UNFCCC

Workshop on reducing emissions from deforestation in developing countries

30 August – 1 September, 2006

Rome, Italy

"The Role of Forests in the Global Carbon Cycle"

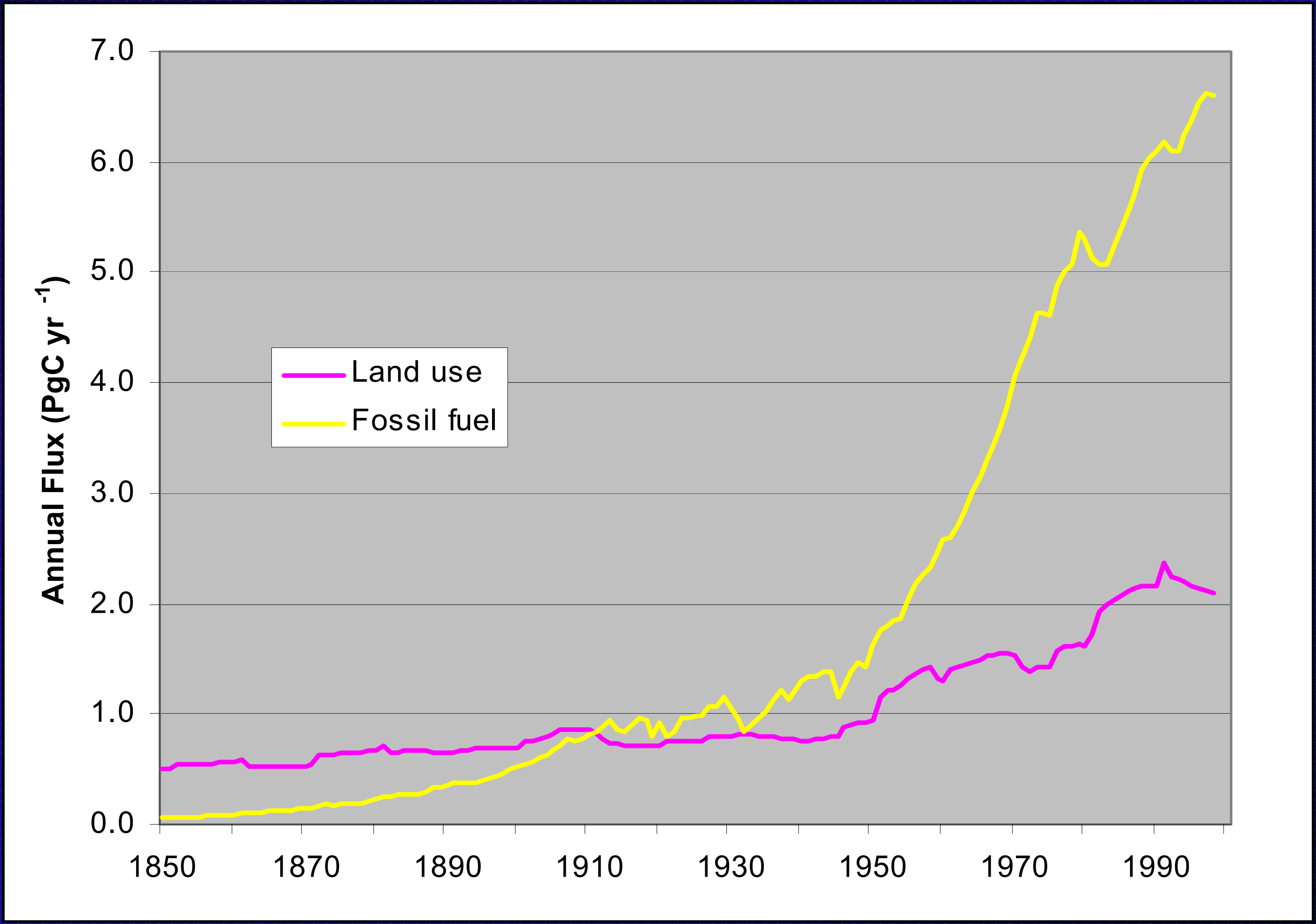
R.A. Houghton

THE WOODS HOLE RESEARCH CENTER

Outline

- How significant are the emissions of carbon from tropical deforestation?
- How are the emissions determined?
- How certain are the estimates?
- What might future emissions be?

Global Results:
Annual Emissions of Carbon

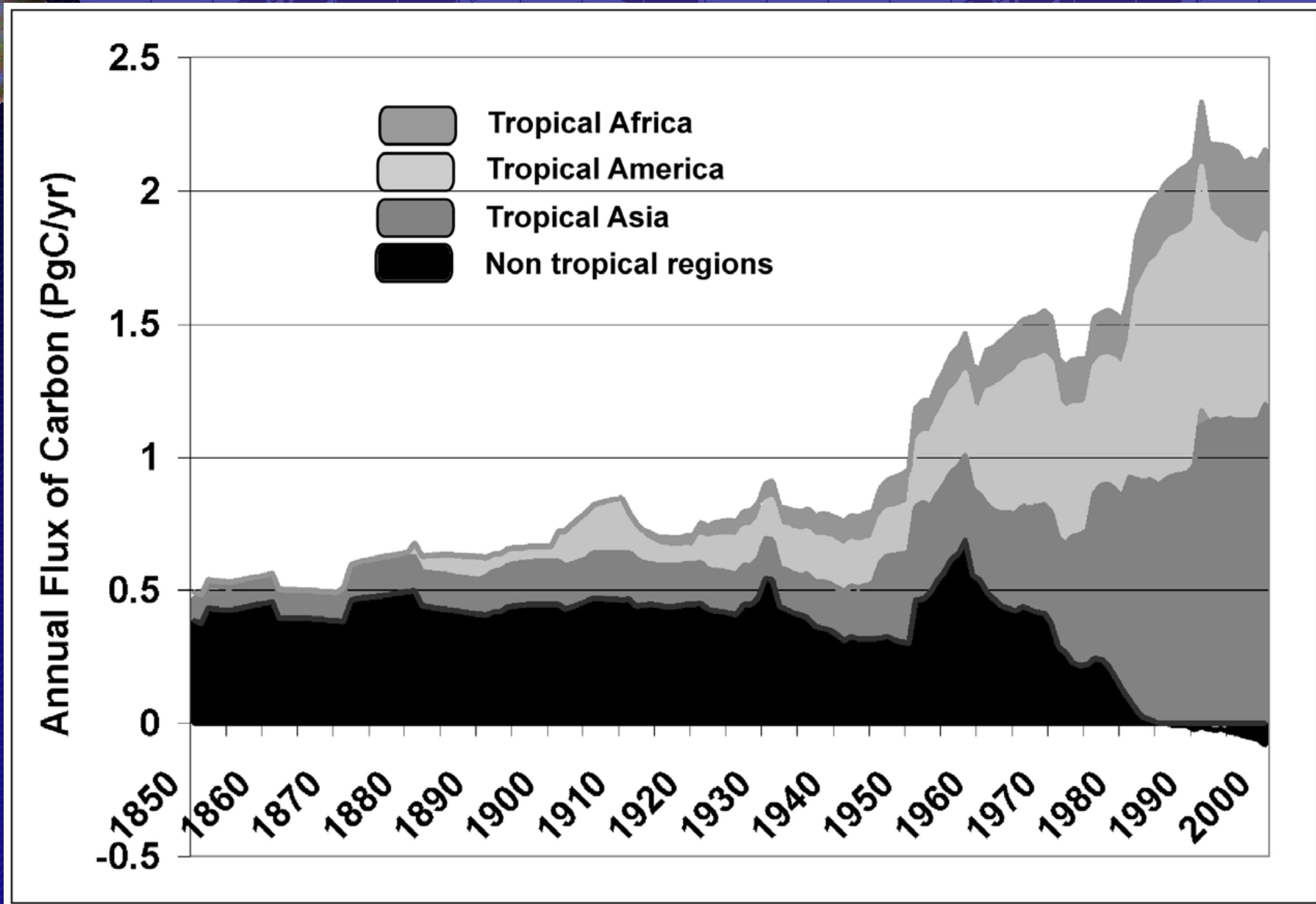


1850-2000

275 PgC

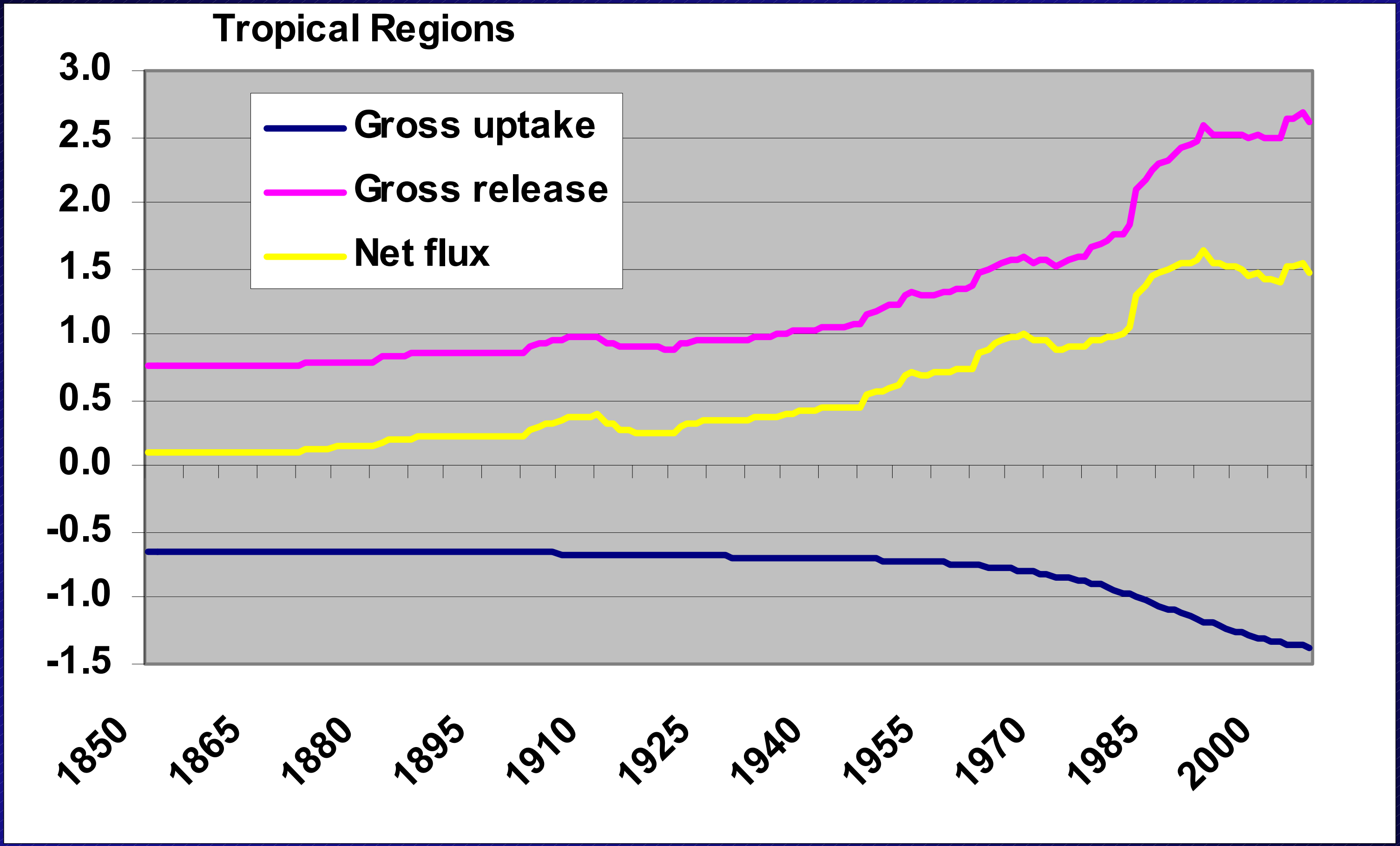
155 PgC (36%)

(~20% in recent years)



	Tropics	Non-tropics
Long term	52%	48%
1990s	100%	0%

Stopping deforestation would reduce emissions of carbon by more than 1-2 PgC/yr.



Both sources and sinks of carbon are included in the ‘net flux’.

How do we know the effects of deforestation on carbon storage?

Fluxes

Changes in stocks

Changes in land use

Emphasis on forests

Deforestation
Afforestation

- Changes in area
  - Croplands (clearing and abandonment)
  - Pastures
  - Shifting cultivation
- Changes in carbon stocks (C/ha)
  - Wood harvest & recovery
  - Fire management

Land-use change $\approx$ Deforestation

How do we calculate the emissions of carbon from land-use change?

- Data
  - Rates of land-use change (ha/yr, m^3/yr)
  - Carbon stocks (C/ha)
- Bookkeeping model

Land-use data from….

International agricultural statistics

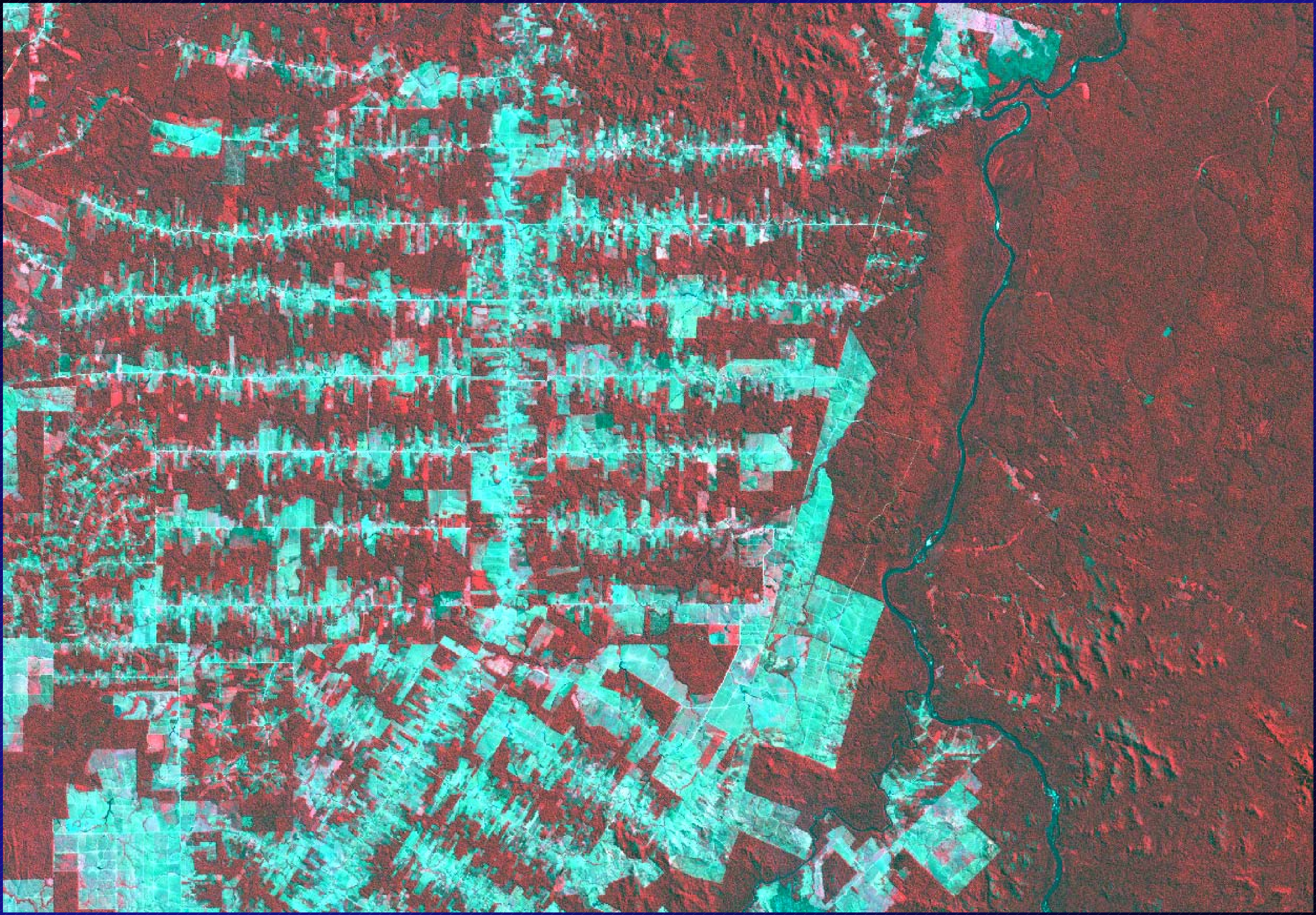
Forestry statistics

Satellites

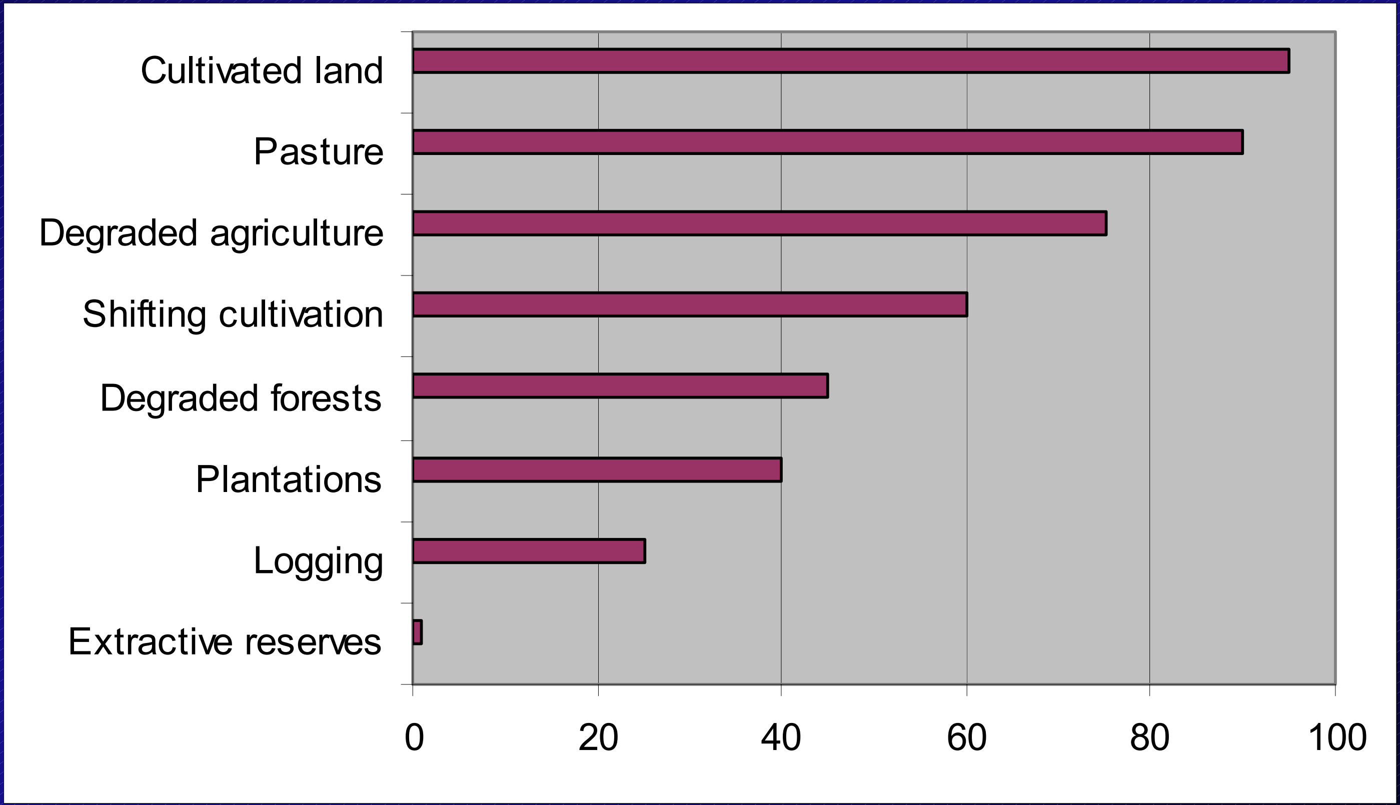
National handbooks

Historical texts & narratives

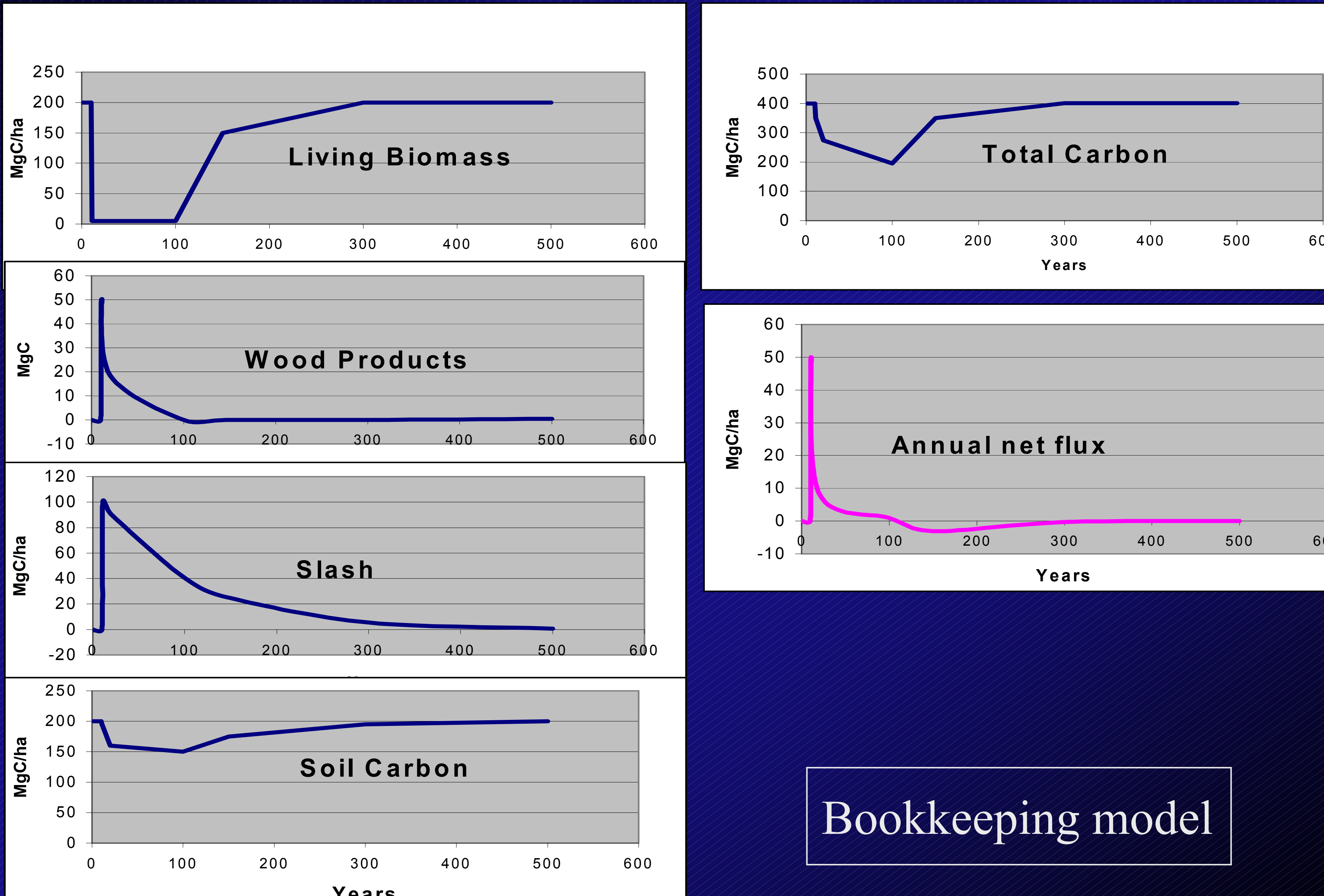
Land-cover maps & atlases



Vegetation (carbon) lost with changes in land use (in %)

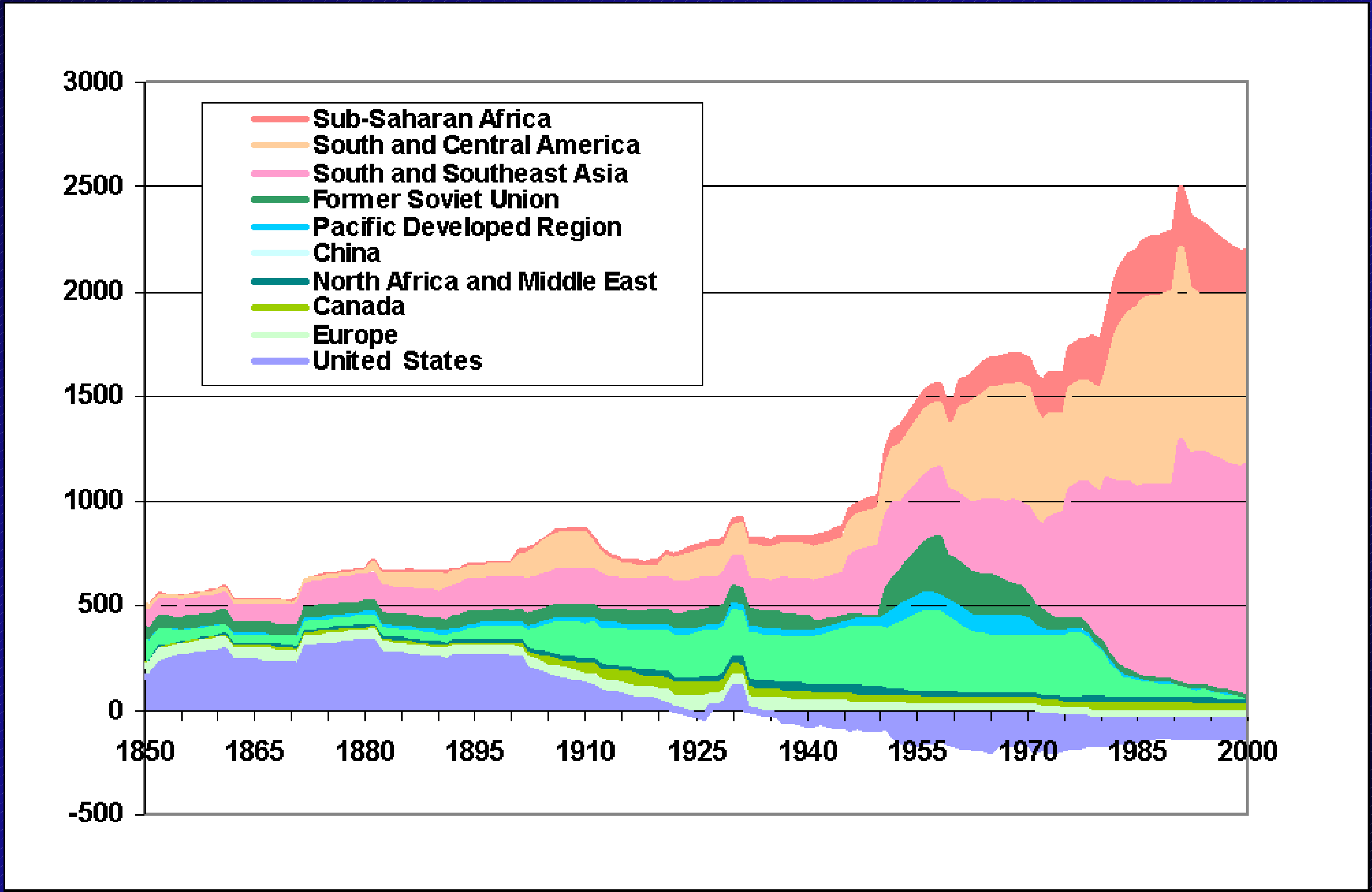


Response Curves (MgC ha^{-1} yr^{-1})



Bookkeeping model

RESULTS: Sources and sinks of carbon region by region



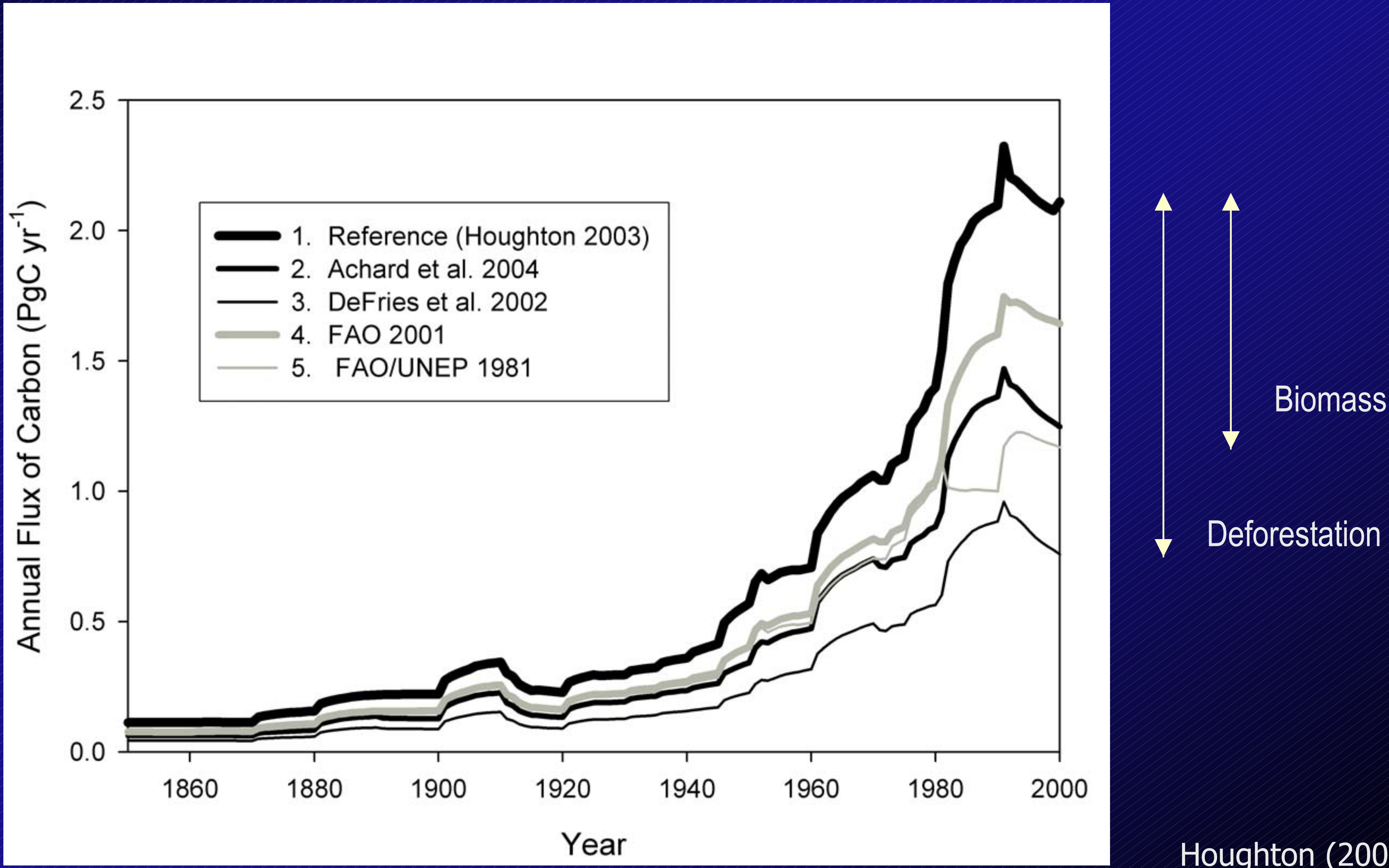
Outline

- How significant are the emissions of carbon from tropical deforestation?
- How are the emissions determined?
- How certain are the estimated emissions?
- Future emissions

Two major uncertainties

- Rates of deforestation (millions of hectares)
  - Rates of land-use change
- Carbon stocks per hectare
  - Changes in carbon stocks (tC/ha)

Deforestation rates vs. Biomass



Houghton (2005

Average annual rates of tropical deforestation (10^6 ha yr^{-1})

	1980s		1990s		
	FAO 1995	DeFries et al. 2002	FAO 2001	DeFries et al. 2002	Achard et al. 2004
America	7.4	4.426	5.2	3.982	4.41
Asia	3.9	2.158	5.9	2.742	2.84
Africa	4.0	1.508	5.6	1.325	2.35
Total	15.3	8.092	16.7	8.049	9.60

Average annual rates of tropical deforestation (10^6 ha yr^{-1})

	1980s	1990s		2000-2005
	FAO 1995	FAO 2001	FAO 2005	FAO 2005
America	7.4	5.2	4.5	4.7
Asia	3.9	5.9	2.7	3.0
Africa	4.0	5.6	4.4	4.0
Total	15.3	16.7	11.6	11.7

Average annual rates of tropical deforestation (10^6 ha yr^{-1})

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Africa	4.0	5.6	4.4	4.0
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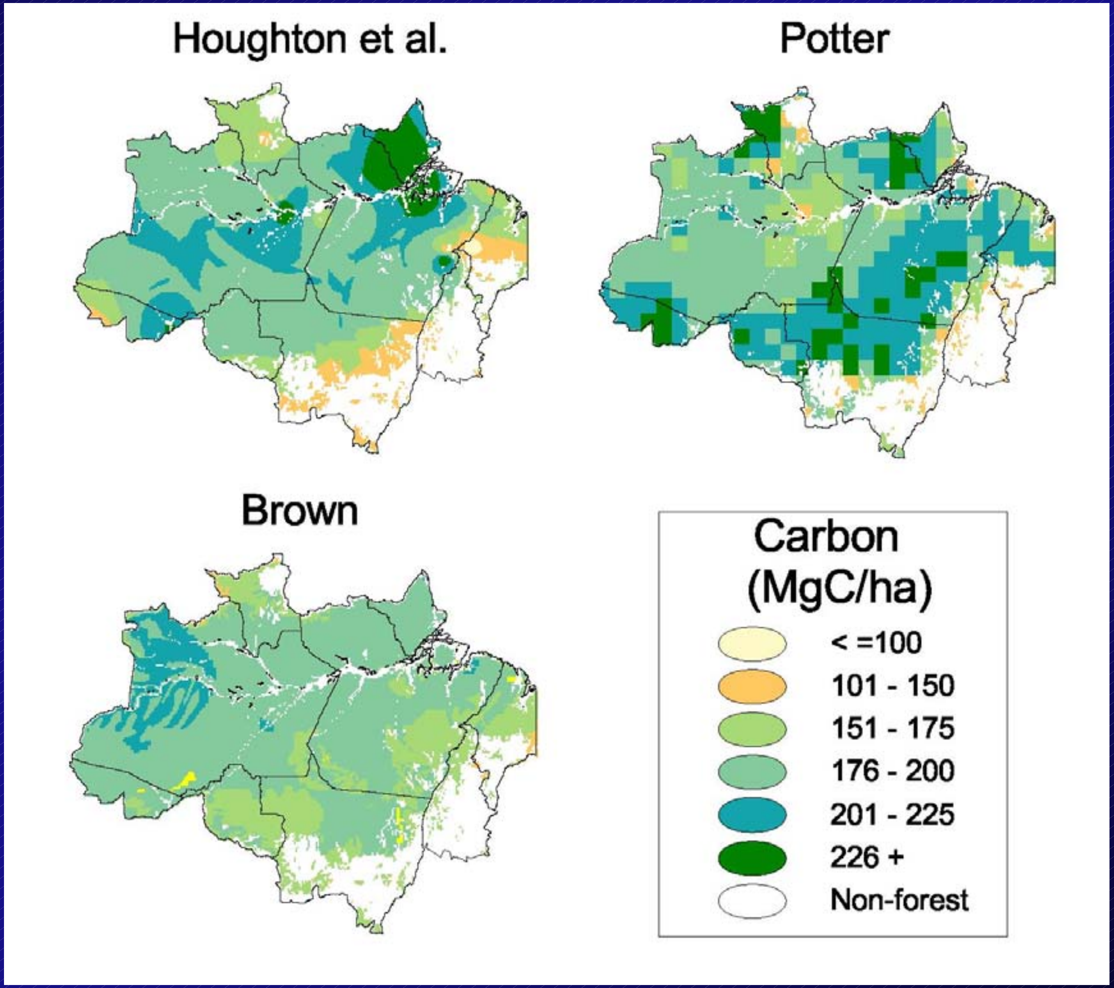
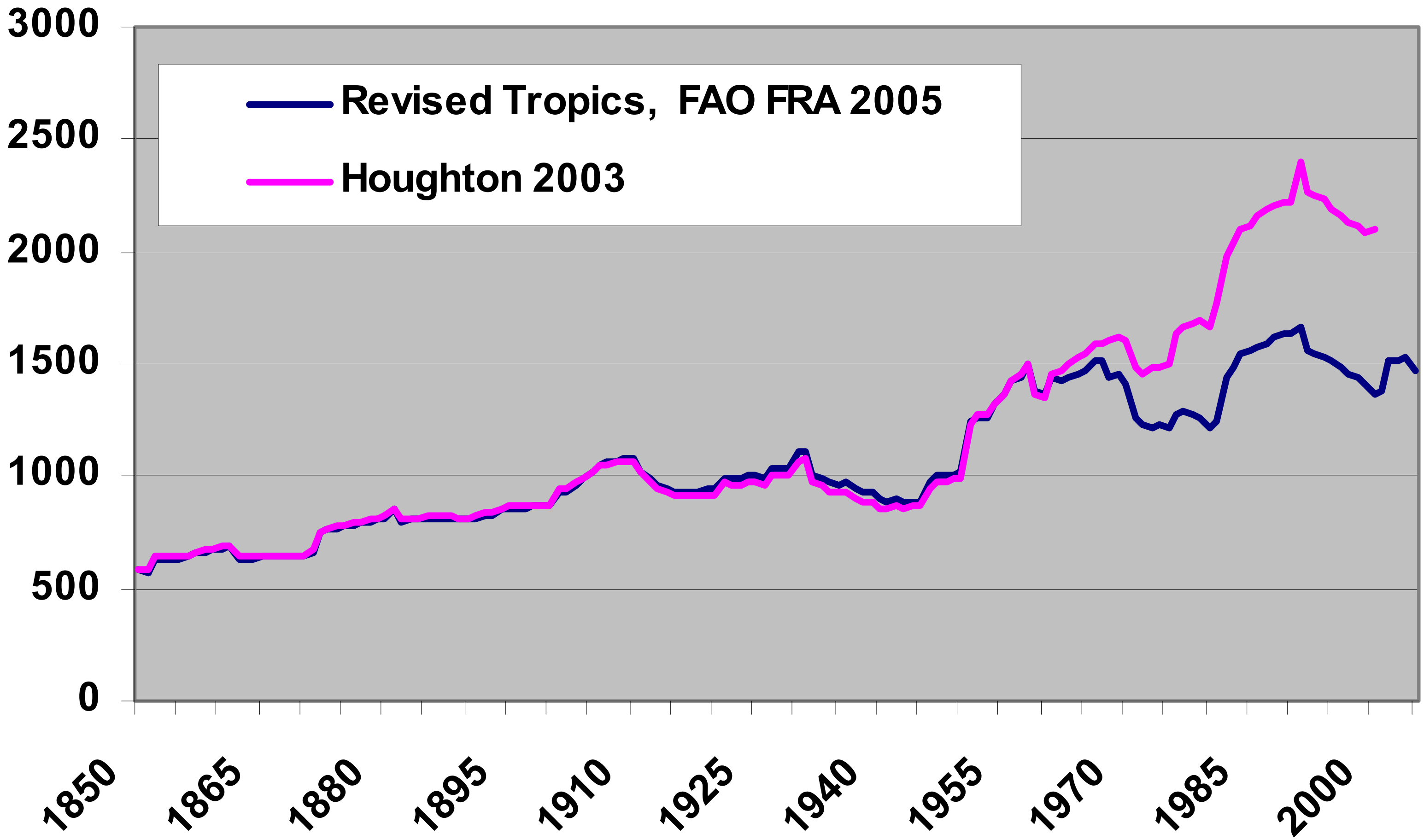
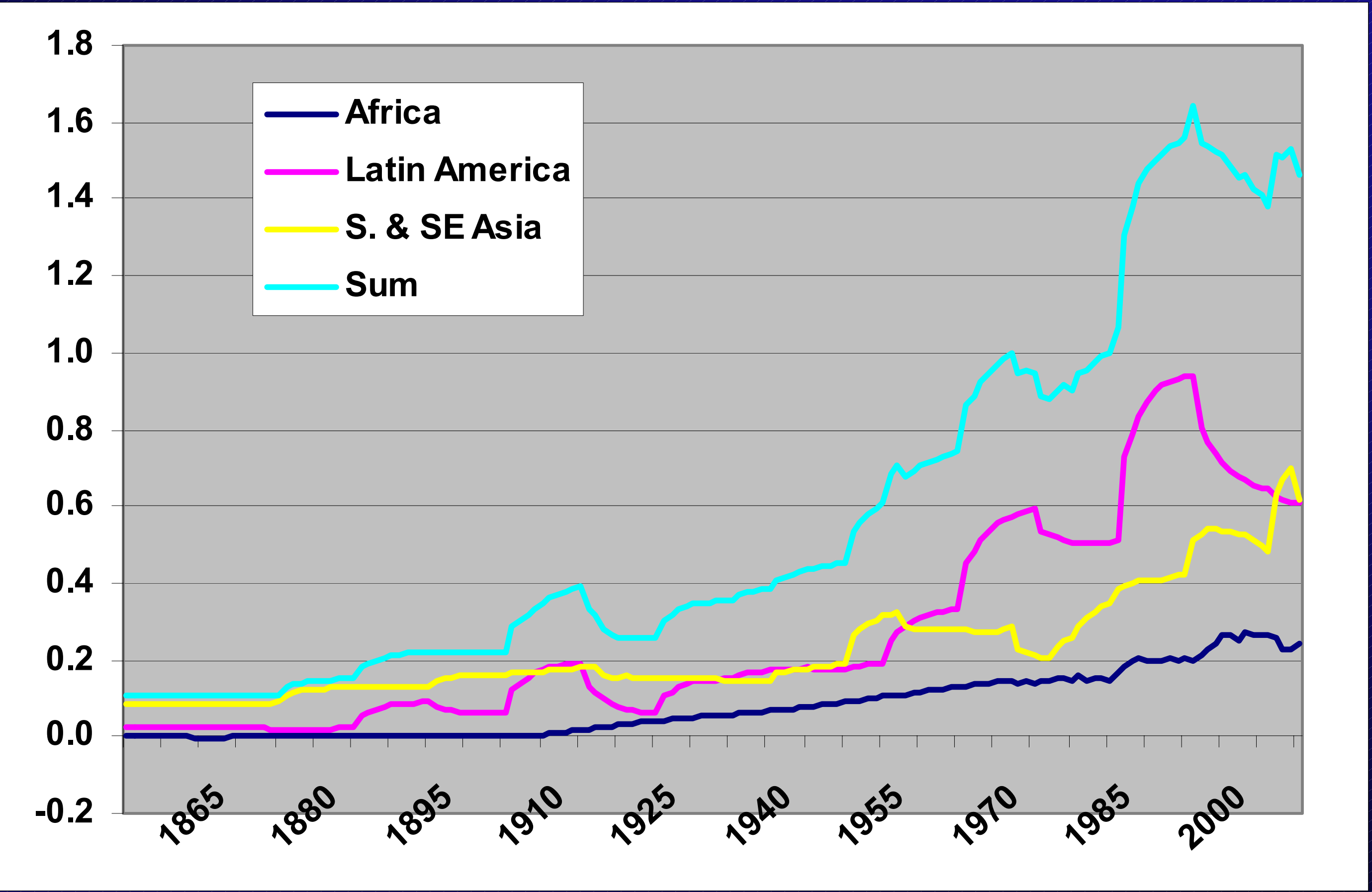
Biomass in Amazonia





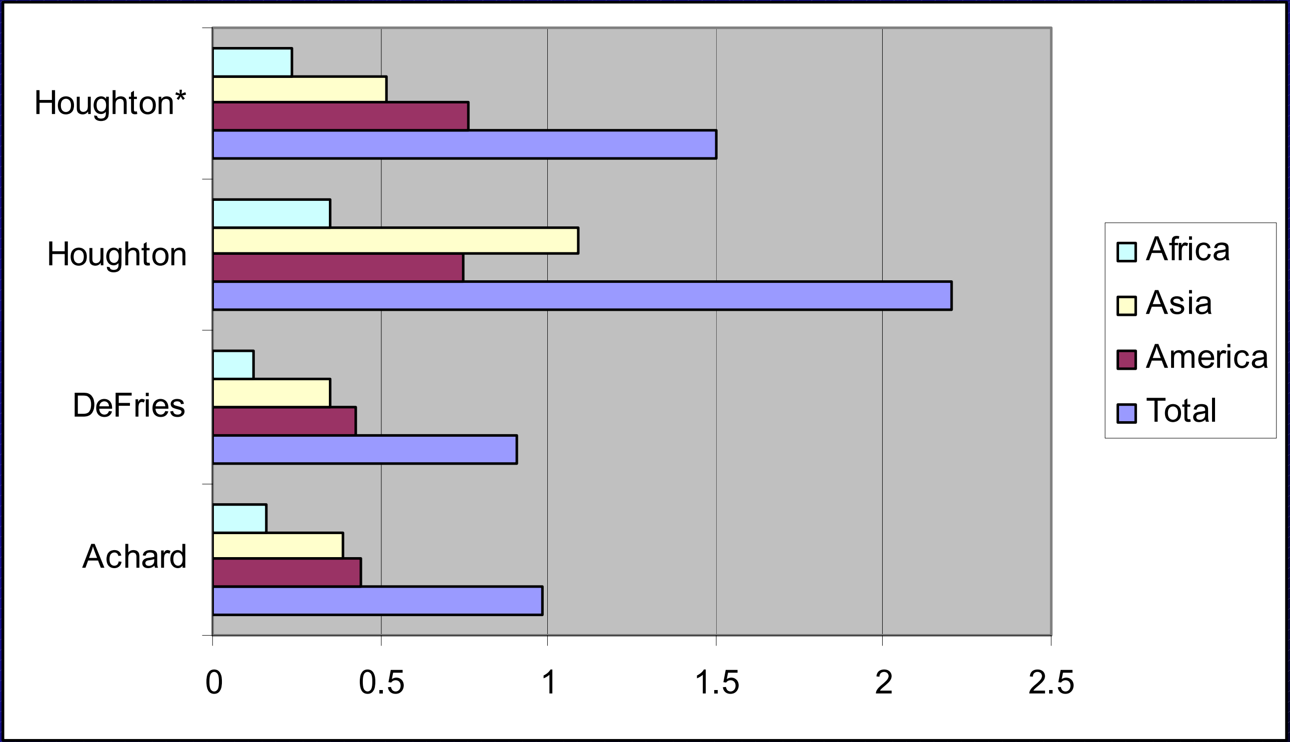
Houghton 2006

Carbon emissions revised with new FAO (2005) deforestation rates



Houghton 2006

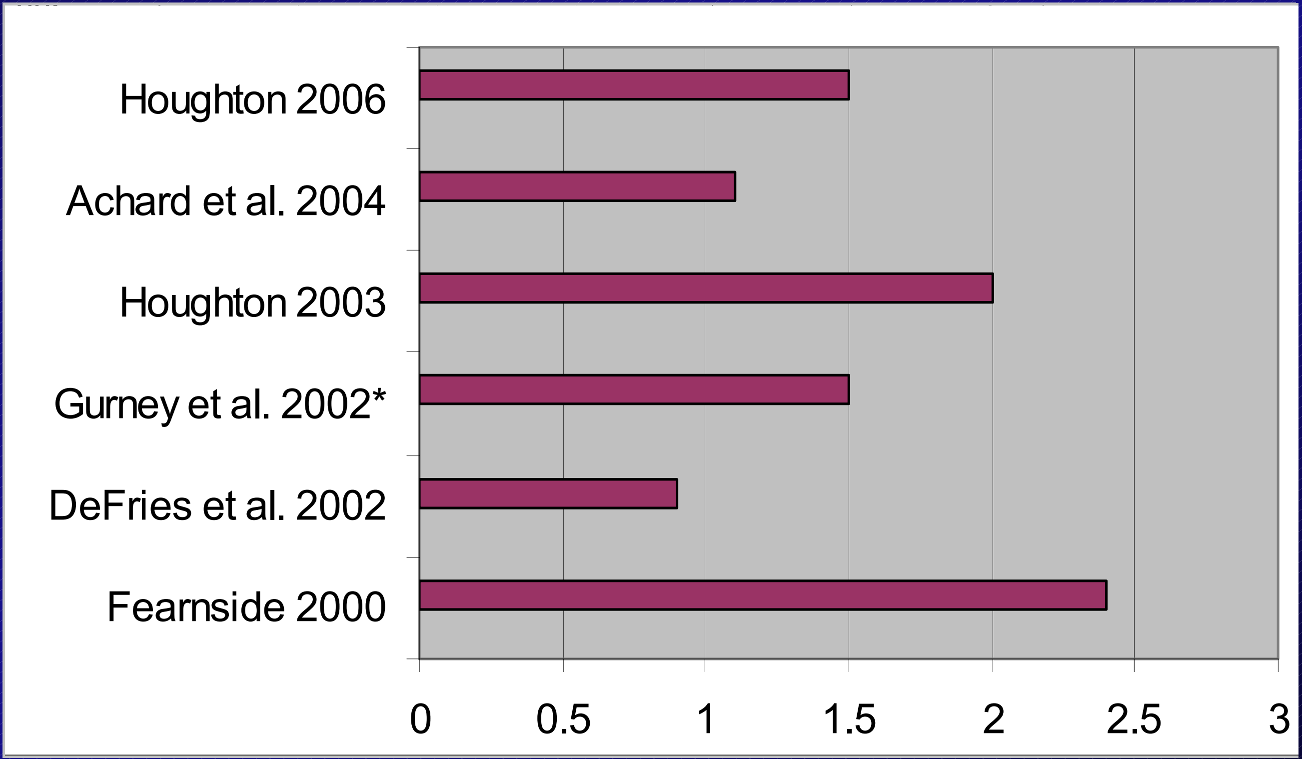
Annual emissions of carbon (PgC/yr) from tropical deforestation during the 1990s



Annual emissions of carbon (PgC/yr) from tropical deforestation during the 1990s

	Achard et al. (2004)	DeFries et al. (2002)	Houghton (2003)	Houghton (2006)
America	0.441	0.43	0.75	0.76
Asia	0.385	0.35	1.09	0.52
Africa	0.157	0.12	0.35	0.24
Total	0.983	0.91	2.20	1.52

Estimates of carbon emissions from tropical deforestation **(PgC/yr)**



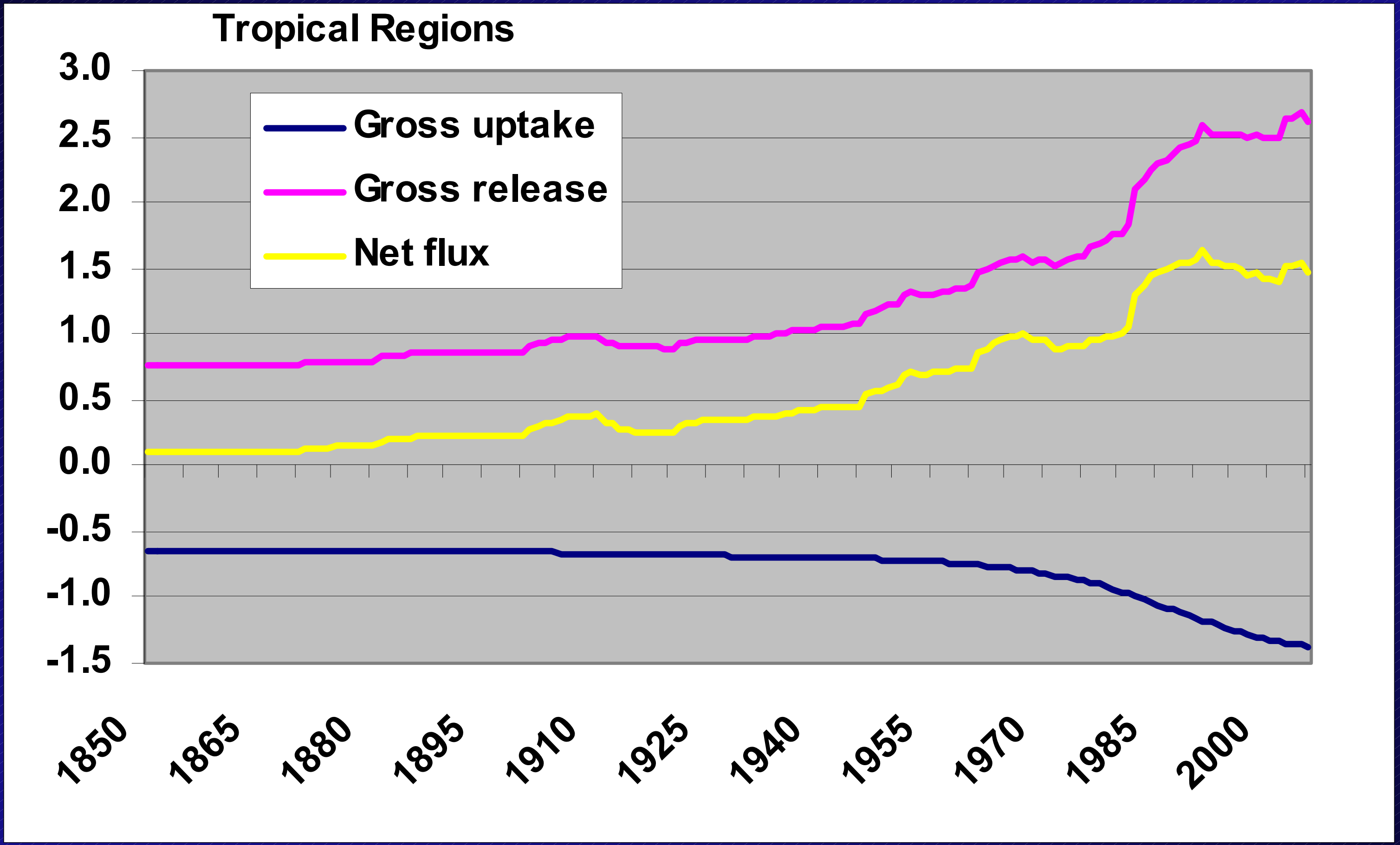
Estimates of carbon emissions from tropical deforestation **(PgC/yr)**

Fearnside (2000)	2.4
DeFries et al. (2002)	0.9 (0.5 to 1.4)
Gurney et al. (2002)*	1.5 (±1.2)
Houghton (2003)	2.2 (±0.8)
Achard et al. (2004)	1.1 (±0.3)
Houghton (2006)	1.5

Outline

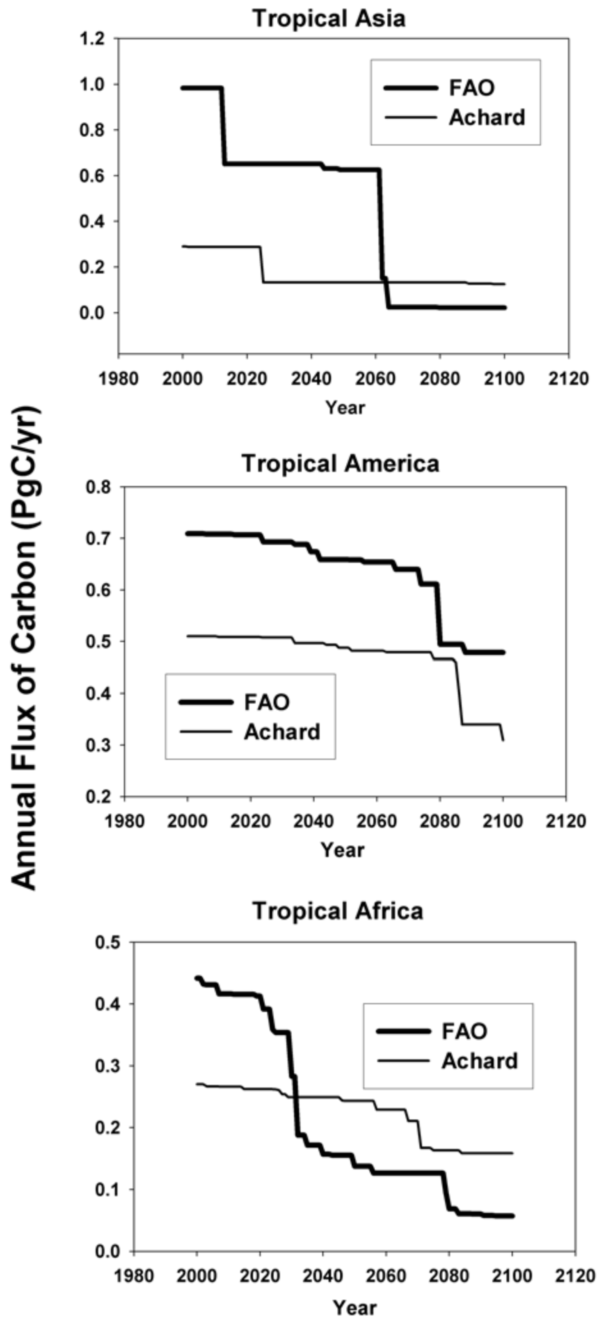
- How significant are the emissions of carbon from tropical deforestation?
- How are the emissions determined?
- How certain are the estimated emissions?
- Future emissions

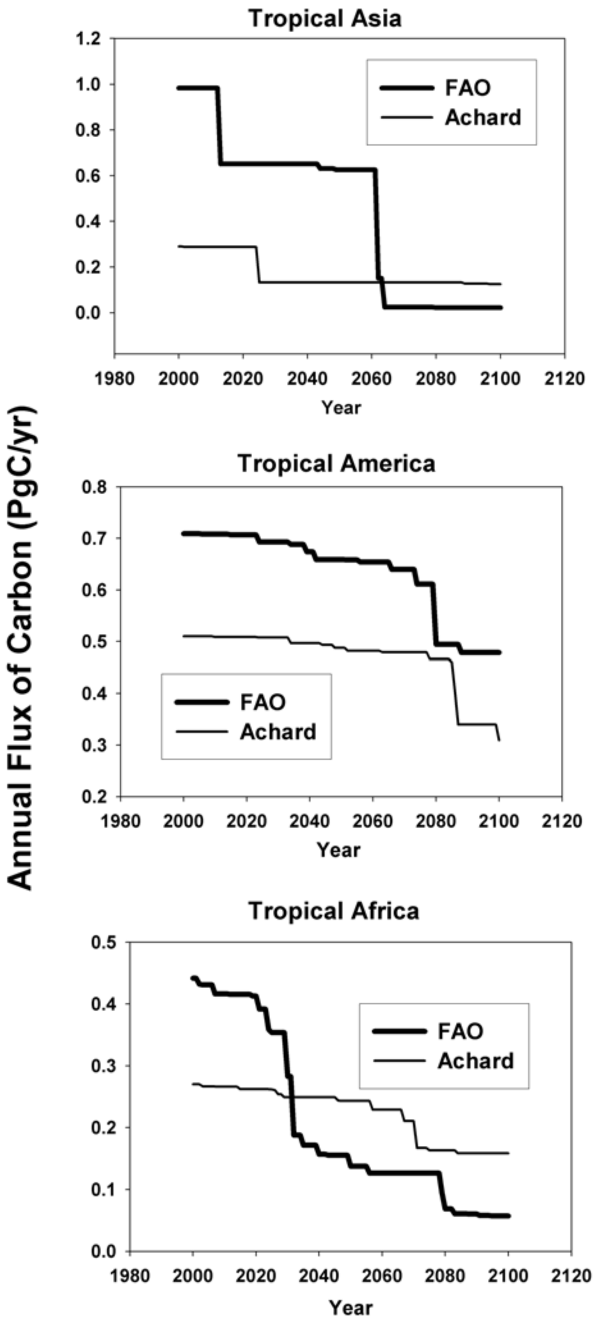
Stopping deforestation would reduce emissions of carbon by more than 1-2 PgC/yr.



Gross emissions from deforestation are greater than the net emissions from deforestation, reforestation, and regrowth.

If current rates of deforestation continue…


Annual Flux of Carbon (PgC/yr)
Tropical Asia
FAO
Achard
Year
Tropical America
FAO
Achard
Year
Tropical Africa
FAO
Achard
Year



Myanmar

Indonesia

Malaysia

Peru

Benin

Ivory Coast

Nigeria

Zambia

Between 1850 and 2000

… 155 PgC were released from land-use change

… 82 PgC from tropical lands (~50%)

Between 2000 and 2100

…87-130 PgC will be released from the tropics
at current rates rates of deforestation.

Conclusions

- Changes in land use and management play a major role in determining sources and sinks of carbon.
- Stopping deforestation would reduce annual emissions by more than 1-2 PgC/yr…
- … and would preserve a valuable resource.

Thank you.

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Gas	Contribution to the enhanced greenhouse effect	Annual emissions	Deforestation as percent of total emissions	Deforestation as percent of the enhanced greenhouse effect
Carbon dioxide	58%	PgC		
Industrial		6.3		
Natural		0		
Deforestation		2.2	26%	15%
Total		8.5		
Methane	21%	Tg CH_4		
Industrial		135		
Natural		160		
Deforestation		275	48%	10%
Total		570		
Nitrous oxide	6%	Tg N_2O		
Industrial		1.5		
Natural		9.5		
Deforestation		5.4	33%	2%
Total		16.4		
HFC's and HCFC's	15%	Gg HFC		
Industrial		1.0		
Natural		0		
Deforestation		0	0%	0%
Total		1.0		
	100%			27%

Revised Global Carbon Budget 1980-2005 (Pg C yr^{-1})

	1980's	1990's	2000-2005
Atmospheric Increase	+3.3±0.1	+3.2±0.1	+4.1±0.1
Emissions (FF)	+5.4±0.3	+6.4±0.3	+7.0±0.3
Net Ocean Sink	- 1.8±0.8	- 2.2±0.4	- 2.2±0.5
Net Land Sink	- 0.3±0.9	- 1.0±0.5	- 0.7±0.5
Deforestation	+2.0	+1.5	+1.5
Residual Land Sink	- 2.3	- 2.5	-2.2

Sabine et al. 2004, GCP-Lequere, Houghton, Canadell, et al, unpublished, IPCC in preparation

Global Carbon Budget

	1990s
Fossil fuel emissions	6.3 ± 0.4
Atmospheric increase	-3.2 ± 0.2
Oceanic uptake	-2.4 ± 0.7
Net terrestrial flux	-0.7 ± 0.8

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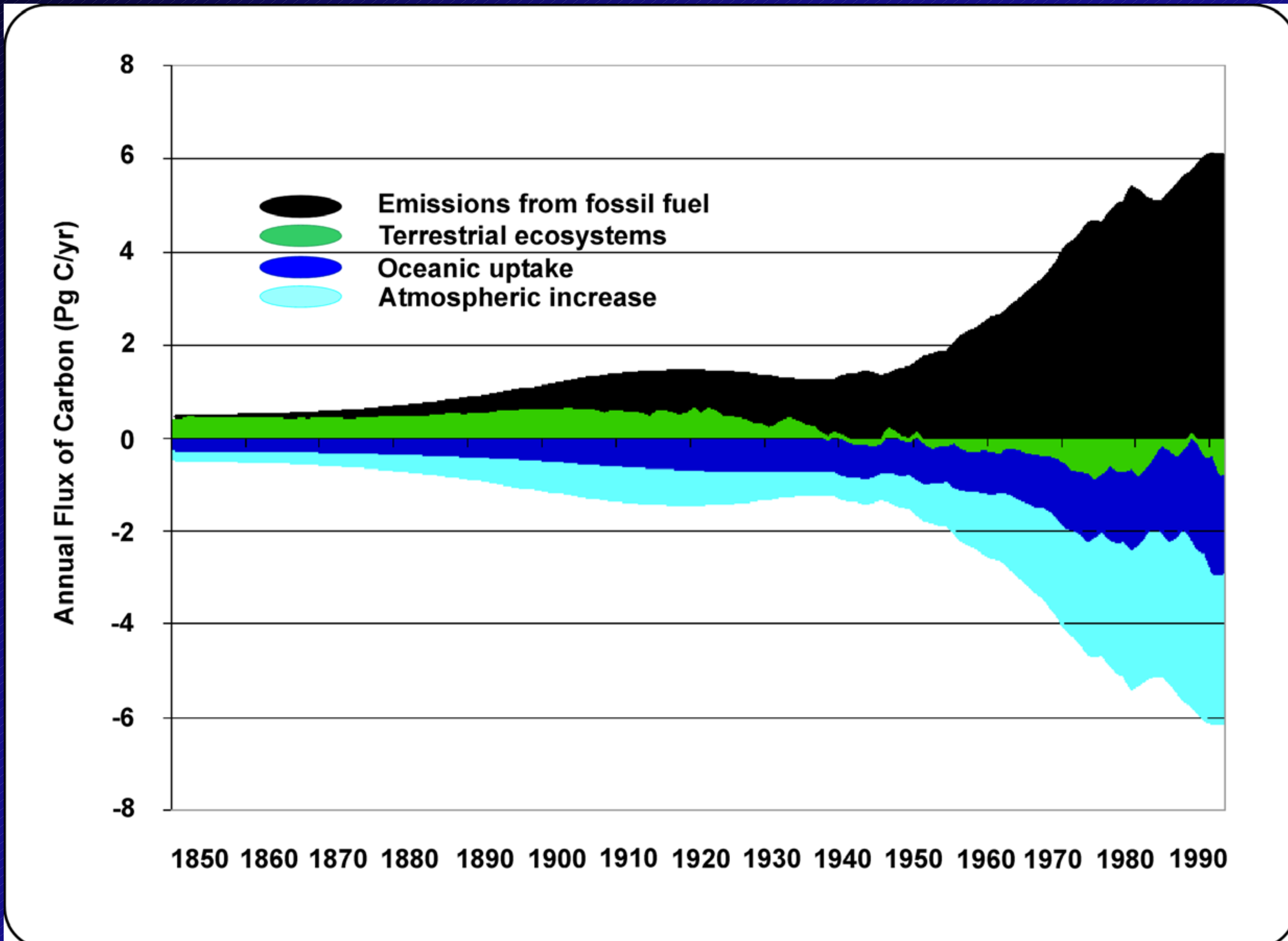
Annual Sources and Sinks of Carbon



Global Carbon Budget

1990s

Fossil fuel emissions	6.3 ± 0.4
Atmospheric increase	-3.2 ± 0.2
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Net terrestrial flux	-0.7 ± 0.8
Land-use change	2.1 ± 0.8

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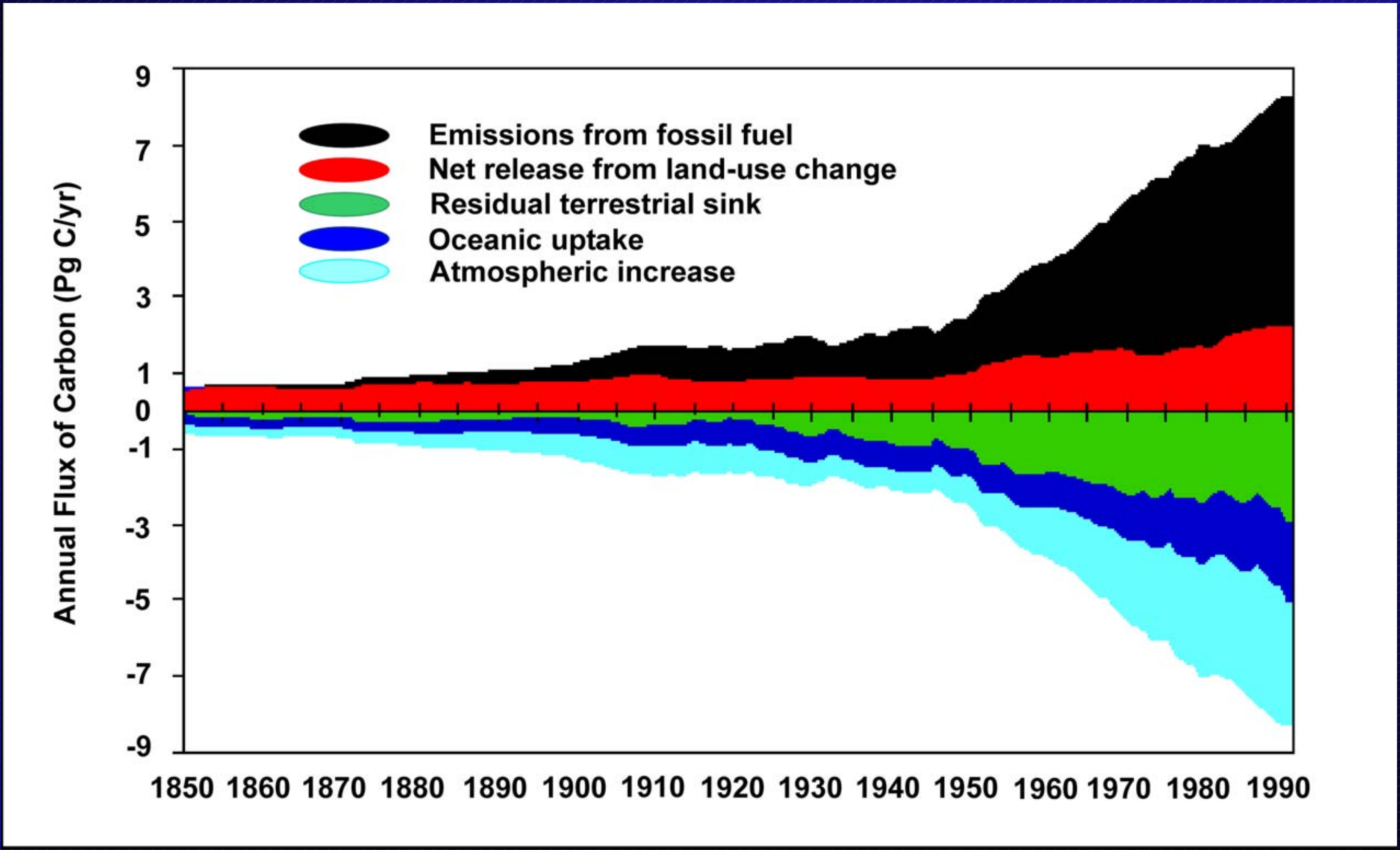
Houghton

Global Carbon Budget

	1990s
Fossil fuel emissions	6.3 $\pm$ 0.4
Atmospheric increase	-3.2 $\pm$ 0.2
Oceanic uptake	-2.4 $\pm$ 0.7
Net terrestrial flux	-0.7 $\pm$ 0.8
Land-use change	2.1 $\pm$ 0.8
Residual terrestrial flux	-2.8 $\pm$ 1.1

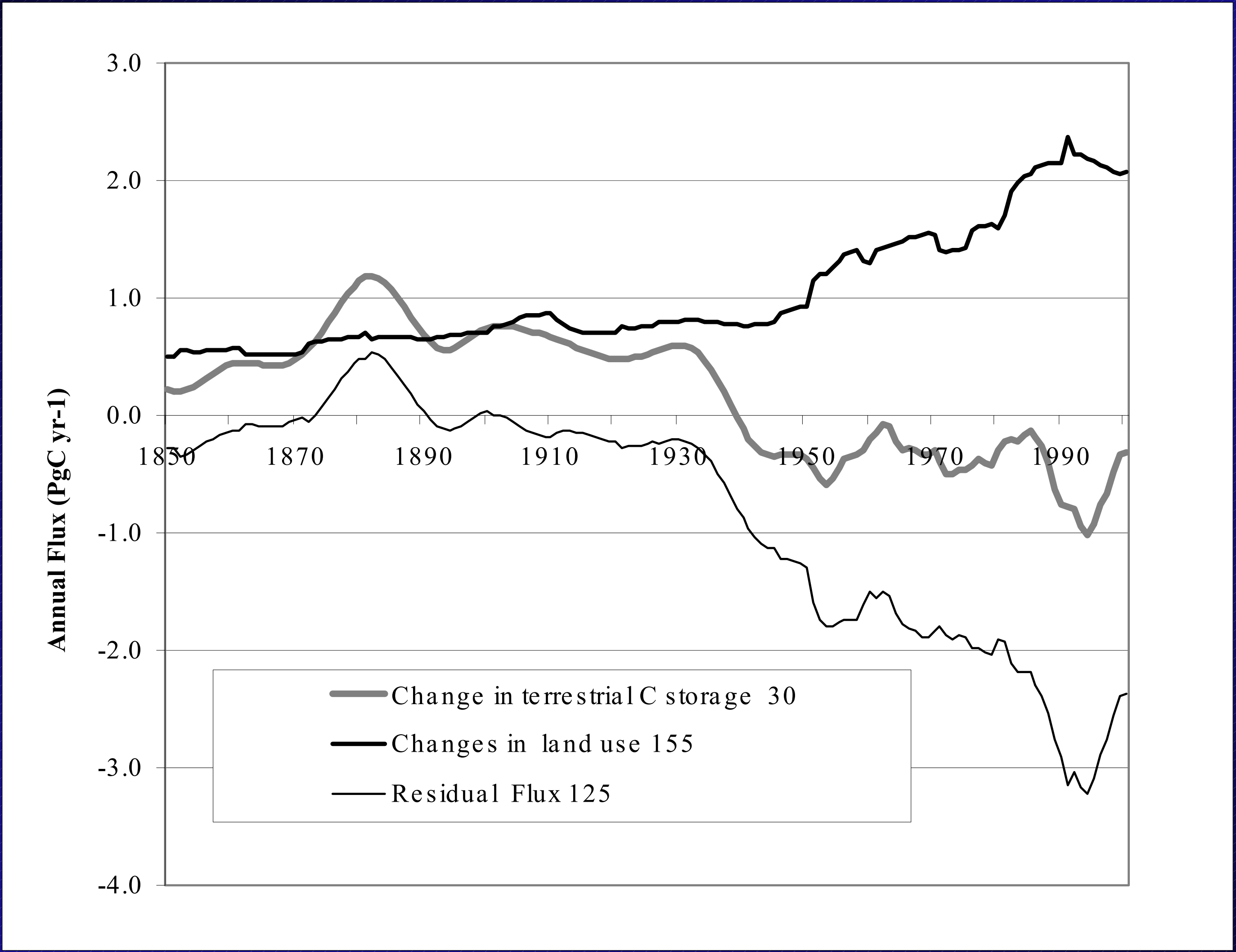
IPCC
Plattner
Houghton

Annual Sources and Sinks of Carbon



Residual Terrestrial Sink

a.k.a. "the missing carbon sink"



Land-use change

Net terr. flux "Deconvolution

The difference (the residual) "missing sink" ???

Historically the residual terrestrial sink has been attributed to environmentally-enhanced growth (e.g., CO_2 fertilization).

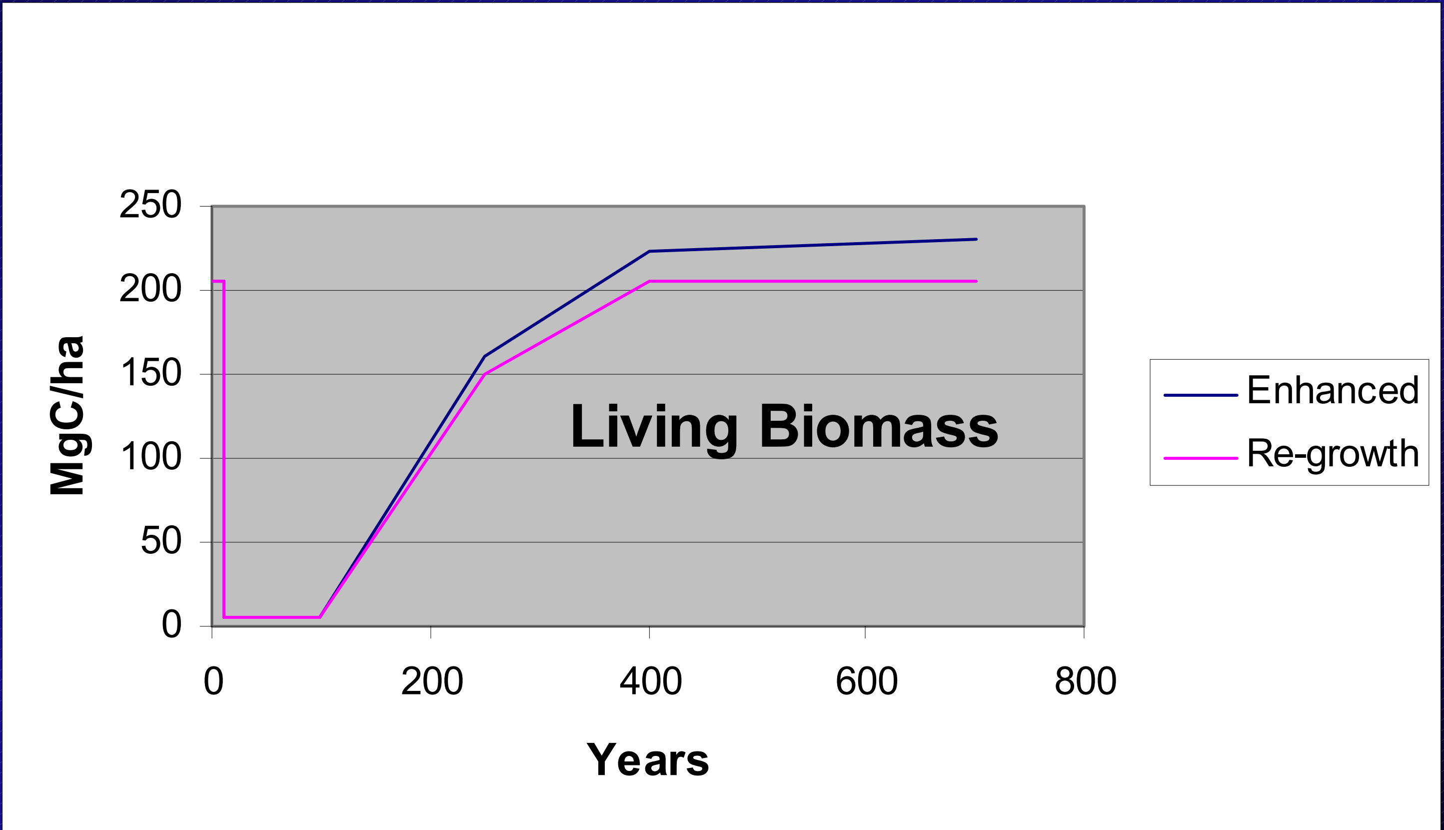
Enhanced growth

But the "residual" flux might also be due to…

- Errors, poor data
- Omissions from analyses of land-use change
  - Management
- Recovery from natural disturbances
  - More secondary forests

Re-growth

Regrowth vs. Enhanced Growth



The Question:

Is the residual sink attributable to environmental change (e.g., CO_2 fertilization, N deposition…)? Indirect

Or is it attributable to omissions in our accounting of land-use change (e.g., regrowth)? Direct

Why does it matter?

Political reason :

Carbon accounting (Kyoto Protocol)

- Direct human effects — Carbon credits
  - Management
  - Land-use change
- Indirect human effects — No carbon credits
  - CO_2 fertilization
  - N deposition
  - Climatic change

Scientific reason:

Will the Carbon Sink continue?

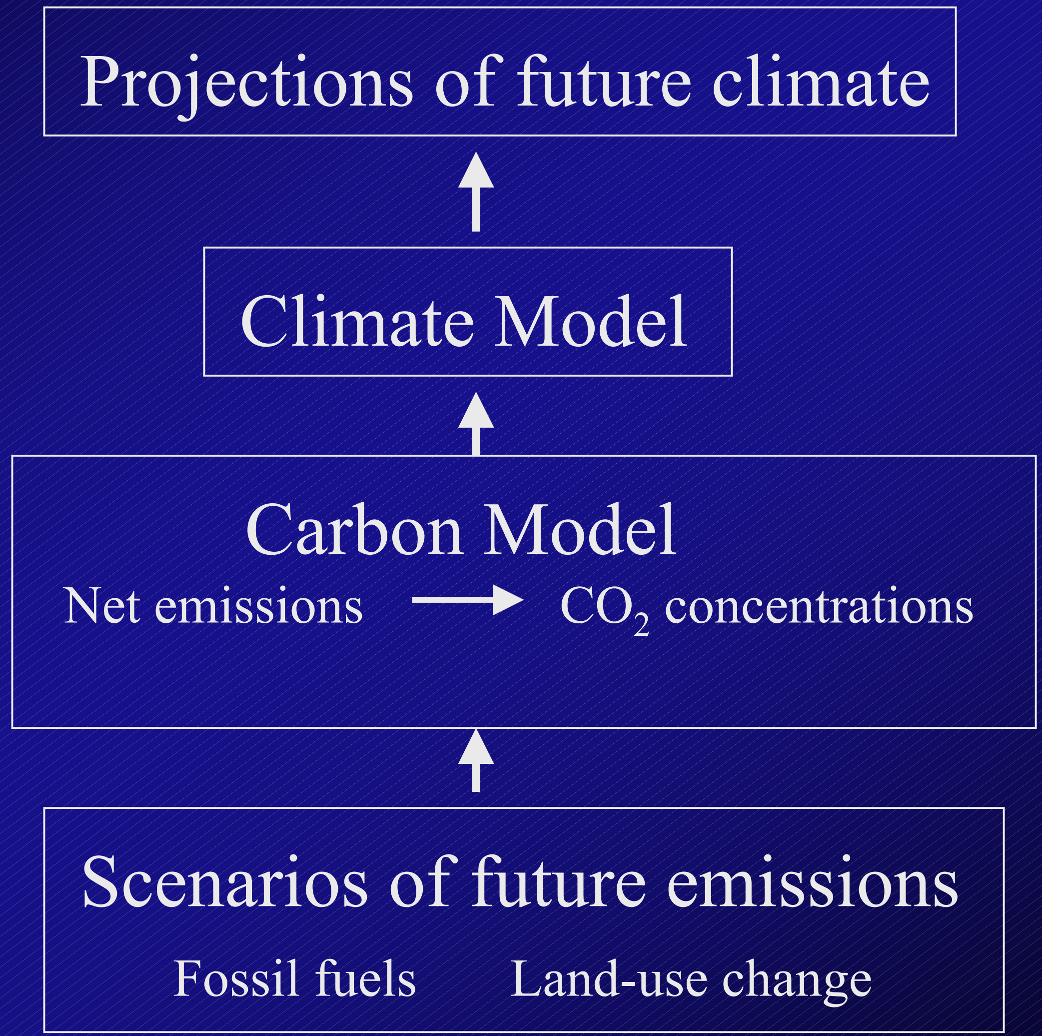
If the important mechanism is CO_2 fertilization, the sink will increase in the future.

If the important mechanism for the sink is regrowth, the sink will decrease in the future.

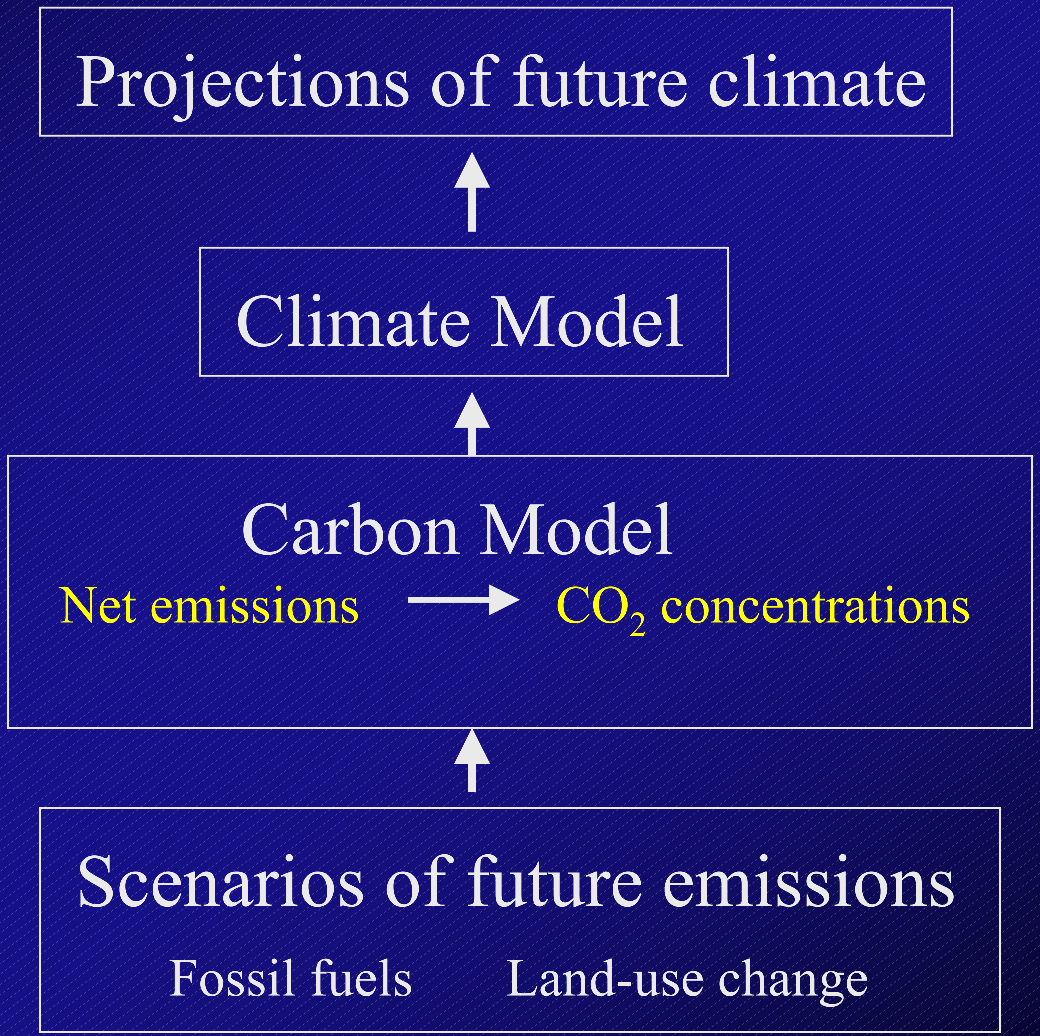
Climatic change as predicted.

Climatic change more rapid than predicted.

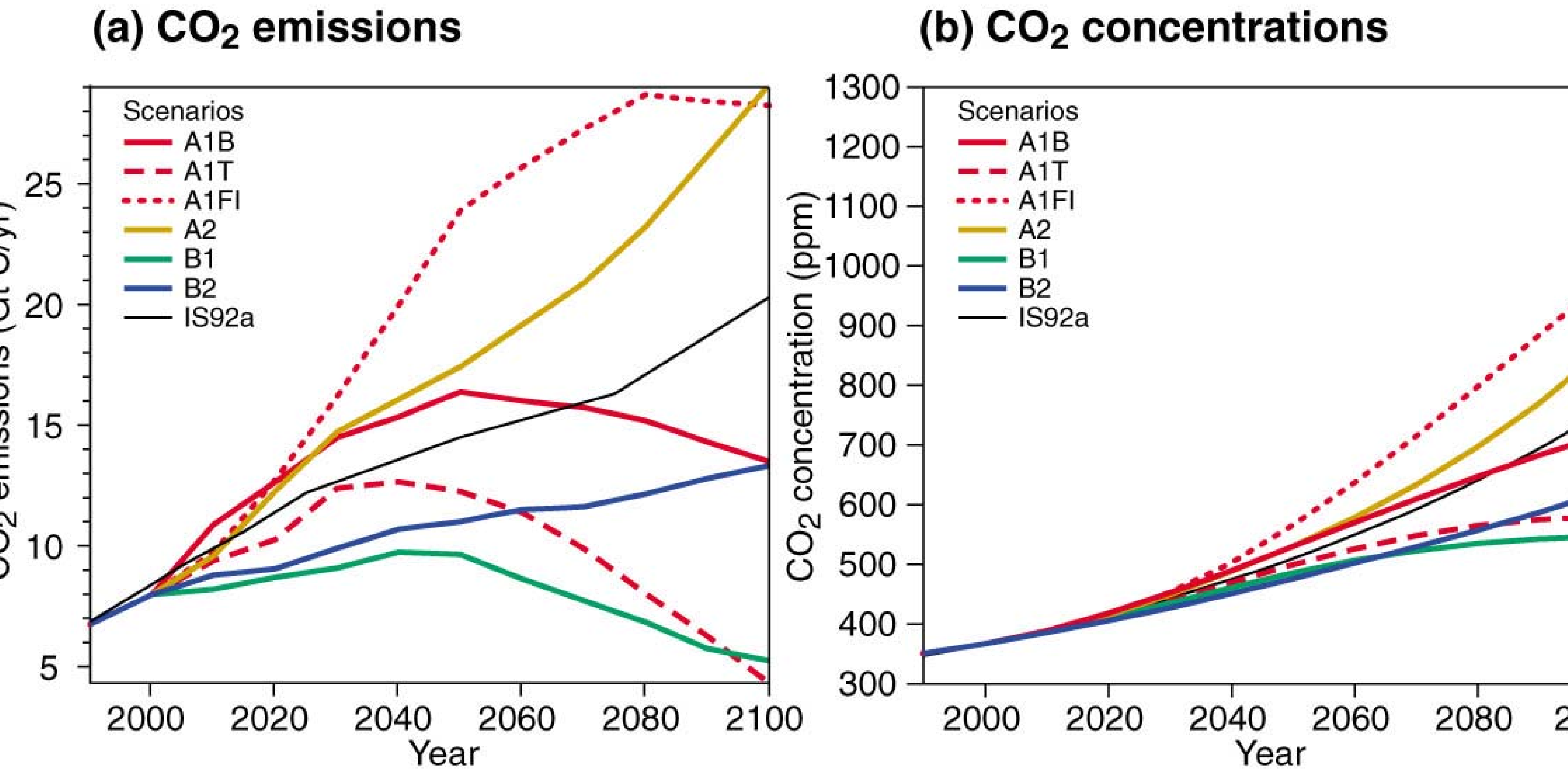
Projections of climate change may be optimistic



Projections of climate change may be optimistic

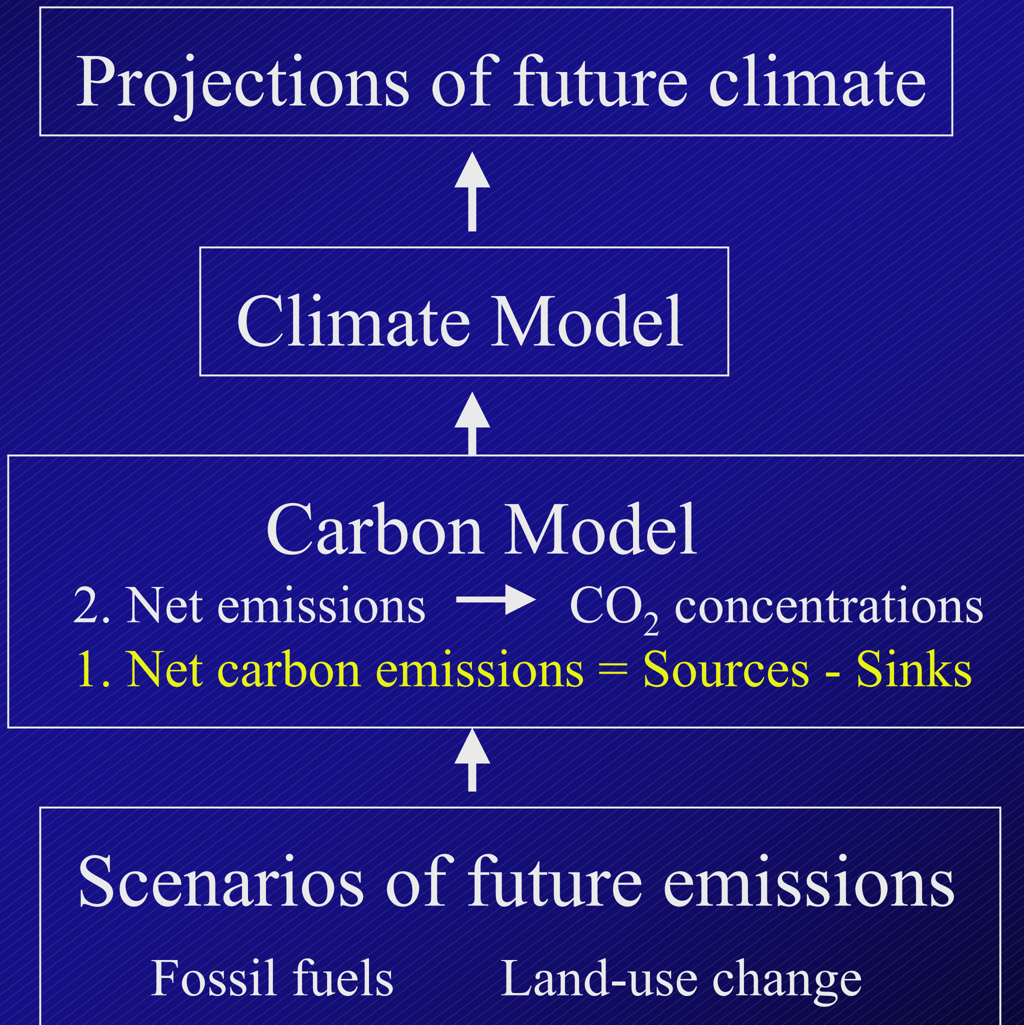


Emissions vs. Concentrations



Keeping emissions at today's levels increases concentrations.

Projections of climate change may be optimistic



Global Carbon Budget

	1990s
Fossil fuel emissions	6.3 ± 0.4
Atmospheric increase	-3.2 ± 0.2
Oceanic uptake	-2.4 ± 0.7
Net terrestrial flux	-0.7 ± 0.8
Land-use change	2.1 ± 0.8
Residual terrestrial flux	-2.8 ± 1.1

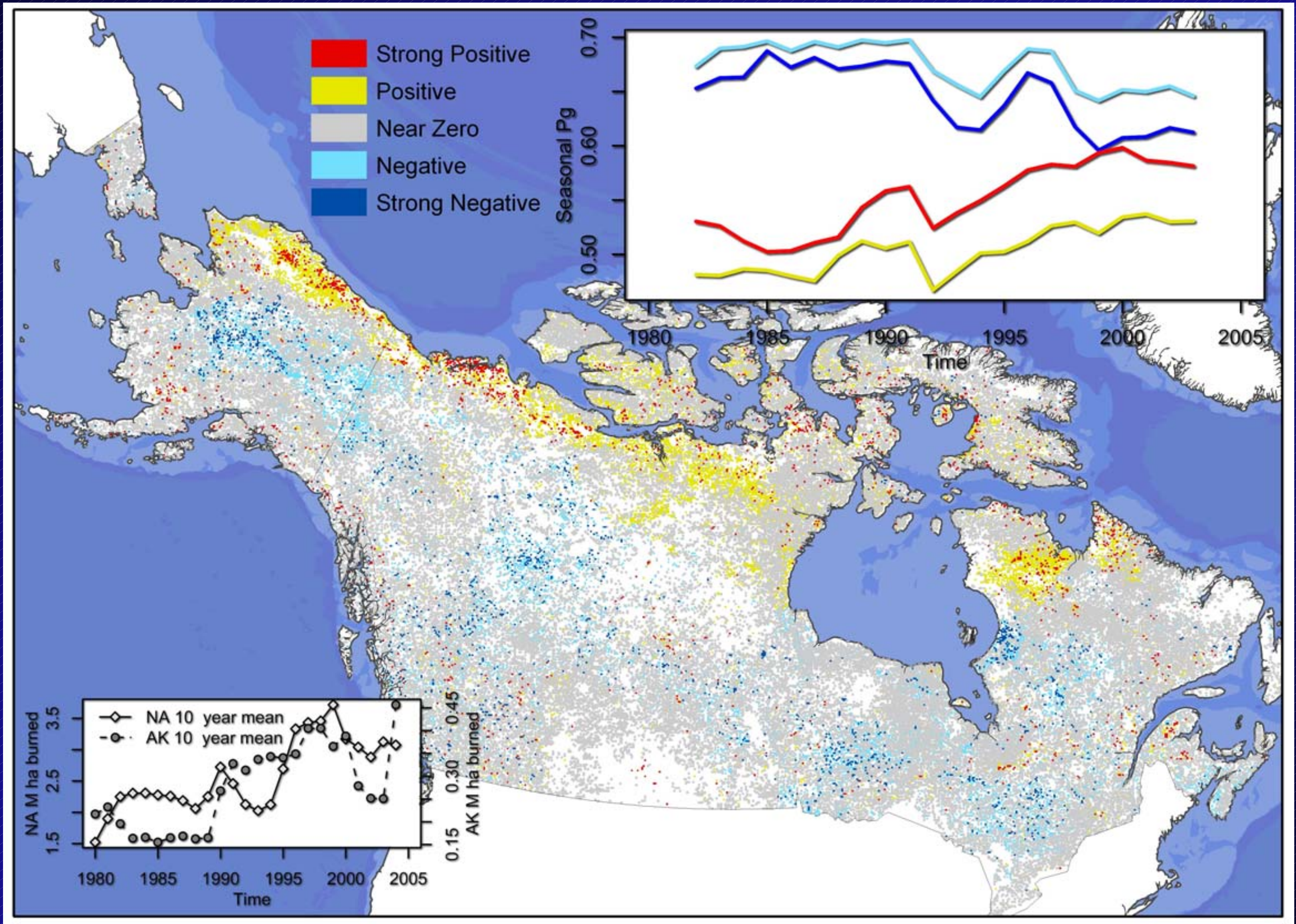
Future sink assumed to increase in proportion to CO_2

On the contrary, the terrestrial sink may diminish or turn into a net source as the earth surface warms.

Recent evidence suggests the sink may be declining

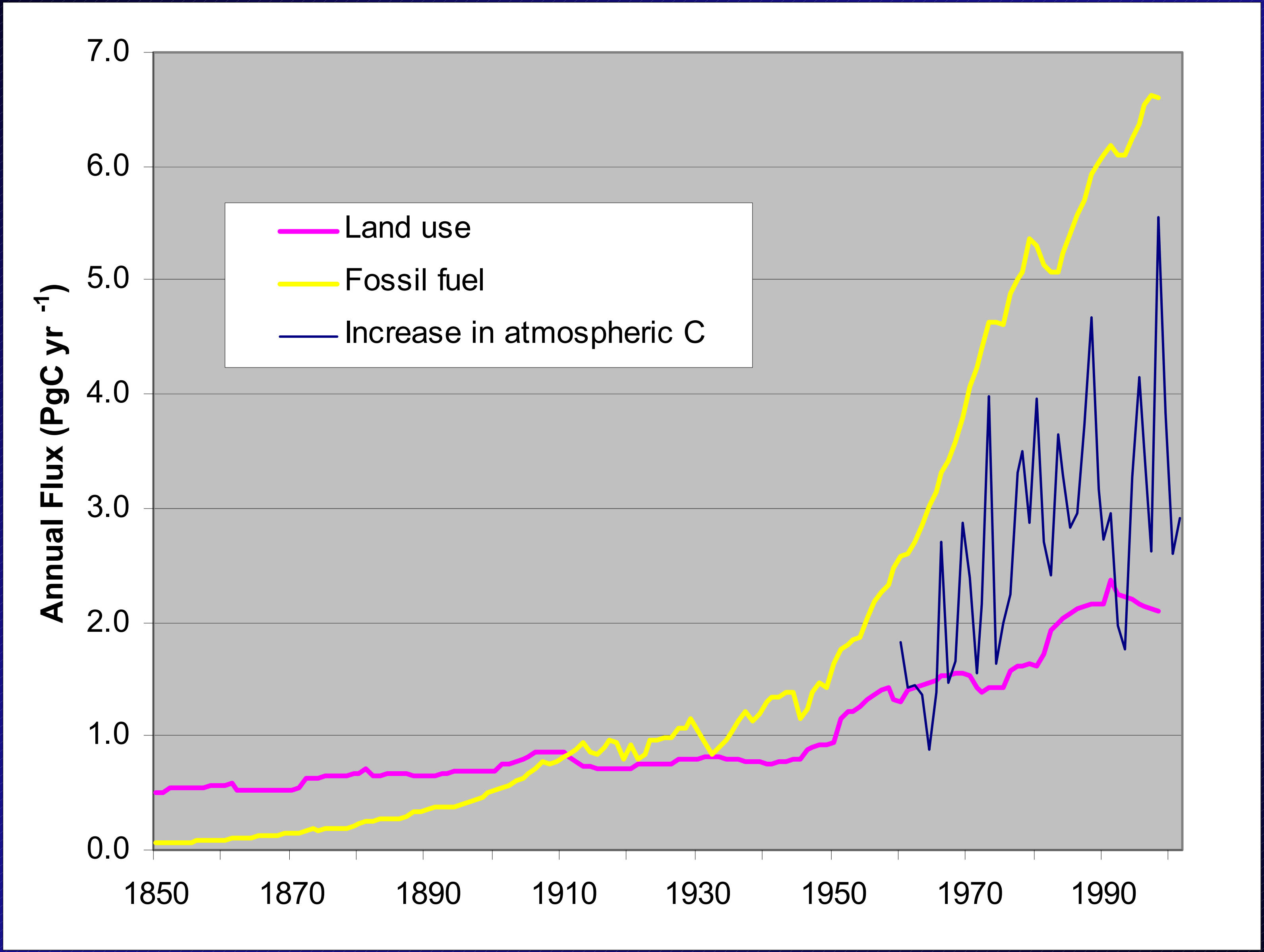
- Soil carbon in England and Wales
  - Bellamy et al. 2005 (*Nature*, Sept. 8, 2005)
- Boreal forests in North America
  - Goetz et al. 2005 (*PNAS*, Sept. 20, 2005)
- NH terrestrial sink lower 1992-2003 (ICDC7)
  - [Largest change has been since 1998]

Trends in 'greenness'



Goetz et al. 2005

Annual Fluxes of Carbon



How do we know that human activities have been responsible for the increase in CO_2?

- 1. For thousands of years CO_2 concentrations have varied little, but since ~1850 concentrations have increased by 30% (280-370 ppm).
- 2. The rate of increase in the atmosphere is similar to the rate of fossil fuel combustion.
- 3. The Suess Effect
- 4. The North-South gradient in concentrations
- 5. There's a missing carbon *sink*, not a missing source.

Conclusions

- Changes in land use and management play a dominant role in determining sources and sinks of carbon.
- Management accounts for a major portion of today’s carbon sink.
- And nature seems to have been helping … so far.

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Where is the residual sink?

Most of it seems to be in the northern mid-latitudes…

…and not in the tropics

Annual terrestrial flux of carbon in the 1990s (PgC yr^{-1})

	O_2 and CO_2	Inverse calculations CO_2, $^{13}CO_2$, O_2	"Forest" inventories	Land-use change
Globe	-0.7	-0.8	-	1 to 2

2-3 PgC/yr difference, globally

Annual terrestrial flux of carbon in the 1990s (PgC yr^{-1})

	O_2 and CO_2	Inverse calculations CO_2, $^{13}CO_2$, O_2	"Forest" inventories	Land-use change
Globe	-0.7	-0.8	-	1 to 2
Tropics	-	1.5 (±1.1)	-	1.5 range: 0.5 to 3.0

In the Tropics

- Estimates of flux are variable, but…
- …the net source is consistent with the source attributable to land-use change (deforestation)

There is no residual sink.

No need to invoke another mechanism besides land-use change.

Annual terrestrial flux of carbon in the 1990s (PgC yr^{-1})

	O_2 and CO_2	Inverse calculations CO_2, $^{13}CO_2$, O_2	Forest inventories	Land-use change
Globe	-0.7	-0.8	-	1 to 2
Northern mid-latitudes	-	-2.1($\pm$0.8)	-0.7^{+}	-0.03

1-2 PgC/yr difference in the north

The difference is equivalent to a sink of 1-2 PgC yr^{-1} in the northern temperate zone.

Possible explanations:

- Incomplete accounting of land-use change?
- Management (direct effect)?
- Natural disturbances & recovery?
- Environmentally enhanced growth (indirect effect)?