Background: global carbon cycle and NAS workshop on direct and indirect effects (2003)

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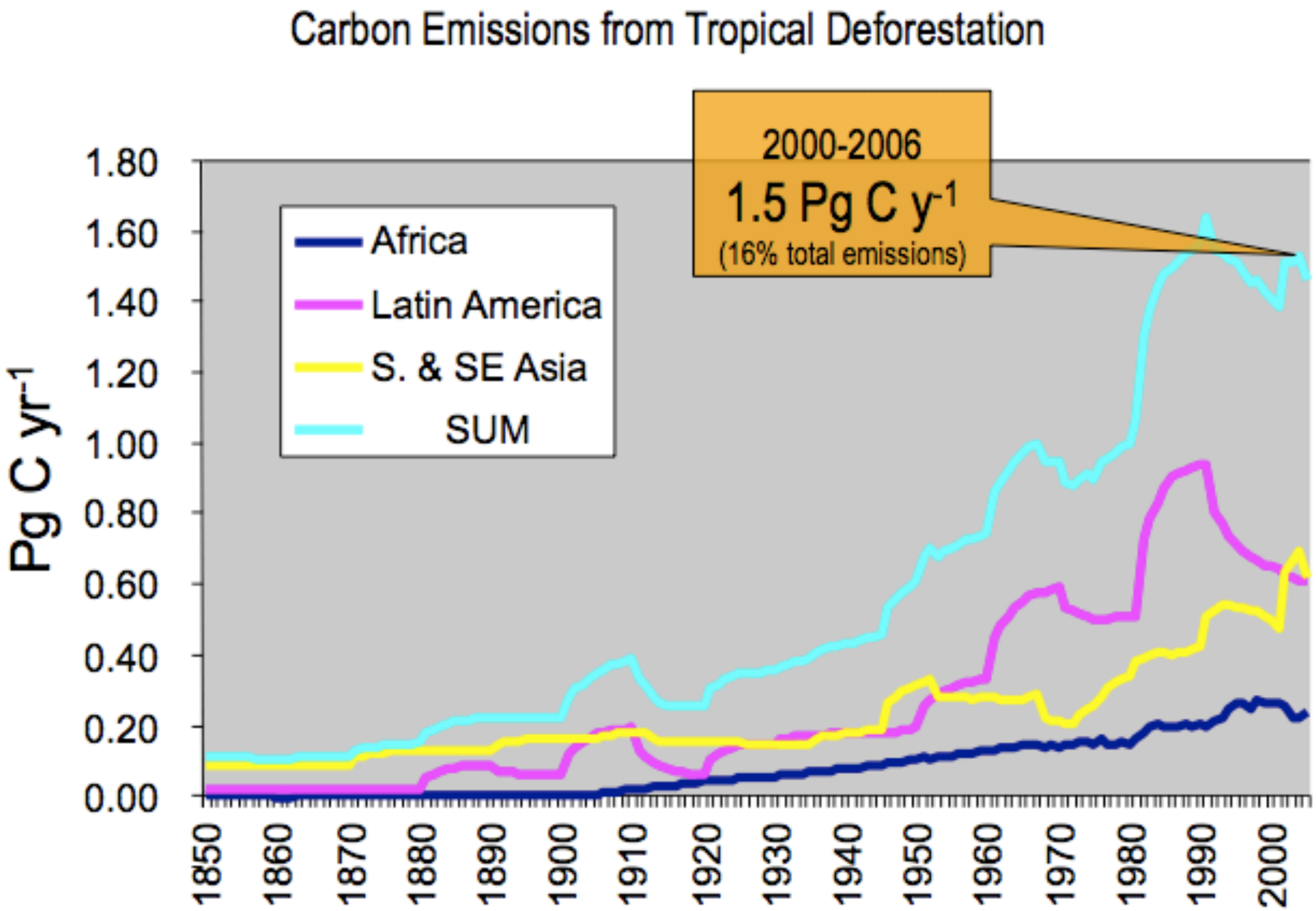
Table TS.1. *Global carbon budget. By convention, positive values are CO_2 fluxes ($GtC\ yr^{-1}$) into the atmosphere and negative values represent uptake from the atmosphere (i.e., 'CO_2 sinks'). Fossil CO_2 emissions for 2004 and 2005 are based on interim estimates. Due to the limited number of available studies, for the net land-to-atmosphere flux and its components, uncertainty ranges are given as 65% confidence intervals and do not include interannual variability (see Section 7.3). NA indicates that data are not available.*

	1980s	1990s	2000–2005
Atmospheric increase	3.3 ± 0.1	3.2 ± 0.1	4.1 ± 0.1
Fossil carbon dioxide emissions	5.4 ± 0.3	6.4 ± 0.4	7.2 ± 0.3
Net ocean-to-atmosphere flux	–1.8 ± 0.8	–2.2 ± 0.4	–2.2 ± 0.5
Net land-to-atmosphere flux	–0.3 ± 0.9	–1.0 ± 0.6	–0.9 ± 0.6
Partitioned as follows			
Land use change flux	1.4 (0.4 to 2.3)	1.6 (0.5 to 2.7)	NA
Residual land sink	–1.7 (–3.4 to 0.2)	–2.6 (–4.3 to –0.9)	NA

from: IPCC Fourth Assessment Report, WG1 Technical Summary

Anthropogenic C Emissions: Land Use Change

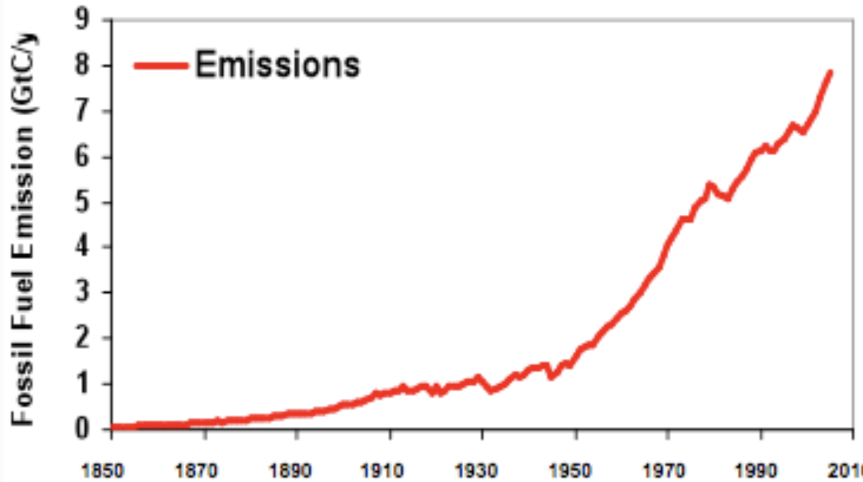


Houghton, unpublished

Anthropogenic C Emissions: Fossil Fuel

2006 Fossil Fuel: 8.4 Pg C

[2006-Total Anthrop. Emissions:8.4+1.5 = 9.9 Pg]



1990 - 1999: 1.3% y^{-1}

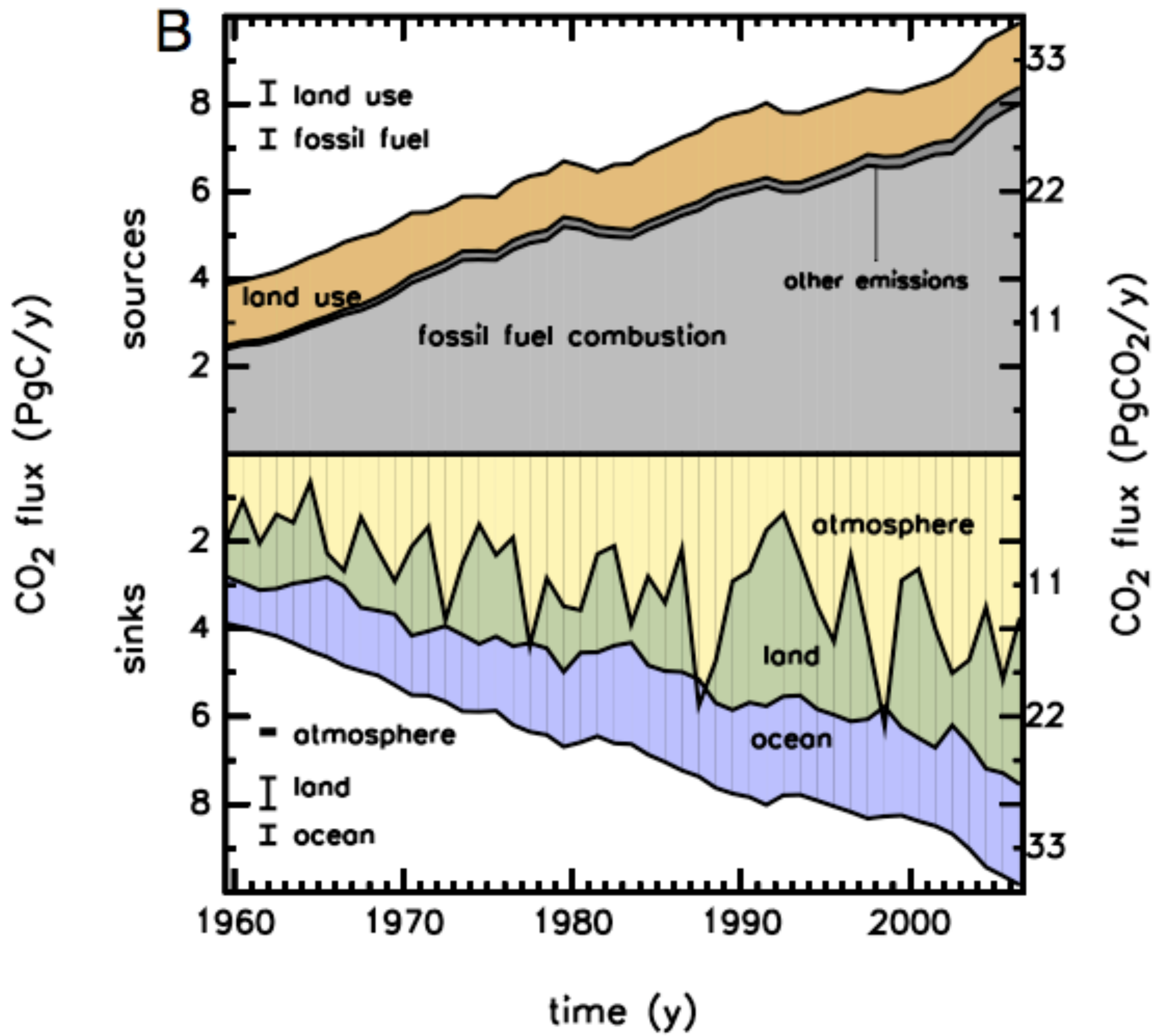
2000 - 2006: 3.3% y^{-1}

Raupach et al. 2007, PNAS; Canadell et al 2007, PNAS

Table 1. Summary of means and proportional trends of the global carbon budget for various time periods

Global carbon budget	Mean 1959–2006	Mean 1970–1999	Mean 1990–1999	Mean 2000–2006	Proportional trend, % y^{-1} 1959–2006
Economy, kgC/U.S. dollars					
Carbon intensity	0.29*	0.30	0.26	0.24	−1.18†
Sources, PgC y^{-1}					
Fossil Fuel (F_{Foss})	5.3	5.6	6.5	7.6	2.12
Land Use Change (F_{LUC})	1.5	1.5	1.6	1.5	0.21
Total ($F_{Foss} + F_{LUC}$)	6.7	7.0	8.0	9.1	1.71
Sinks, PgC y^{-1}					
Atmosphere	2.9	3.1	3.2	4.1	1.89
Ocean	1.9	2.0	2.2	2.2	1.25
Land	1.9	2.0	2.7	2.8	1.87
Distribution of annual emissions					
Atmosphere‡	0.43	0.44	0.39	0.45	0.25 ± 0.21§
Ocean	0.28	0.28	0.27	0.24	−0.42
Land	0.29	0.28	0.34	0.30	0.06

*The proportional trend for a quantity $X(t)$ is $\langle X \rangle^{-1} \langle dX/dt \rangle$, where angle brackets denote an average over the indicated period.
†Data available from 1970 only.
‡This is the airborne fraction.
§This value (mean ± standard deviation) of the proportional trend in AF was determined from the noise-reduced (monthly) series for AF (see *Methods* and *SI Text*). All other proportional trend estimates were derived from the annual series.


B
land use
fossil fuel
land use
fossil fuel combustion
other emissions
sources
sinks
atmosphere
land
ocean
atmosphere
land
ocean
CO_2 flux (PgC/y)
CO_2 flux ($PgCO_2$/y)
time (y)
1960
1970
1980
1990
2000
2
4
6
8
11
22
33

Take-home messages

- It is possible to measure directly:
  - fossil fuel emissions
  - land use change emissions
- The residual sink is found by difference, and is the aggregate result of all other land-based activities (incl. management, indirect effects, legacy effects, and all other natural effects)
- The airborne fraction is increasing, but not as fast as fossil fuel emissions are increasing
- There is substantial interannual variability in the terrestrial sink

NAS Workshop (Sept. 2003)

What methods are available for quantifying, characterizing, and cross-checking terrestrial carbon stocks over differing timescales and spatial scales?

- top-down and bottom-up methods, as well as field experiments and process models
- data needs:
  - high-resolution remote sensing for land use change
  - satellite lidar for mapping forest height and age

NAS Workshop (Sept. 2003)

How do terrestrial carbon stocks and related greenhouse gas emissions change over time as a function of ***direct*** *human-induced changes in land use, forestry, and other practices?*

- Depends on the activity:
  - for example, soil C decreases following agricultural cultivation while other effects depend on species, management practice, and age
  - afforestation and reforestation generally increase C stocks, while deforestation releases C

NAS Workshop (Sept. 2003)

How do terrestrial carbon stocks and related greenhouse gas emissions change over time as a function of ***indirect*** *human-induced effects, natural effects, and past practices in forests and current or former agricultural lands?*

- This is much less certain:
  - disturbances can disrupt ecosystem processes, esp. fires, insect outbreaks, storms, mortality
  - multiple factors interact in non-linear ways, esp. CO2 fertilization, N deposition, fire, drought, and other climate effects

NAS Workshop (Sept. 2003)

What methods are available to distinguish human-induced changes in terrestrial carbon stocks and related greenhouse gas emissions from those caused by indirect human-induced effects, natural effects, and effects due to past practices in forests and current or former agricultural lands?

- Progression of approaches:
  - inventory data
  - standard values ("rules of thumb")
  - control plot studies
  - multifactor manipulations
  - bottom-up and top-down models