results – Global land … ross 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 [b]	Carbon Price ($/t C)		Benefits Gained (Mt C)			
2010 C Price + Annual Increase	**2050**	**2**			**2050**	**2100**
1. $5 + 5%	**35**				**13,570**	**70,145**
Forestation					5,554	33,162
Avoided deforestation			122	499	8,034	37,105
2. $10 + 5%	**70**	**807**	**327**	**880**	**24,917**	**96,496**
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Results – Global land a… …oss scenarios

Mitigation Options : Long and … …ed deforestation

Avoided deforestation accounts from 51% to 78% of gained 2100 carbon depending on the carbon price and path.

Scenario [b]	Carbon Price ($/t C)				Benefits Gained (Mt C)	
2010 C Price + Annual Increase	**2050**	**2100**			**2050**	**2100**
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Forestation			83	56	13,587	17,245
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6. $75 + $5	**275**	**275**	**664**	**1081**	**63,300**	**113,208**
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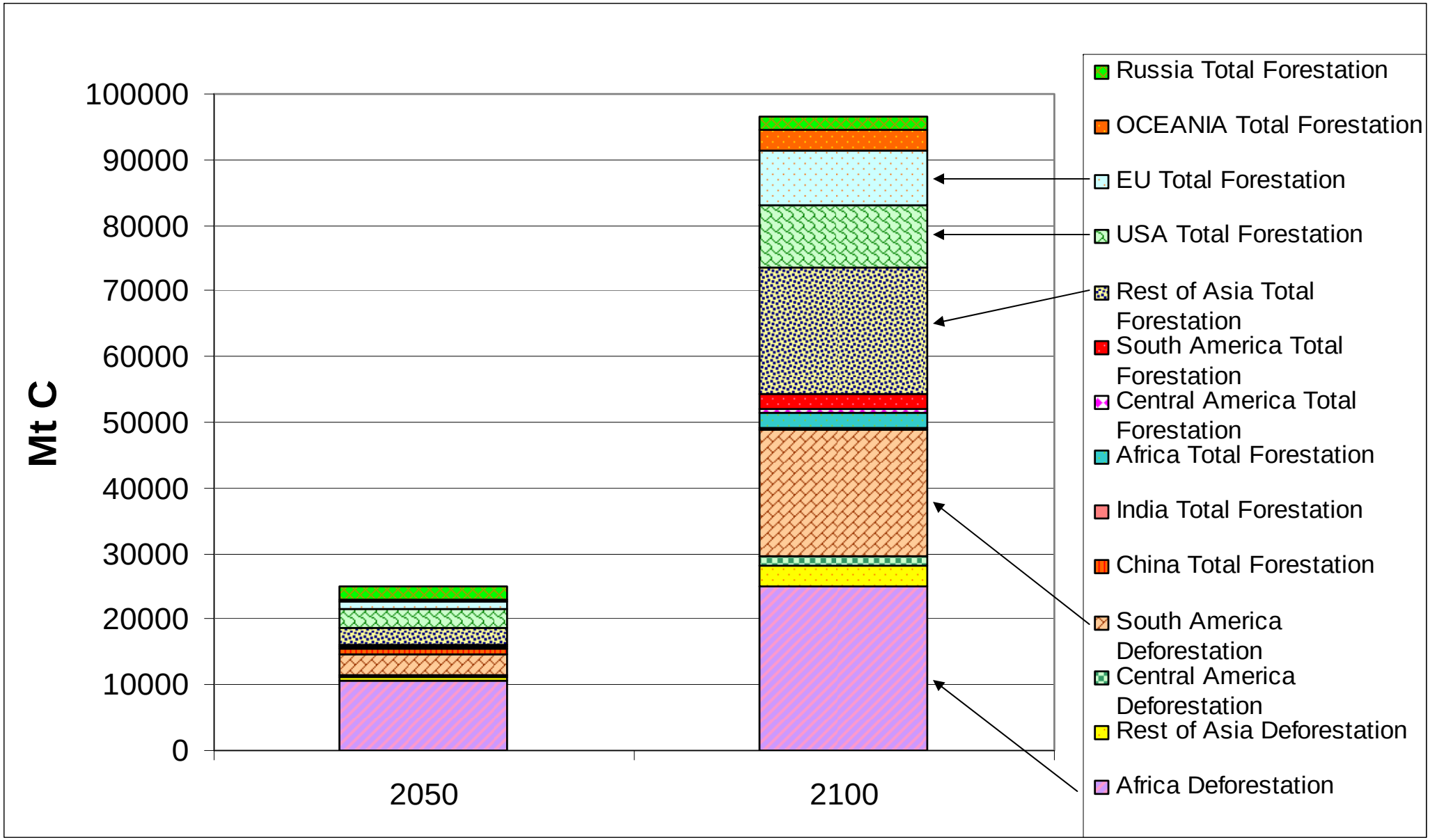
Notes: a) Gained amount refers to the cumulative difference between a mitigation scenario and the reference case scenario by 2050 and 2100

b) All carbon prices are zero until 2009, and begin with the stated value in 2010

Scenario 2 ($10+5%/year): Regional Contribution to Carbon Gain in 2050 and 2100

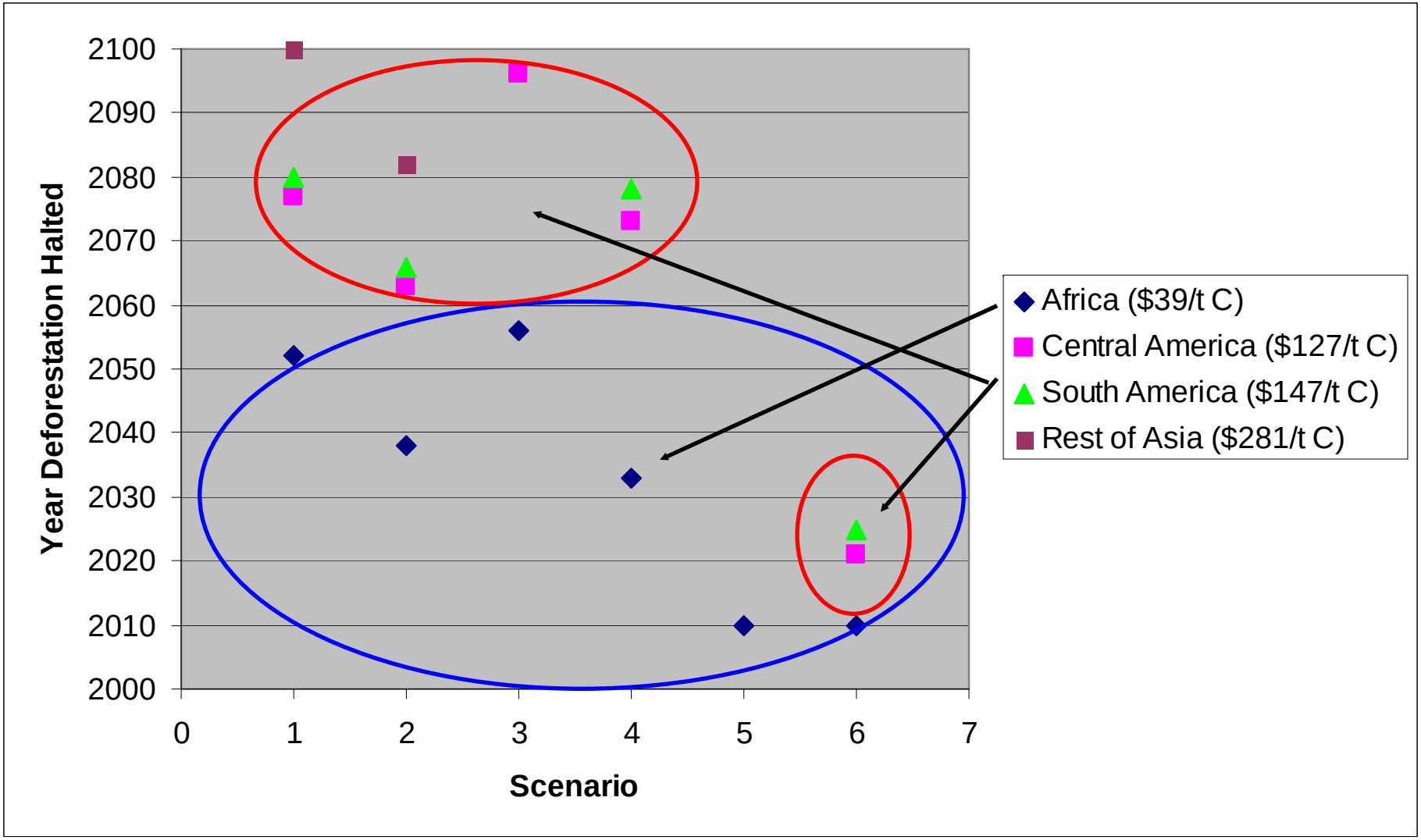


Carbon price to virtually stop deforestation (i.e., C price > opportunity cost) varies across the tropics

- 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

Deforestation virtually halted – Dates by 4 regions and 6 scenarios



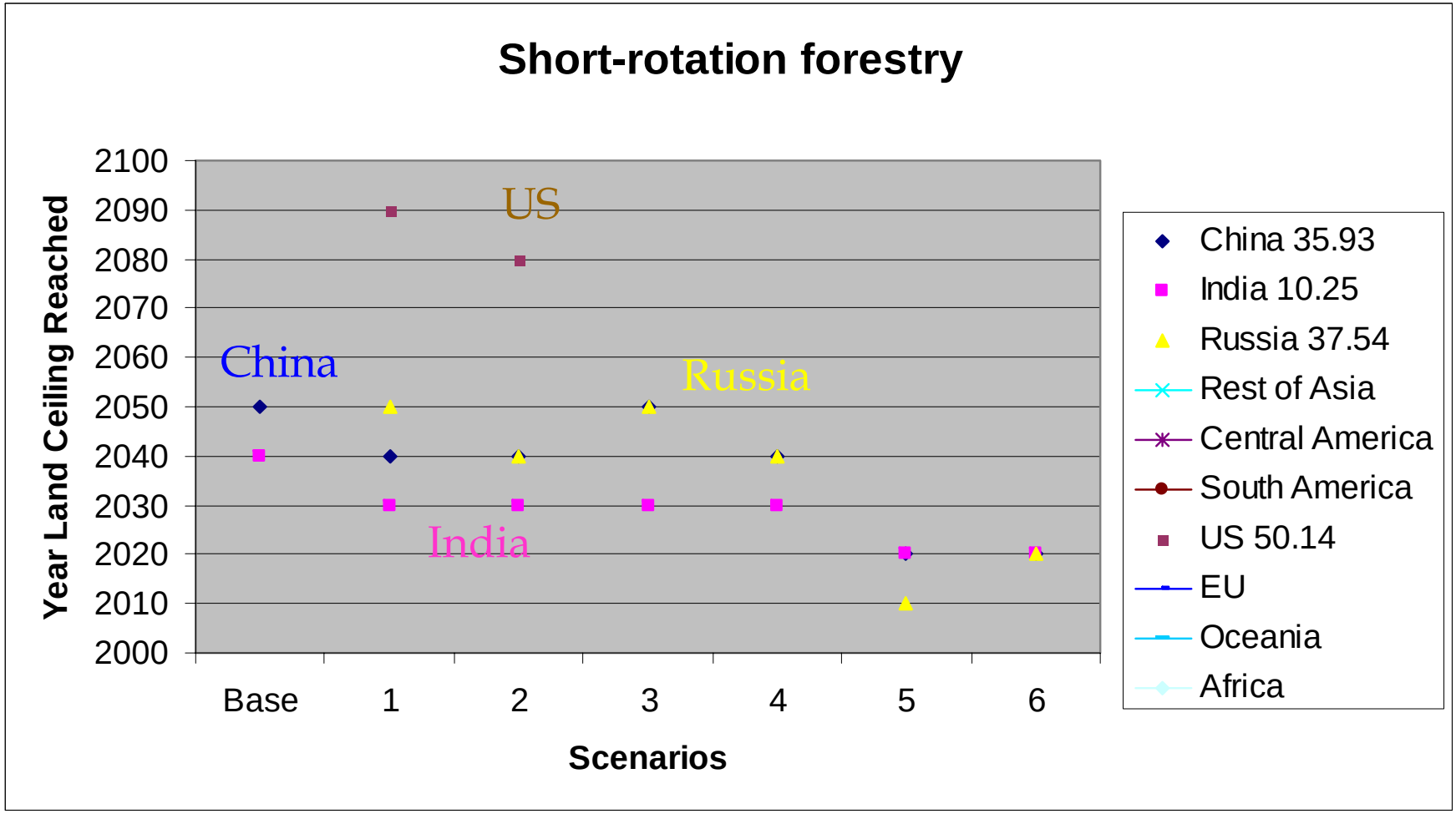
Caps on land suitable for forestation limits the full benefit of the carbon price in several regions

Land availability for forestation varies by region and option

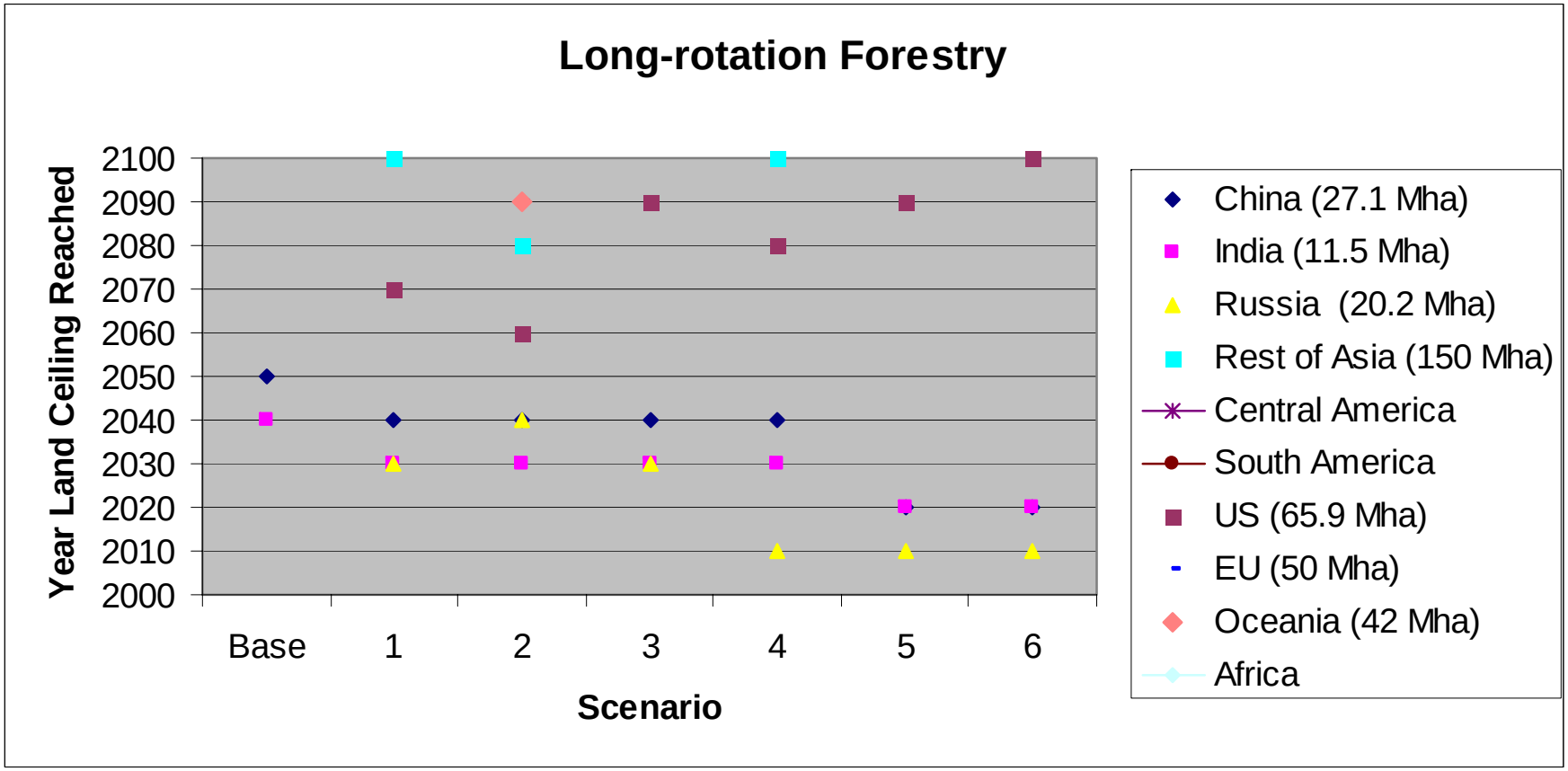
Regions	Short-rotation Mha	Long-rotation Mha	Comments
Africa	80.0	120.0	Grassland, abandoned ag. land, and some deforested land.
China	35.9	27.1	Based on China's short, medium, an d long-term expansion plans
India	10.2	11.5	Government forestry plans to 2020
Russia	37.5	20.2	Doubled current afforestation 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

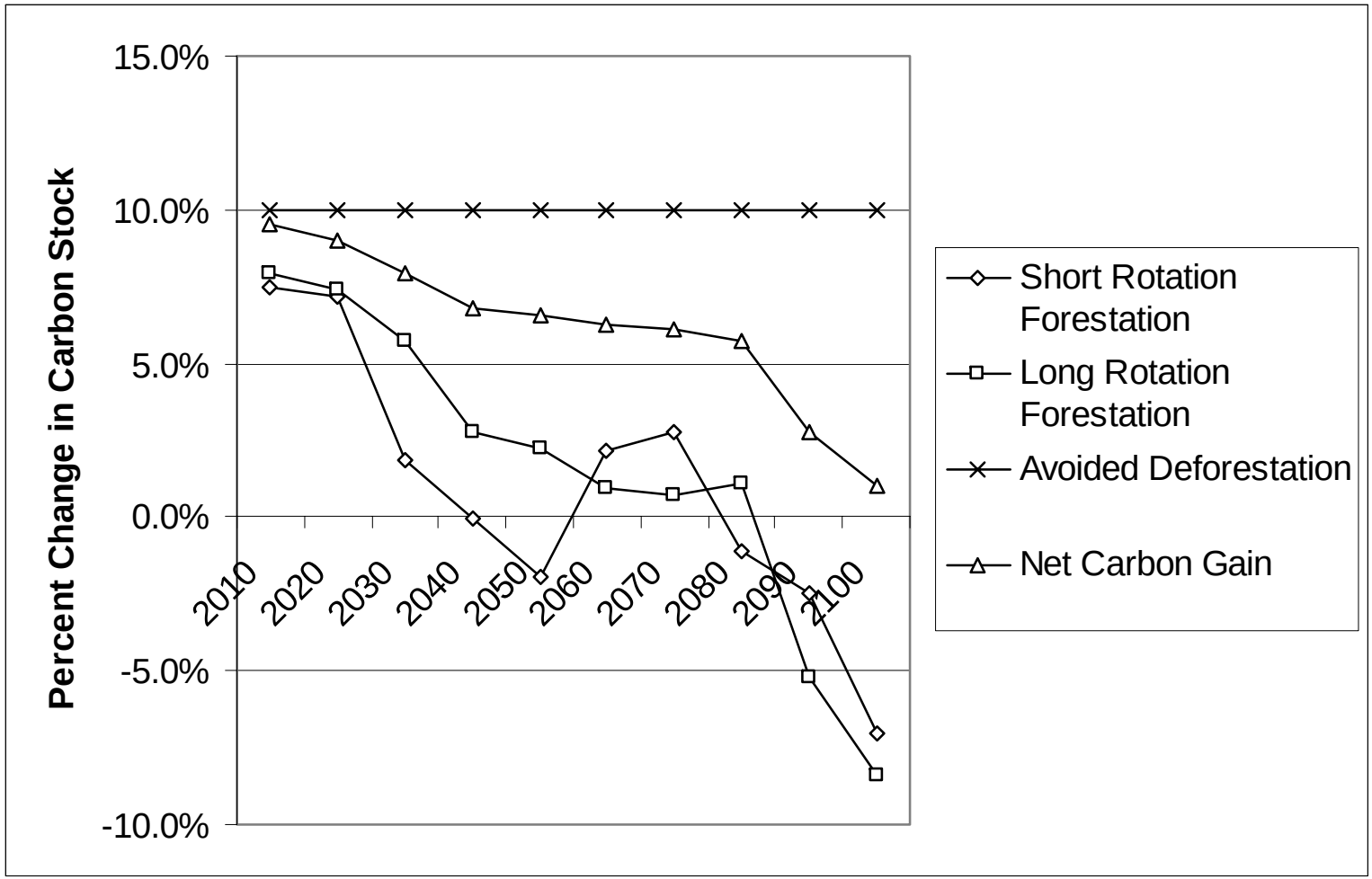


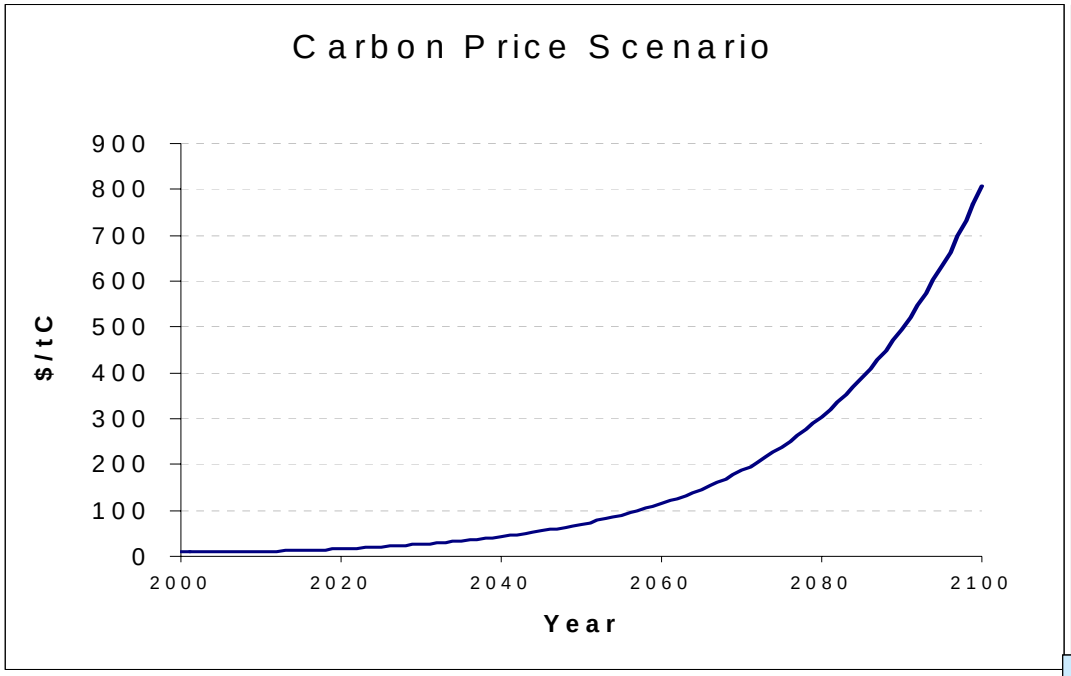
Carbon price benefit is mitigated since land area ceiling is reached before 2100 in some regions

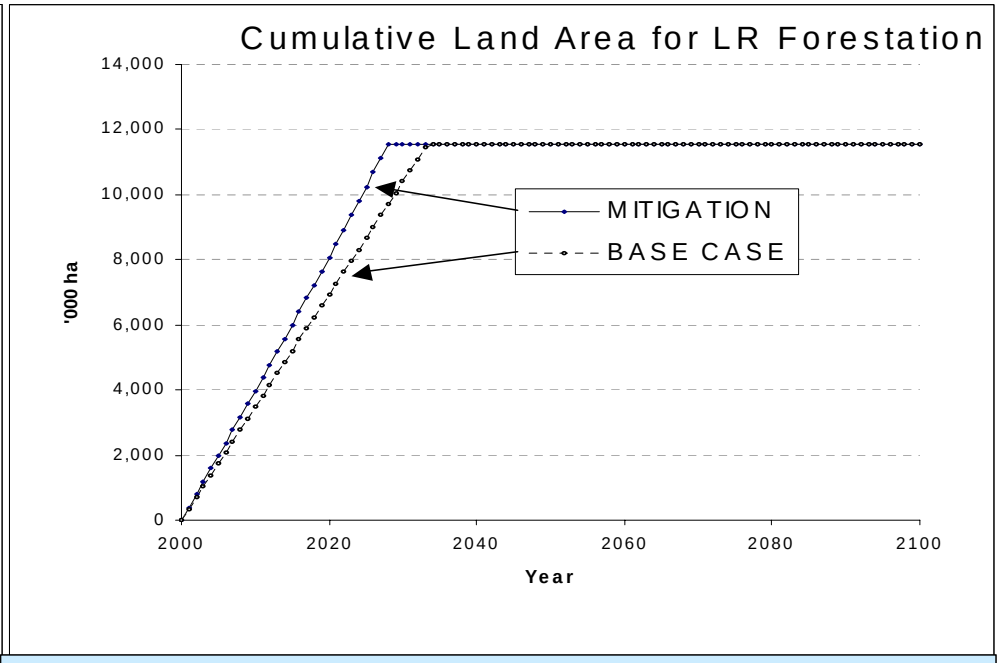


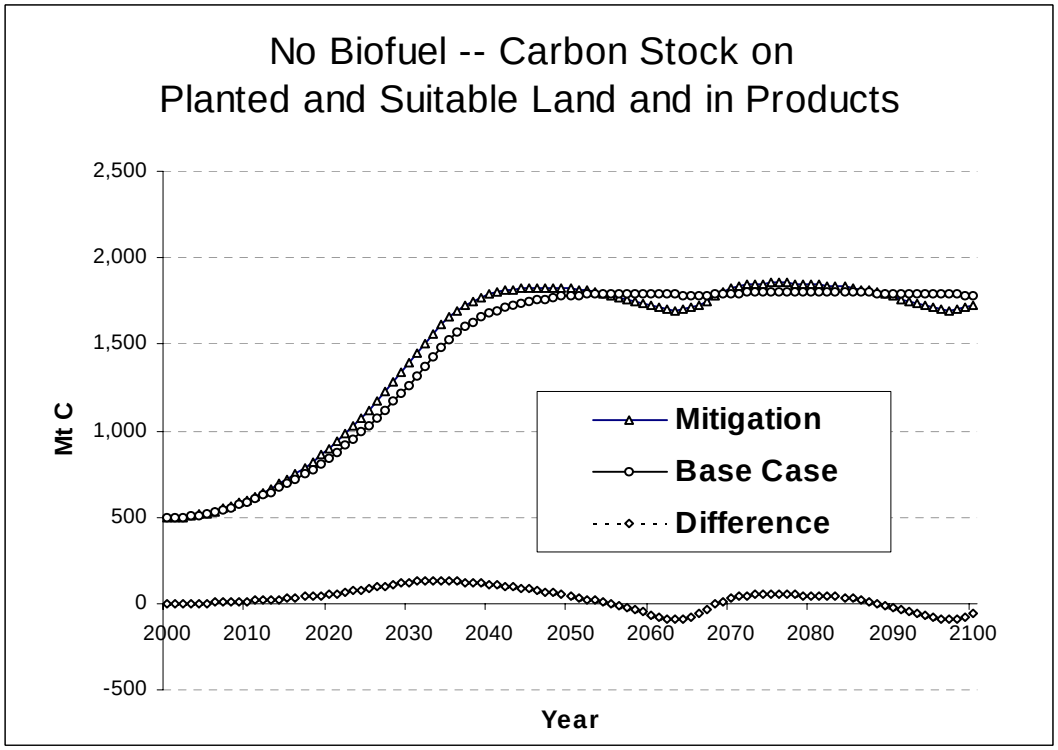
Base Case 1990-2000 – All planting Rates (thousands ha/yr) :
India – 350; China – 615; Rest of Asia – 1,100; Africa – 115;
Central America – 60; S America – 80

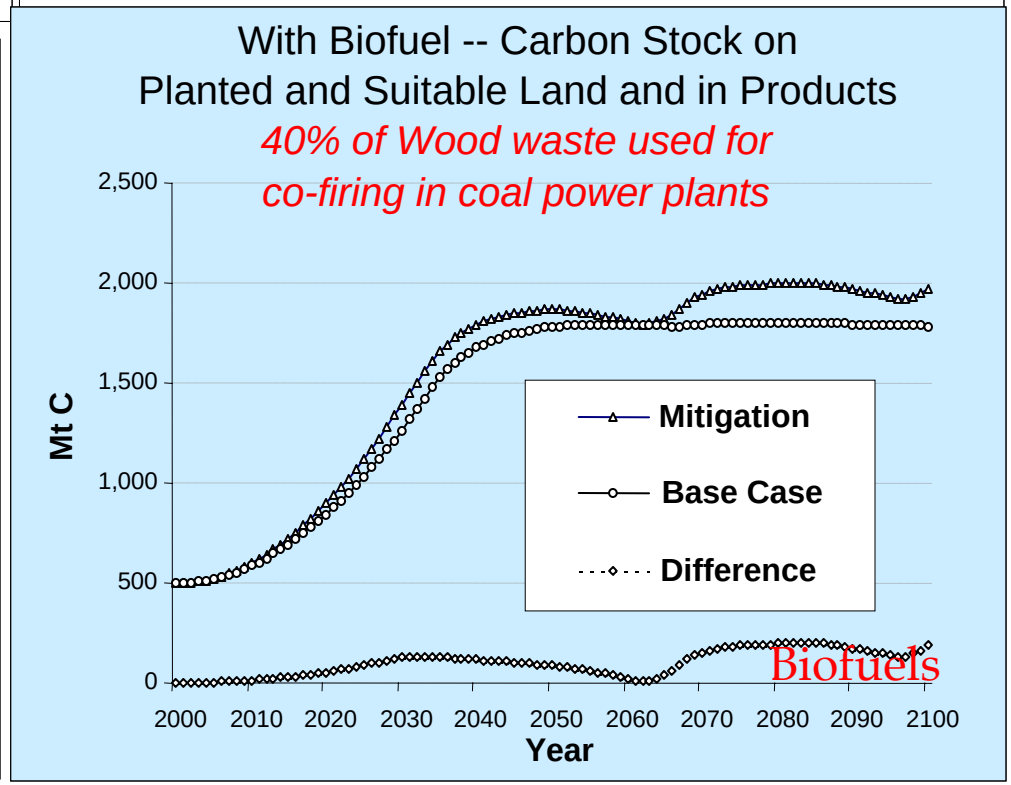
Scenario 2 ($10+5%/year) Sensitivity Analysis: Change in carbon stock for a 10% increase in reference case forestation, and deforested area



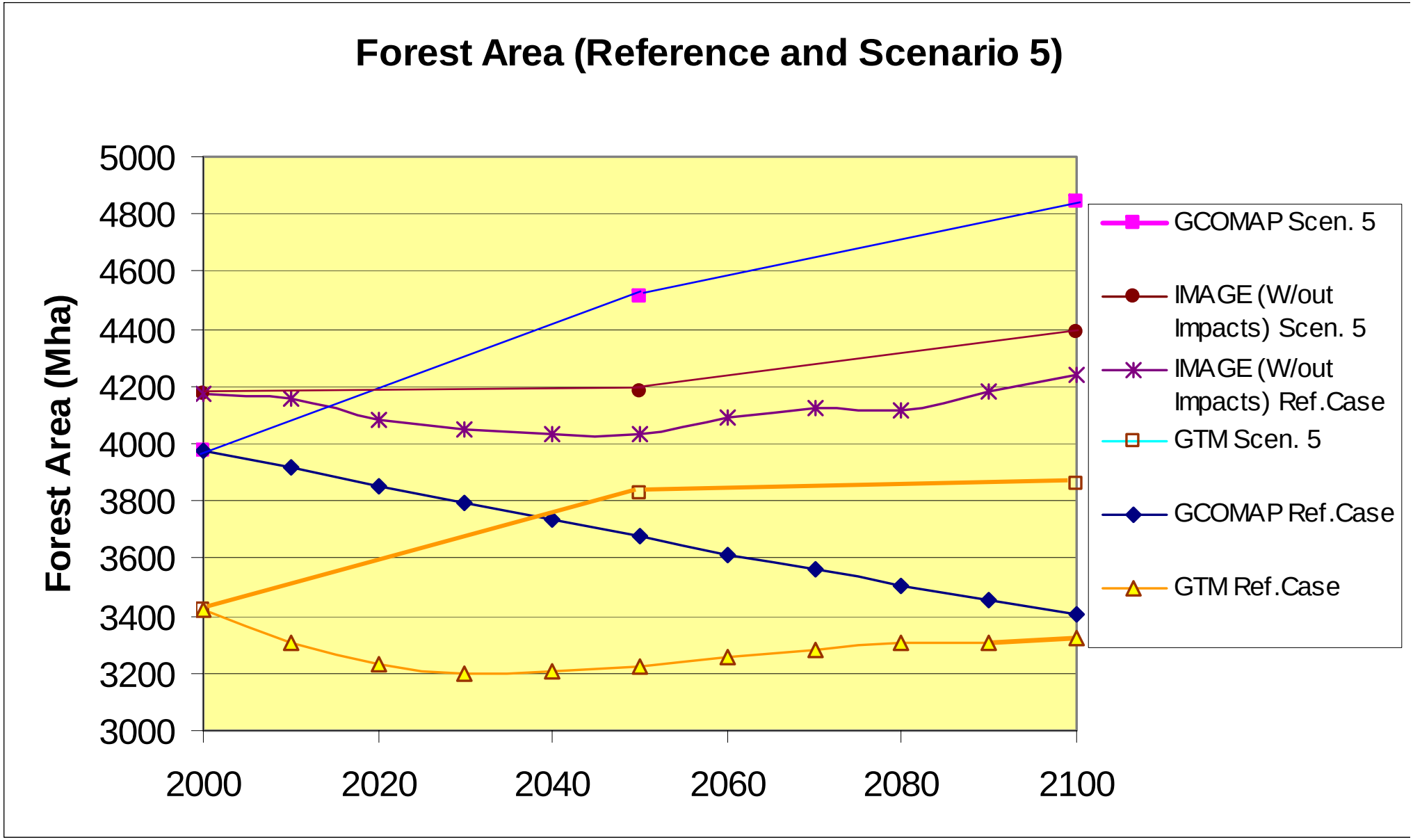

Carbon Price Scenario
900
800
700
600
500
400
300
200
100
0
$ / t C
2000
2020
2040
2060
2080
2100
Year

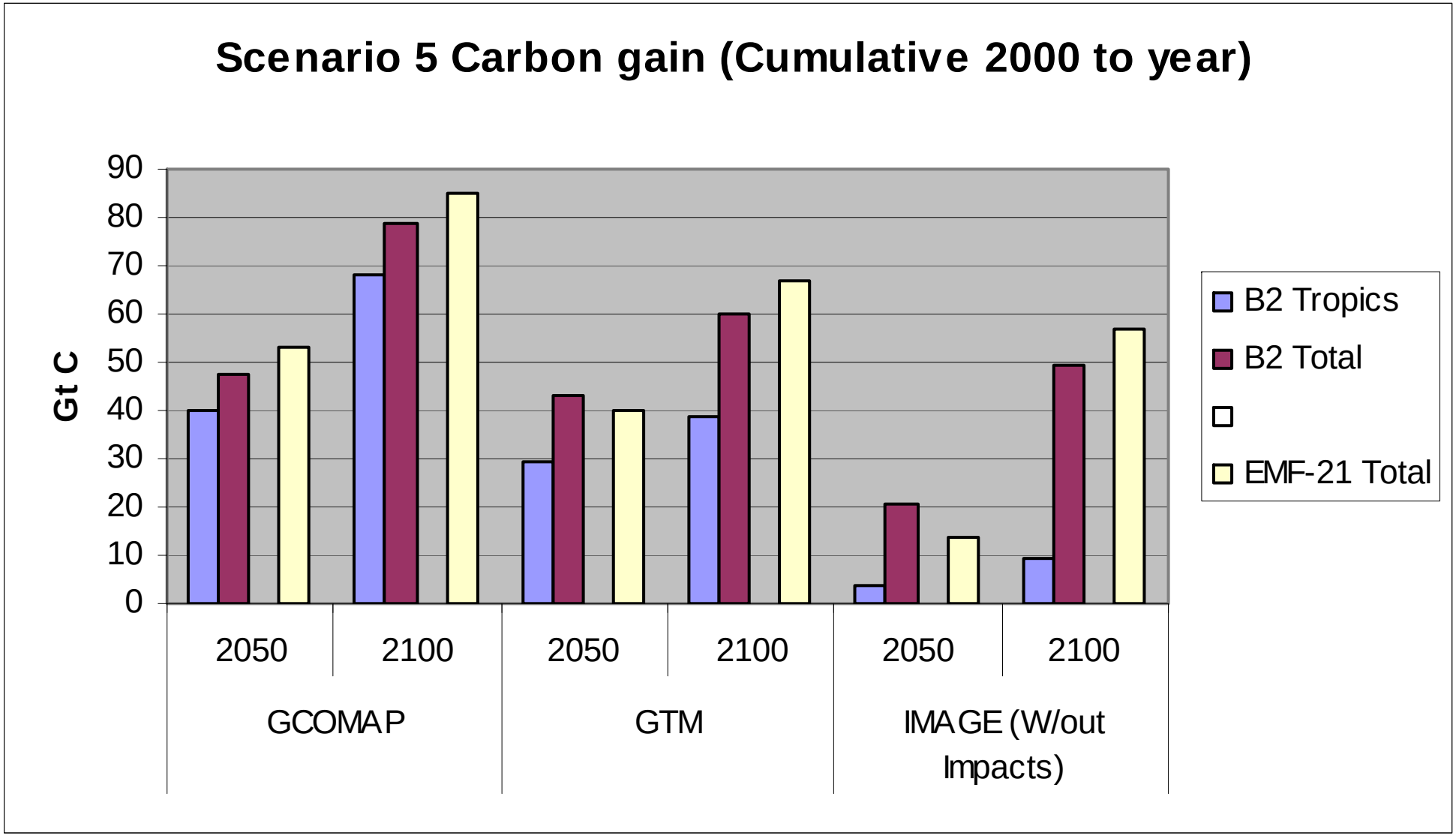

Cumulative Land Area for LR Forestation
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
'000 ha
2000
2020
2040
2060
2080
2100
Year
MITIGATION
BASE CASE


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

EMF-21: Scenario 5 - World Forest Area Increases in the 3 Models




Scenario 5 Carbon gain (Cumulative 2000 to year)
Gt C
90
80
70
60
50
40
30
20
10
0
2050
2100
2050
2100
2050
2100
GCOMAP
GTM
IMAGE (W/out Impacts)
B2 Tropics
B2 Total
EMF-21 Total

EMF-21: How Deforestation Handled – Critical for Reference & Mitigation Scenarios

- Global deforestation: c. 17 million ha/yr 2000 (FAO)
- GTM: DEFOR baseline & as mitigation option (not reported)
- IMAGE: DEFOR in baseline & scenarios, but not as mitigation option.

- GCOMAP: DEFOR in baseline & avoided deforestation as mitigation:

Scenario GCOMAP	Avoid DEFOR Cum. C, 2050	% of Total Mitigation 2050	Avoid DEFOR Cum. C, 2100	% of Total Mitigation 2100
Scen. 2	10.9 Pg	48%	40 Pg	41%
Scen. 5	28.8 Pg	55%	52 Pg	64%

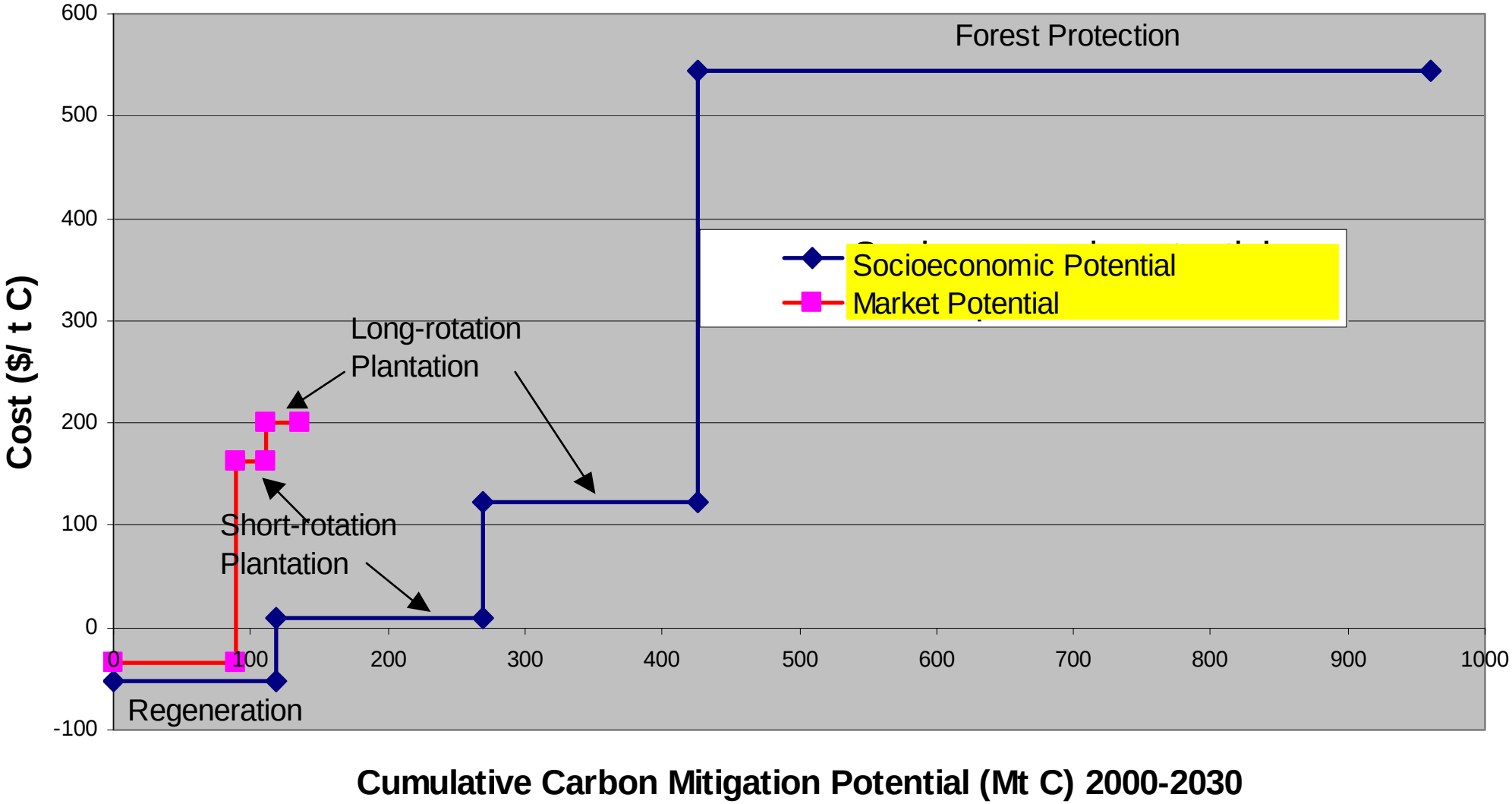
Summary and Conclusions

- **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 assumptions, 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 theoretically halt deforestation in Africa and Latin America in all scenarios, and in Asia in the high priced scenarios
- Model results being used by global carbon economics models, such as MERGE.
- Three different EMF-21 models show significant variance in base year data and in carbon sequestered.

Forestry Mitigation Options With and Without Barriers, India: Preliminary COMAP Results



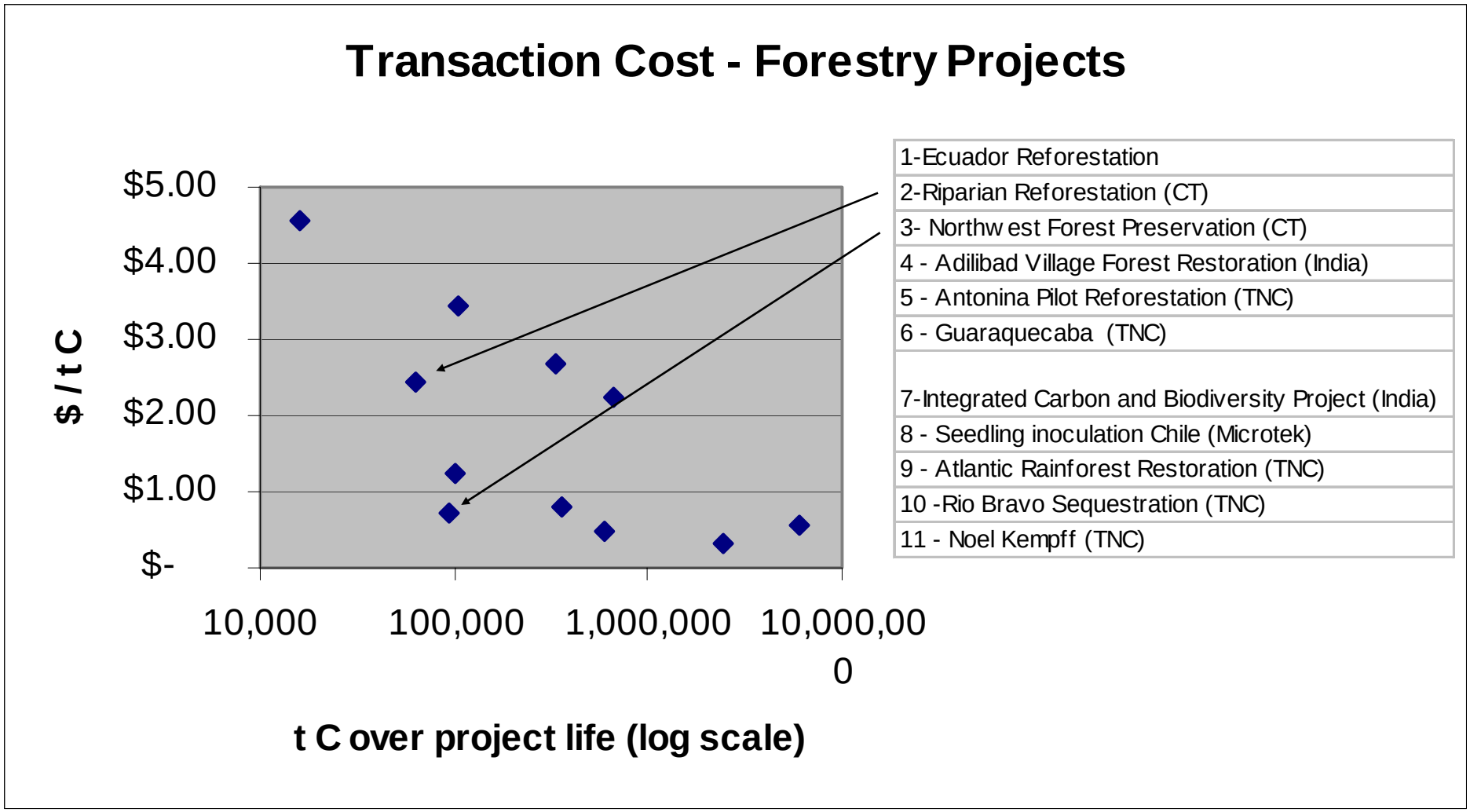
Key Barriers: Absence of organized markets, long distance to market, lack of access to credit, long gestation period, poor seed quality and inadequate fertilizer inputs,

Transaction Cost Components in LBNL Study

- Project search costs – Identification and stakeholder consultation
  - May be spread over many projects
- Feasibility studies costs – engineering, economic, and environmental assessments
  - GHG Baseline estimation and establishing additionality
- Negotiations costs – obtaining permits, negotiating and enforcing contracts for fuel supply, arranging financing
  - Marketing GHG credits, carbon contracting and enforcement
- Insurance costs – project risk insurance
  - GHG credit insurance (Difficult to get or too expensive today)
- Regulatory approval costs (GHG)
  - Project validation and government review (May include both domestic and international validation costs)
- Monitoring and verification costs (GHG) – During project implementation
  - Monitoring including equipment cost, verification and certification (Spread over many years of project life)

Transaction Costs: Data Sources

- Data Set 1: (26 projects)
  - The Nature Conservancy (Forestry) -- Bolivia, and Brazil
  - Indian Institute of Science (Forestry) , LBNL (Household woodstoves)
  - Oregon Climate Trust (Forestry, energy efficiency, renewable energy)
  - Natural Resources Canada (Forestry)
  - Trexler and Associates (Forestry, methane, large power plants, energy efficiency, carbon capture)
- Data Set 2: (13 projects)
  - Ecofys (renewable energy)
  - Ecoenergy (bagasse cogeneration)
- Data Set 3: (50 projects) –
  - Swedish AIJ Programme (Energy efficiency and renewable energy)
- Data Set 4: (10 projects)
  - Global Environmental Facility
  - Transportation, energy efficiency, renewable energy



Source: Data collated by LBNL from 11 international projects of varying sizes

Key Data Inputs: *Elasticity Values*

Elasticities	*Values*	*Sources*
Timber supply price elasticity	0.49	Adams, MacCarl, Farouk et al, 1988
Timber domestic demand price elasticity	-1.0	McKillop, 1977, Robinson, 1976.
Timber international demand price elasticity	30	Makundi, 1990