Negative emissions in managed and unmanaged forests:

What's the potential for managing carbon on land?

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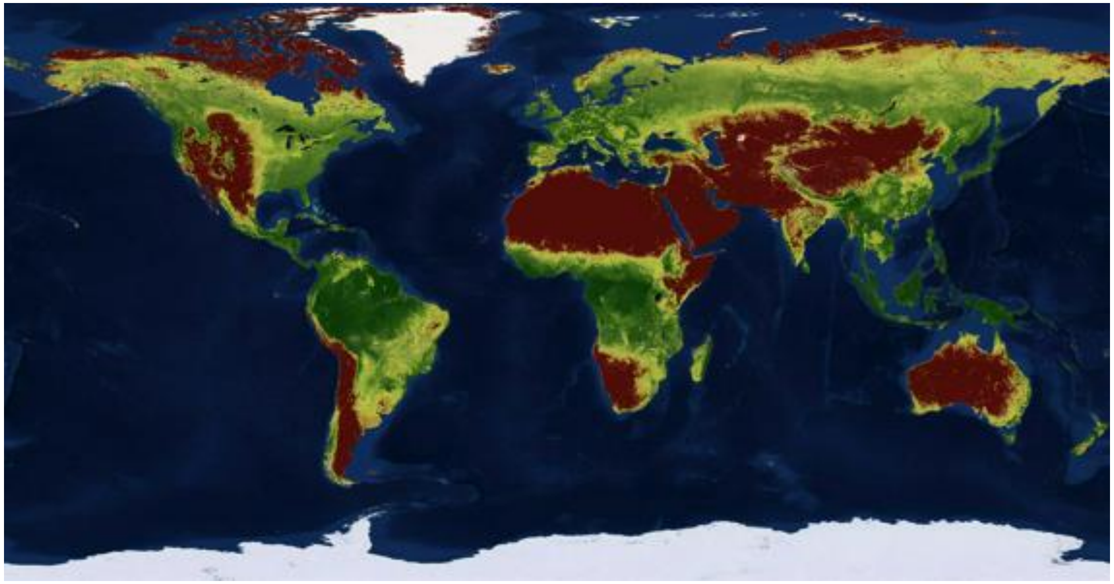
Woods Hole Research Center

Forest Research in the Big Data Era
September 6-9, 2017 Beijing, China

THE WOODS HOLE RESEARCH CENTER

Outline

- Global Carbon Budget
- Negative emissions
- New approach and data for estimating the terrestrial carbon budget

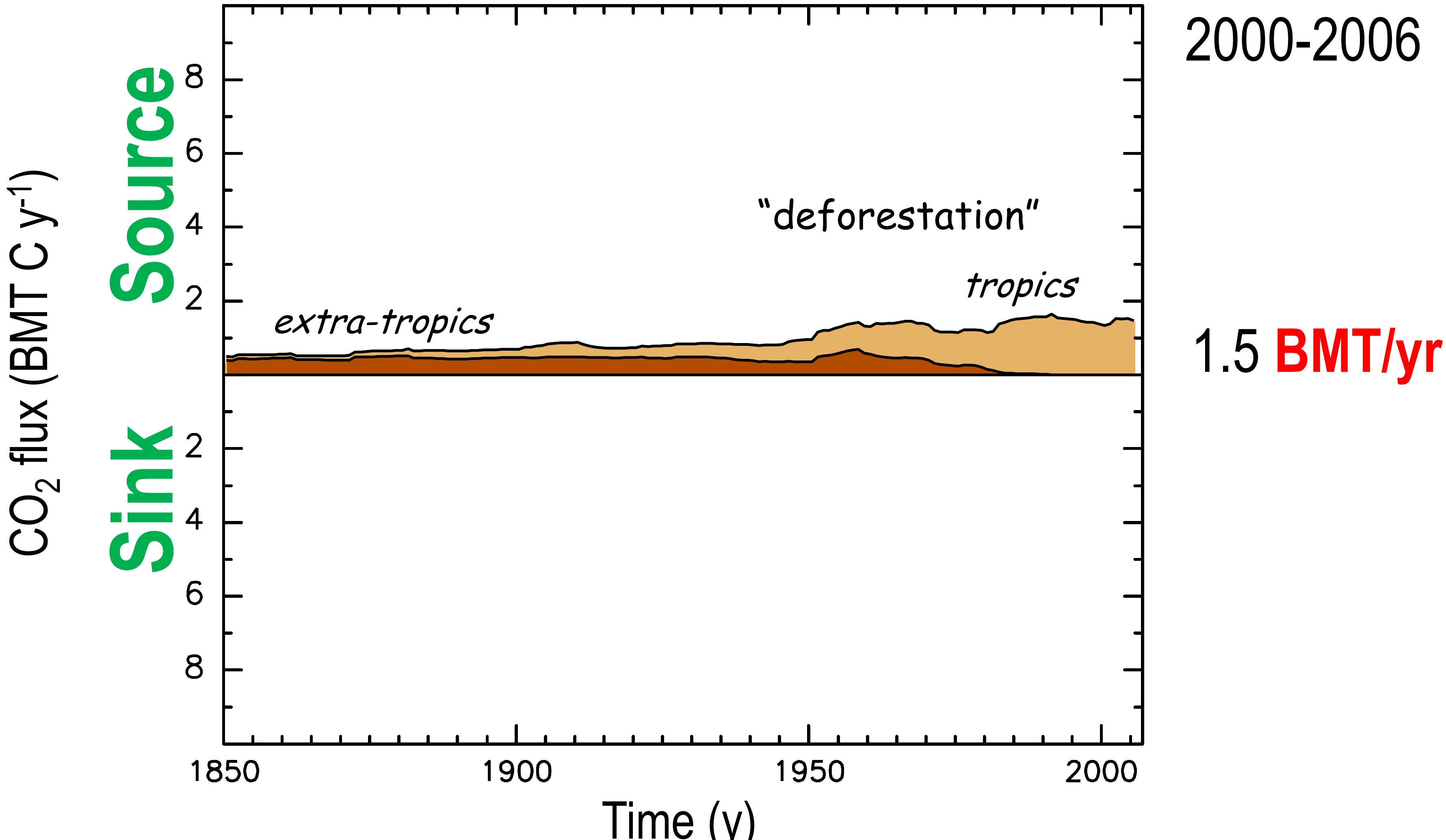


The global carbon budget:

Additions and removals of carbon in four reservoirs:

- Atmosphere
- Oceans
- Land (terrestrial ecosystems)
- Fossil fuels

Perturbation of Global Carbon Budget (1850-2006)



Le Quéré, unpublished; Canadell et al. 2007, PNAS

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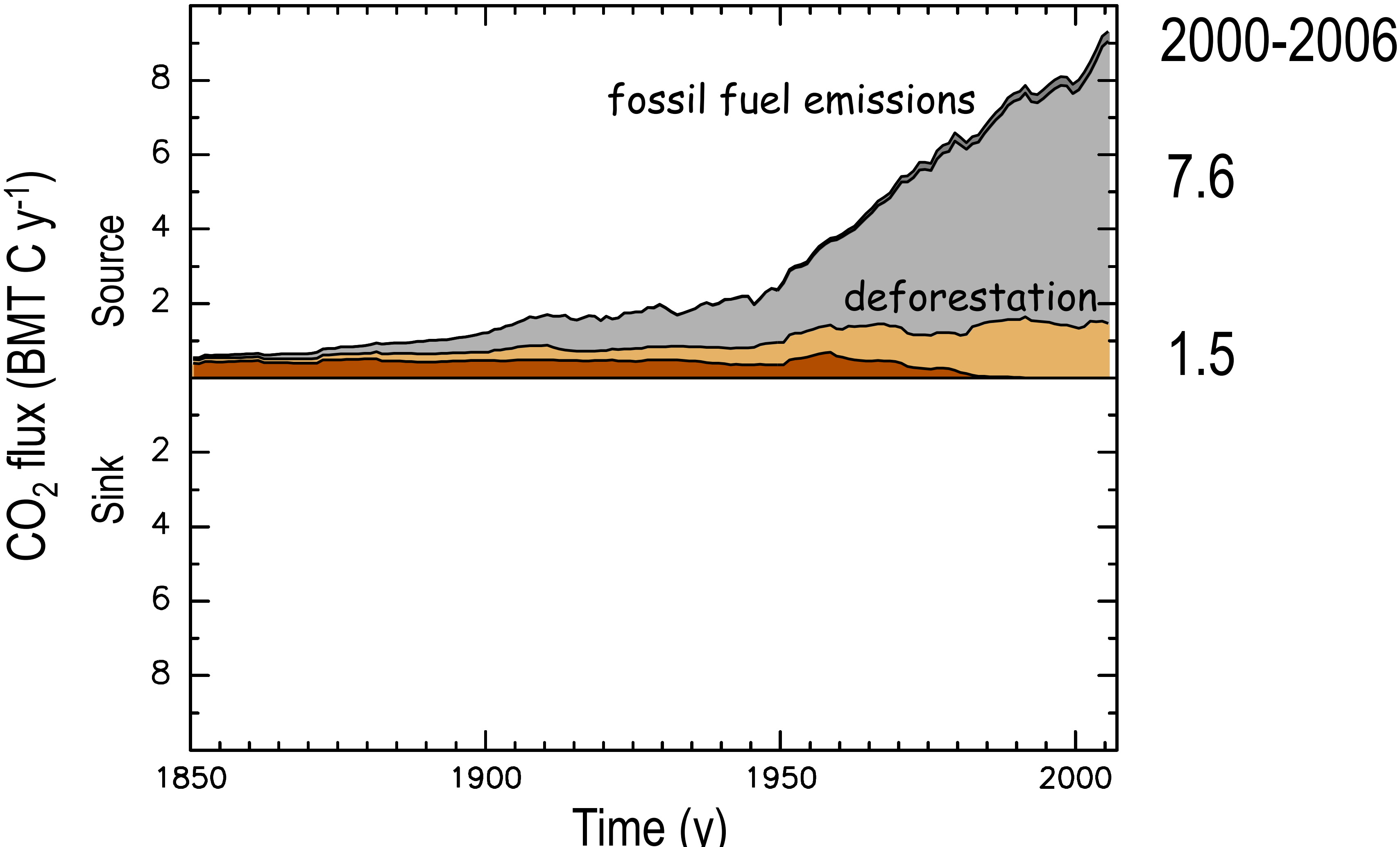

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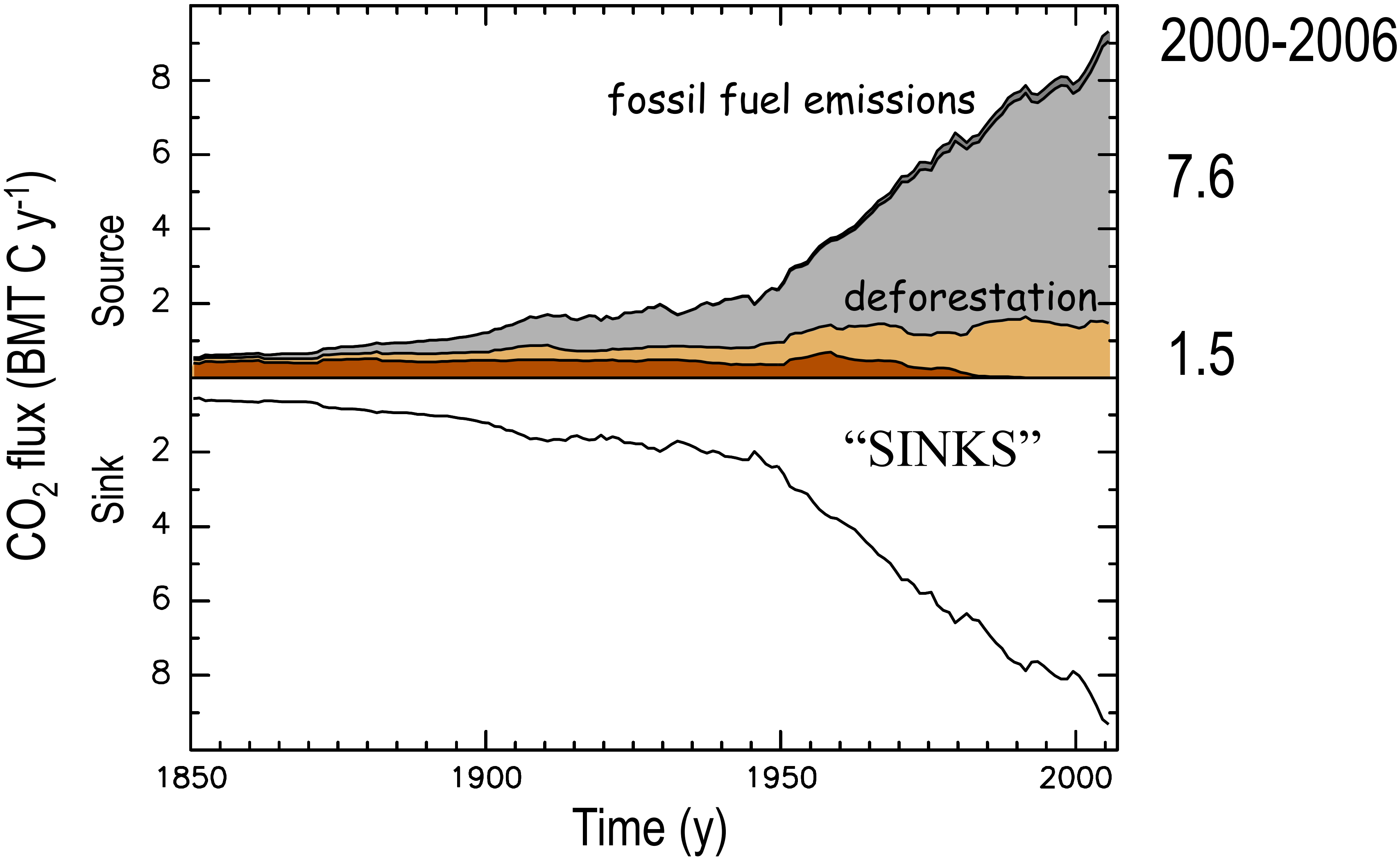

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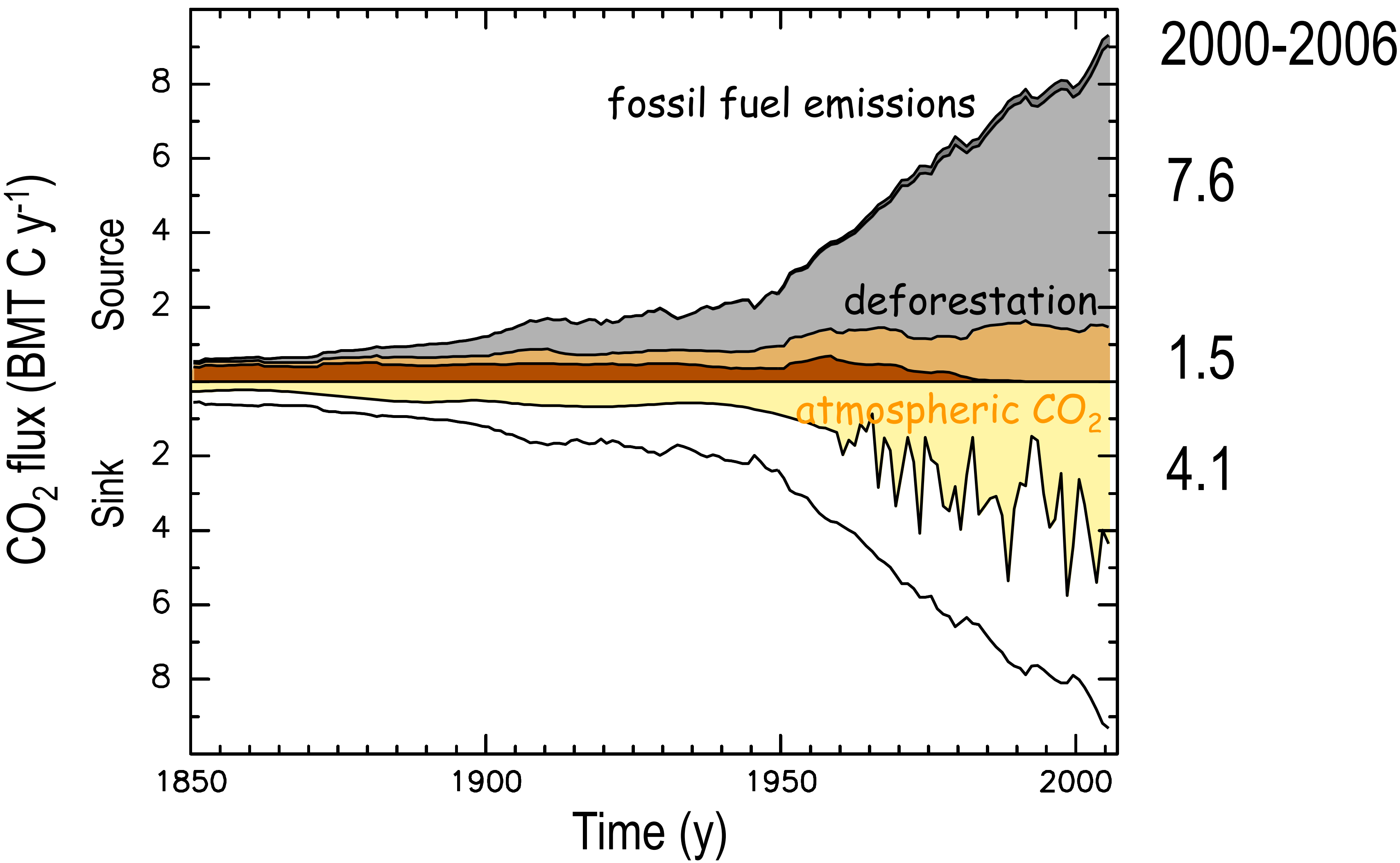

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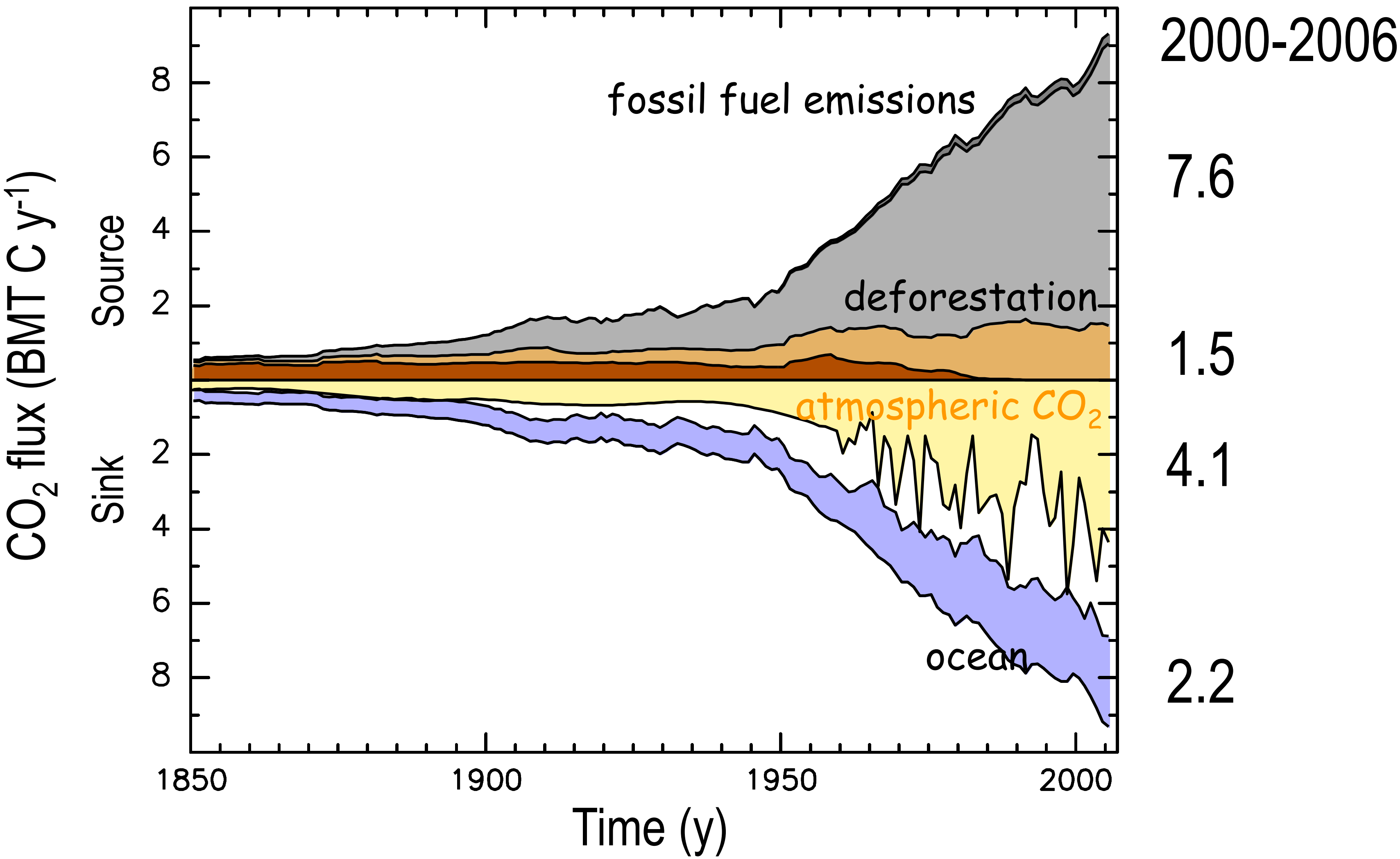

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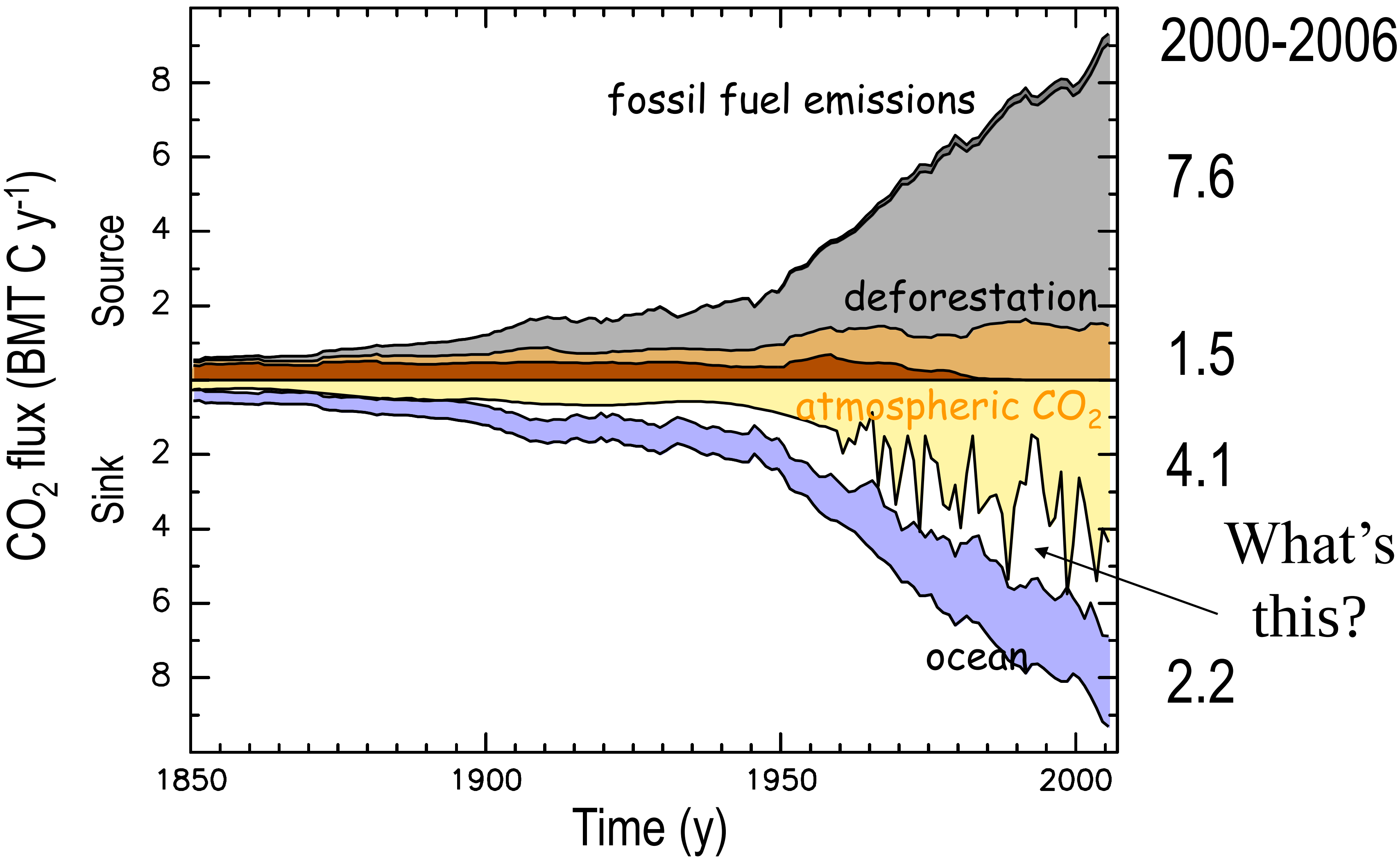

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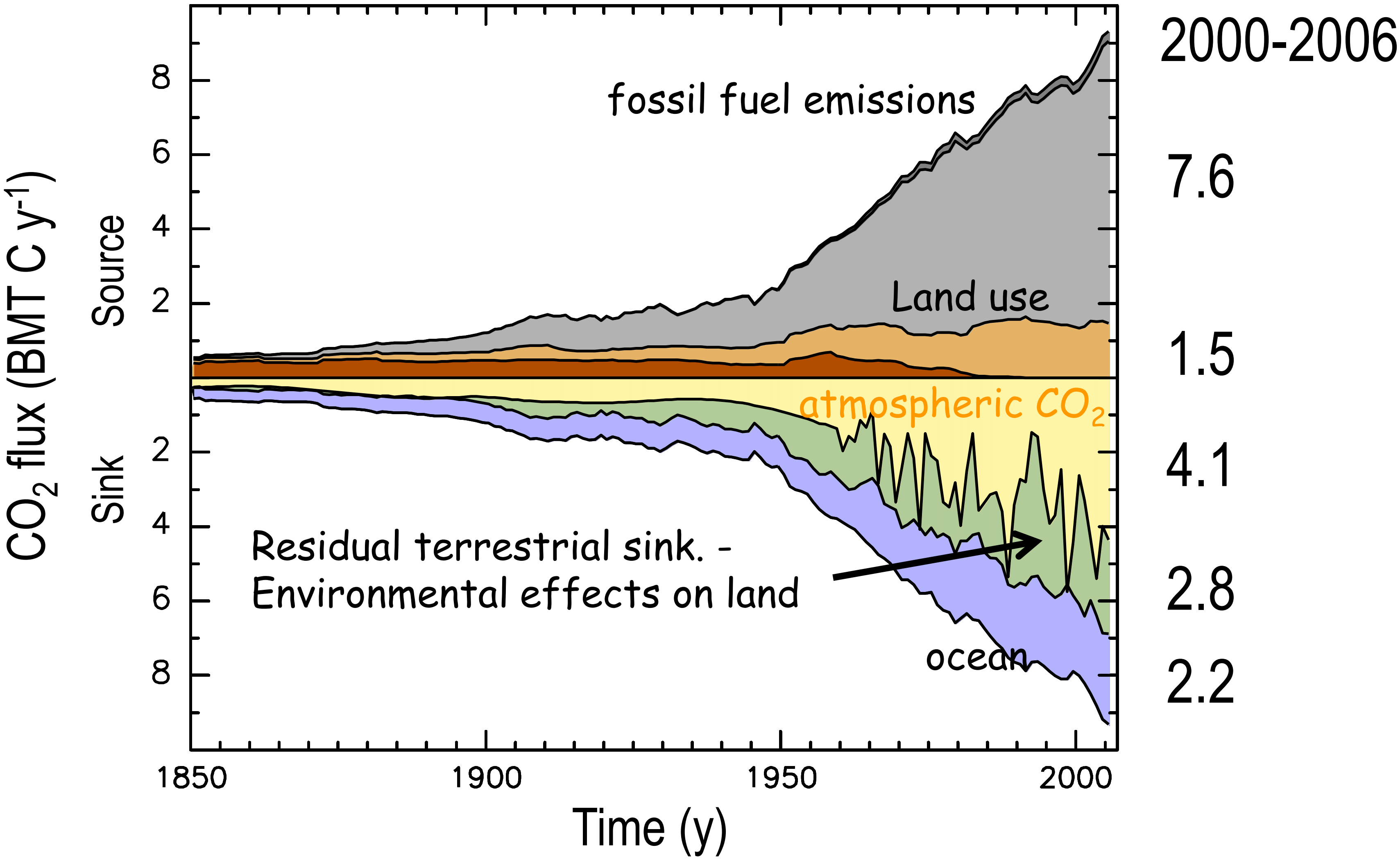

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Global Carbon Budget

3 take-away messages:

1. Land appears in the budget twice.
   a. Management (LULCC) (directly anthropogenic)
   b. Nature (e.g., CO_2, N deposition, climate)
2. The residual sink is calculated by difference.
   a. Not measured. Where is it? Why is it?
3. Both terrestrial terms are NET.
   a. They both have gross sources and sinks comprising the net.

Part 2.

Negative emissions

To have a 67% chance of warming not more than 2^{o}C…

- …total carbon emissions after 2015 must be less than 161-338 PgC.

- Can land management help?

Source: Rogelj et al., 2016

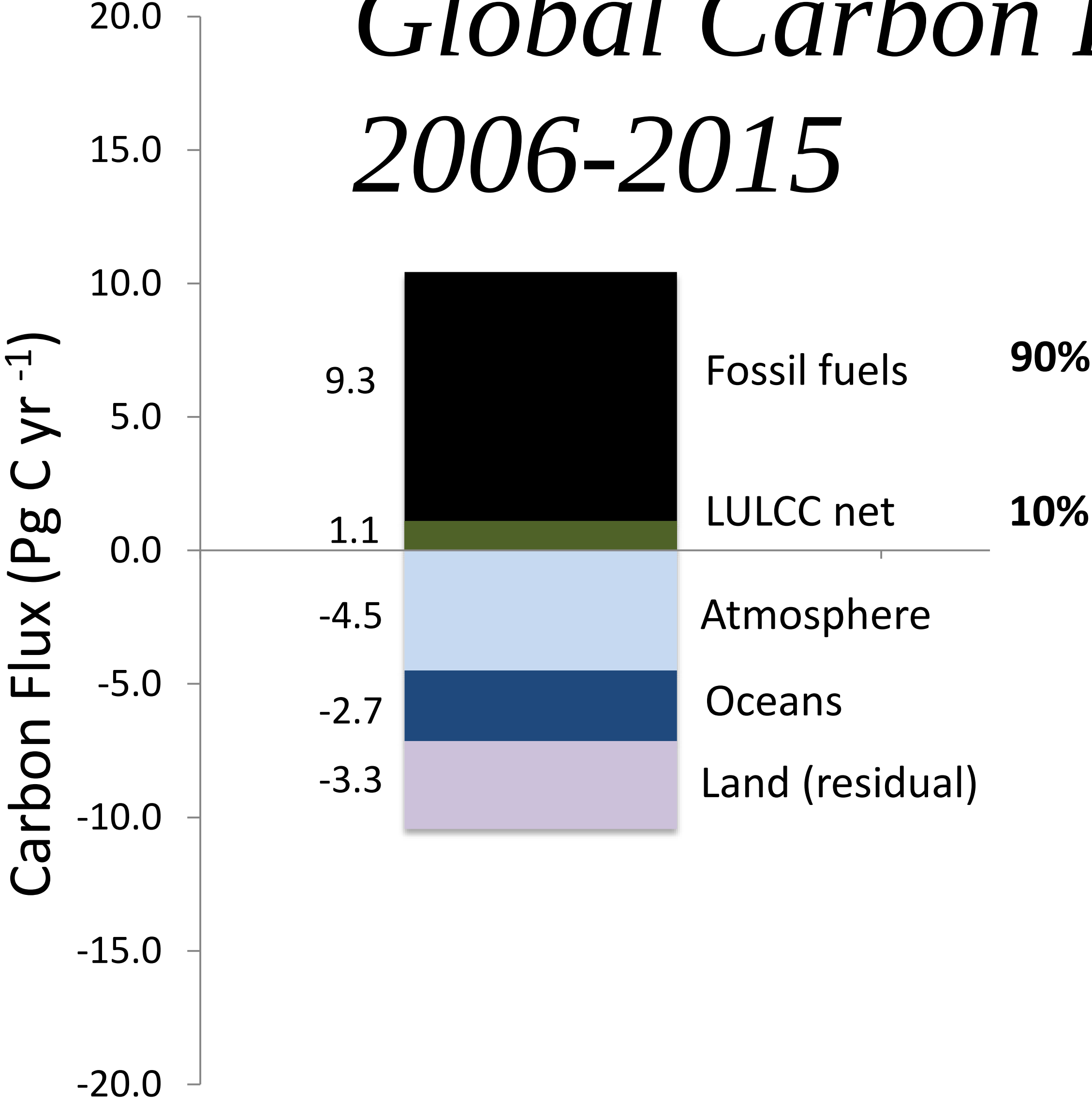
Carbon emissions 2006-2015
10.4 PgC/yr

At that rate, we have 15-32 years.

90% from fossil fuels
10% from LULCC*

*LULCC = Land Use and Land-Cover Change = Management

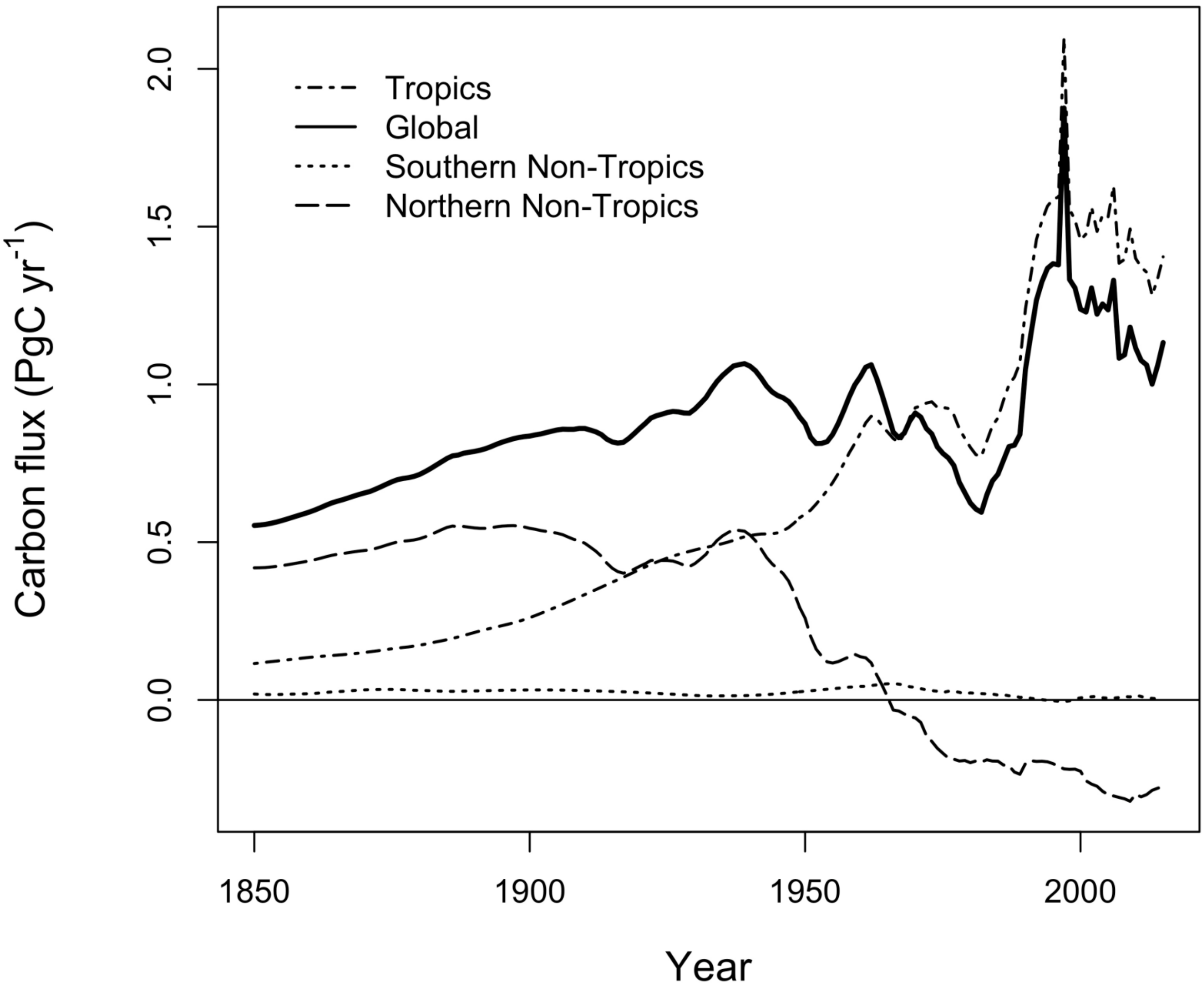
Global Carbon Budget 2006-2015



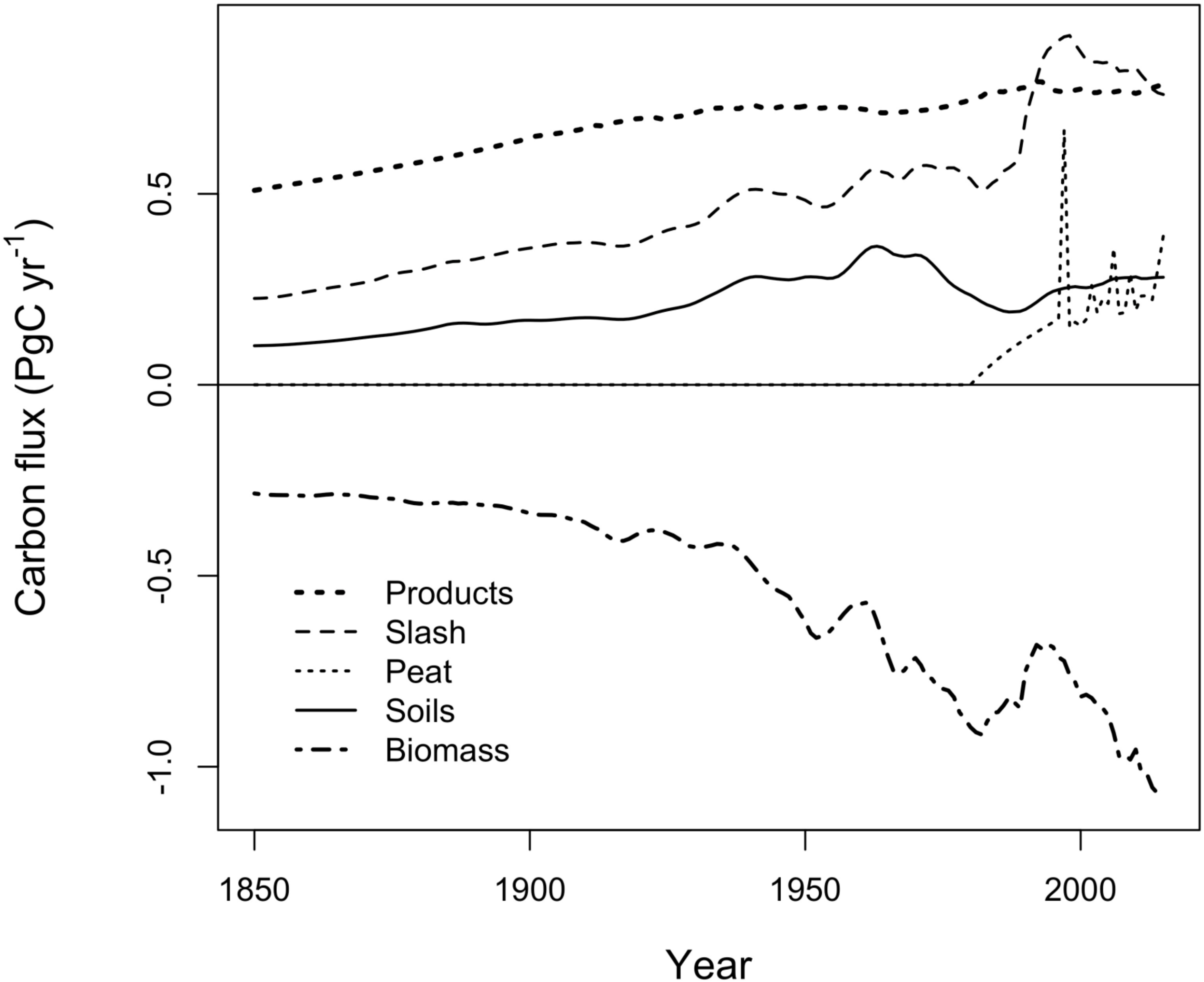
LULCC = Land Use and Land-Cover Change

	Net emissions (PgC) 1850-2015
• Land use	
– Wood harvest	25
• Land cover change	
– Croplands	98
– Pastures	16
– Other lands	7
• Total	146

Source: Houghton & Nassikas, 2017



Tropics
Global
Southern Non-Tropics
Northern Non-Tropics
Carbon flux (PgC yr-1)
Year
0.0
0.5
1.0
1.5
2.0
1850
1900
1950
2000



Carbon flux (PgC yr^{-1})
0.5
0.0
-0.5
-1.0
1850
1900
1950
2000
Year
Products
Slash
Peat
Soils
Biomass

What's the potential for managing carbon on land?

- How large are negative emissions on land?
- How large could cumulative emissions be before 2100?

How large are current negative emissions from LULCC?

The analysis by Houghton and Nassikas (2017) inferred changes in forest area based on expansion of croplands, pastures, and tree plantations.

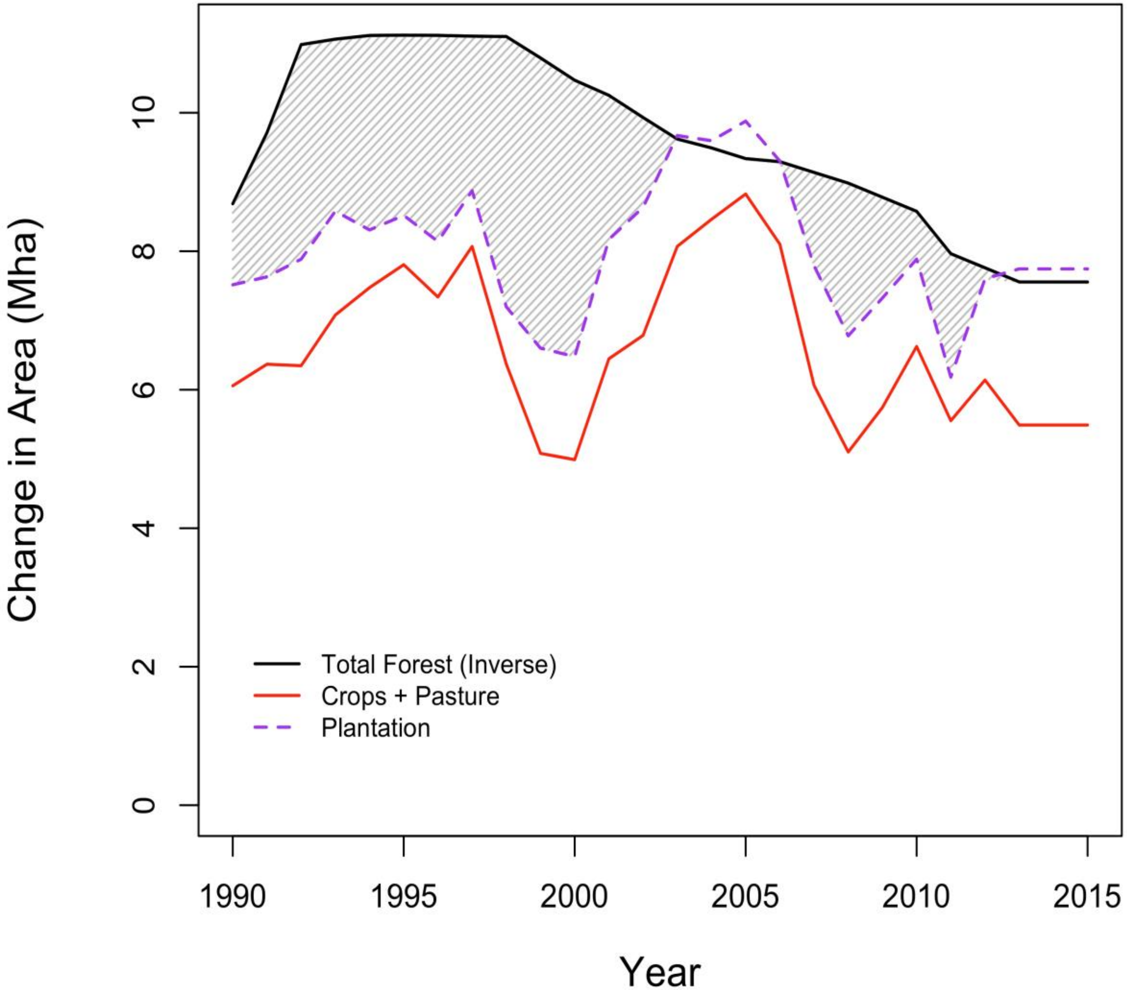
The analysis did not include shifting cultivation.

Two kinds of evidence from the FAO suggest shifting cultivation is important in LULCC:

1. Forest loss in the tropics is often greater than cropland and pasture gain.
2. Primary forests are 36% of tropical forest area.

Shifting cultivation is important because it generates large gross emissions, positive and negative.
And, if the positive emissions are stopped, the negative emissions will continue for some decades.

In the tropics the loss of forest area is greater than the gain in permanent croplands and pastures (and plantations).



Data from FRA 2015

Simulations

- We added shifting cultivation to our earlier analysis (Houghton & Nassikas, 2017).
- We ran simulations of LULCC into the future to estimate future emissions.
- We stopped LULCC after 2015 to reveal the persistence of net and gross emissions.

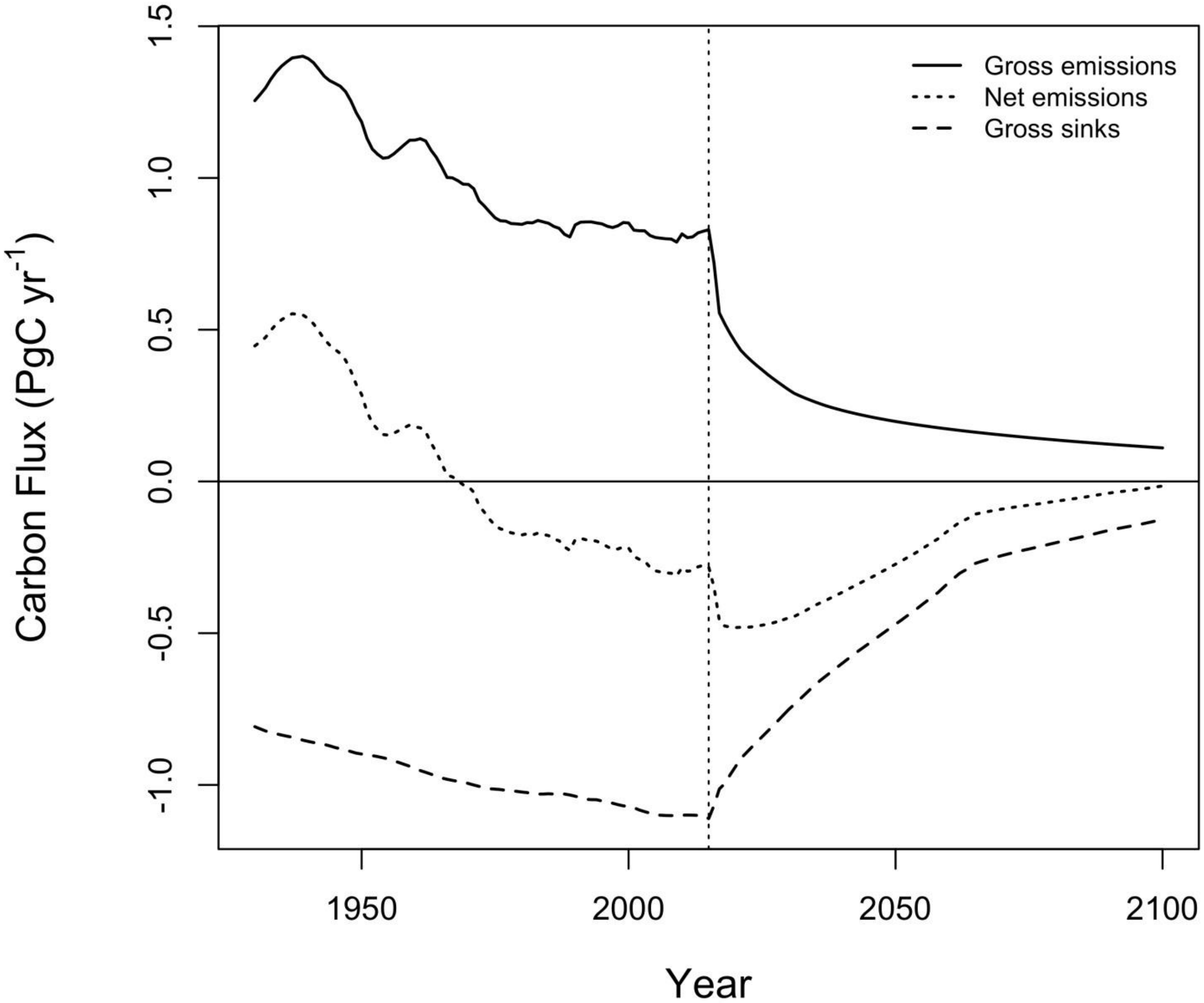
Potential negative emissions from LULCC

- 100-120 PgC between 2016 and 2100

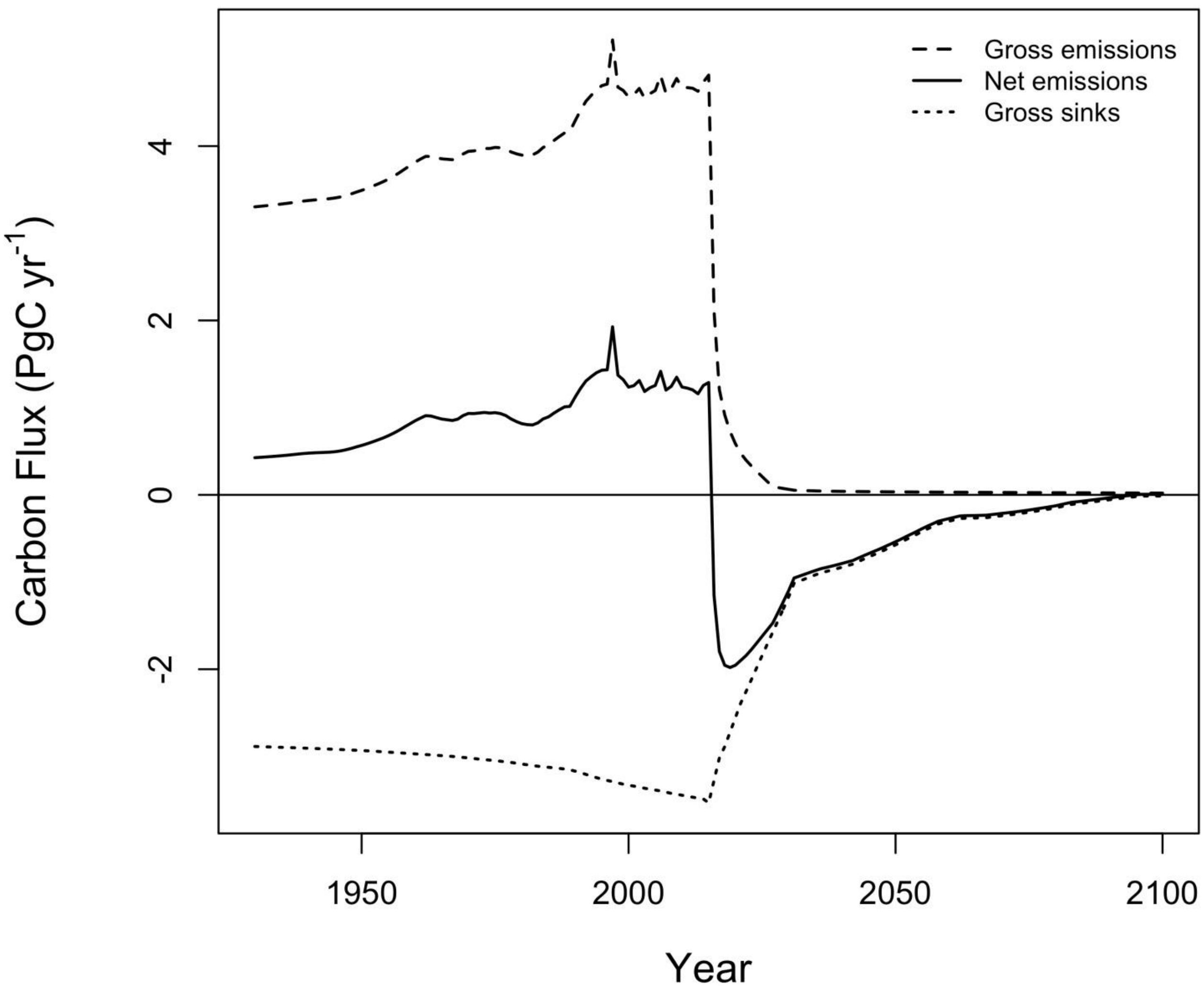
Small relative to fossil fuel reserves.

Large relative to ***allowable*** carbon emissions after 2015 (161-338 PgC).

Temperate and Boreal Zones



The Tropics

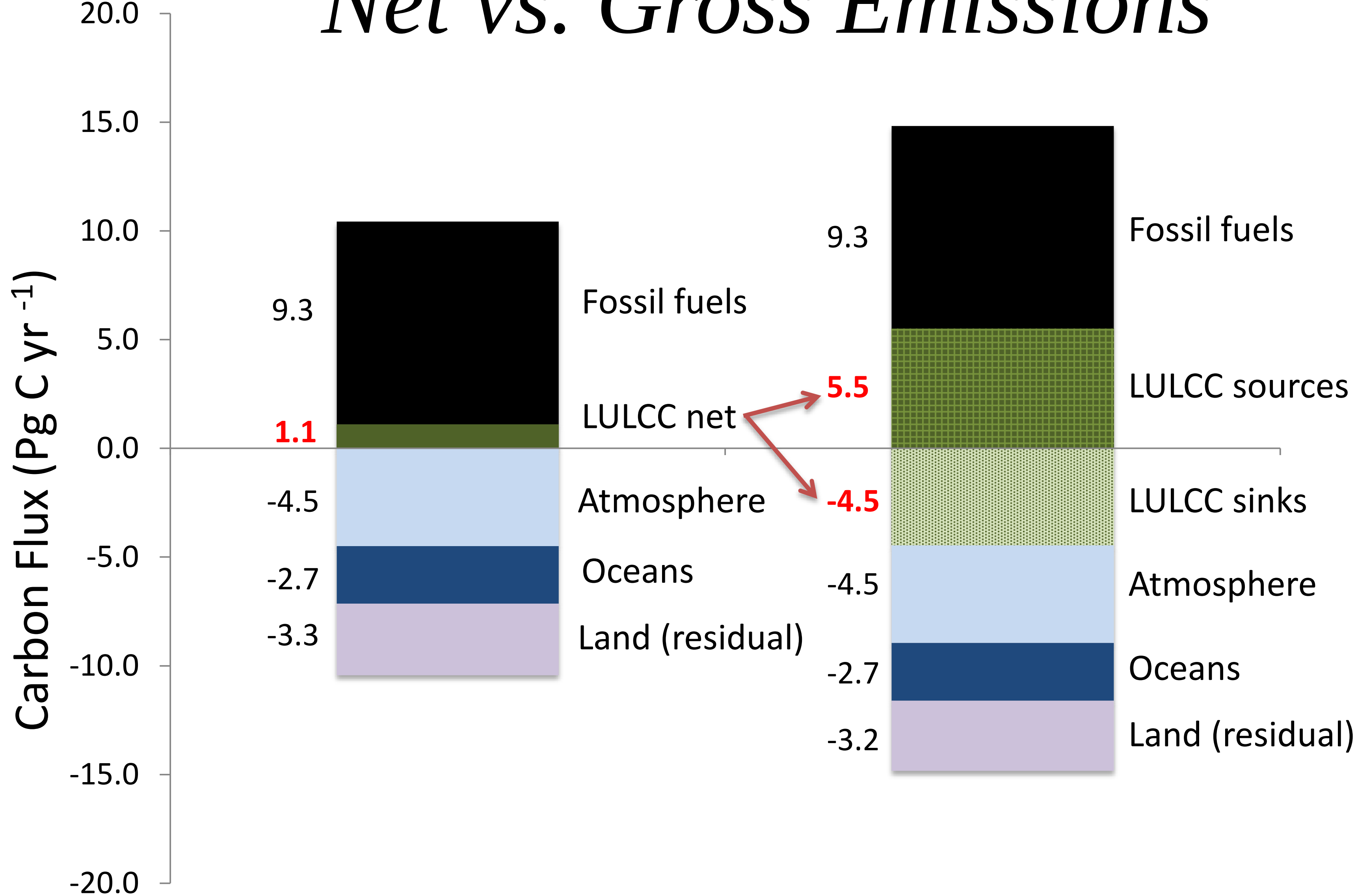


Gross emissions
Net emissions
Gross sinks
Carbon Flux (PgC yr^{-1})
4
2
0
-2
1950
2000
2050
2100
Year

Negative emissions from LULCC

- The good news:
  - Gross emissions are better indicators of management potential than net emissions.
  - LULCC is not 10% of total emissions, but 37%.

Net vs. Gross Emissions



Negative emissions from LULCC

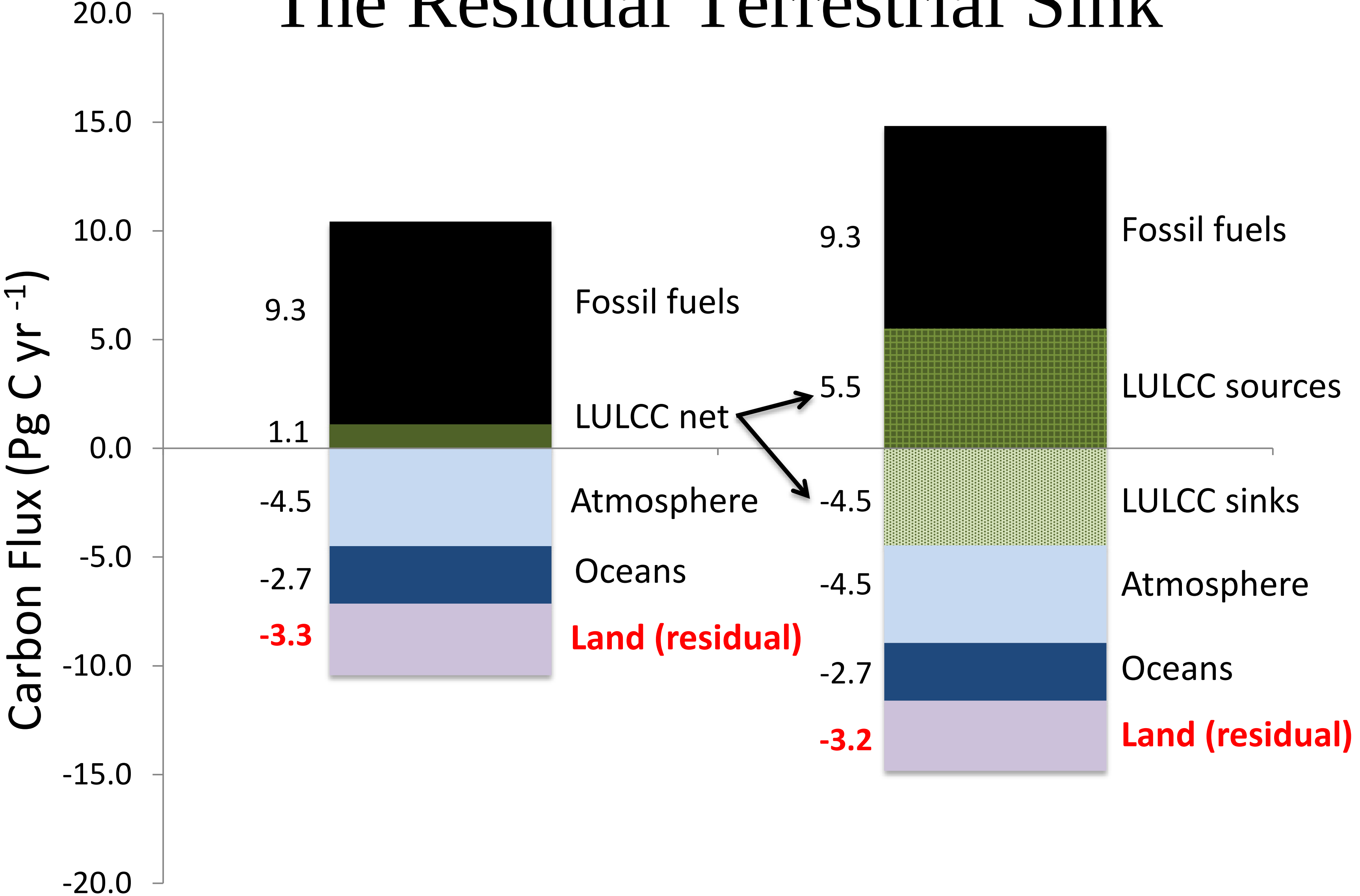
- The good news:
  - Gross emissions are better indicators of management potential than net emissions.
  - LULCC is not 10% of total emissions, but 37%.

- The bad news:
  - Emissions from existing wood products, slash, and soils will continue even if deforestation stops.
  - Not 374 PgC by 2100, but 120 PgC (32%)

Residual Terrestrial Sink

- In addition to the emissions from LULCC, there is a net accumulation of carbon on land (the residual terrestrial carbon sink)

The Residual Terrestrial Sink



Residual Terrestrial Sink

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- Total land sink could be 120 + 272 = 392 PgC.

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- 272 PgC by 2100 if the rate doesn't change.
- Total land sink could be 120 + 272 = 392 PgC.
- But this residual sink is already counted in the allowable emissions.

So…

- Much of ***the residual terrestrial sink*** is in forests
- Losing forests will likely lower that sink.
  - Thus stopping deforestation is good for reducing emissions and maintaining sinks.

Conclusions (Part 2)

How large are current negative emissions from LULCC?

- Potentially, 100-120 PgC between 2016 and 2100

Small relative to fossil fuel reserves

Large relative to ***allowable*** carbon emissions (161-338 PgC after 2015)

Conclusions (Part 2)

- G**ross negative emissions** in managed and unmanaged ecosystems: 4.4 and 3.2 PgC/yr
  - (58% in managed forests)
- **Net negative emissions** between now and 2100: 120 and 272 PgC
  - (31% in managed forests)

Part 3

New approach and data for estimating the terrestrial carbon budget

A. Baccini and W. Walker et al., (in review)

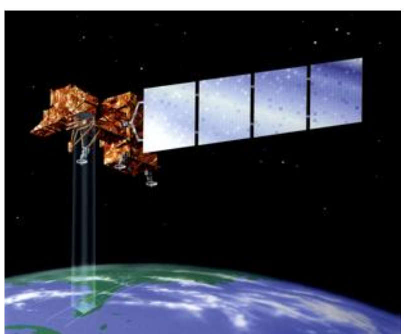
Mapping changes in aboveground carbon storage

General Approach: Input Data

Woods Hole Research Center
Ranked #1 climate think tank in the world.

- Ground-based measurements of biomass density from across the tropics (283 plots)

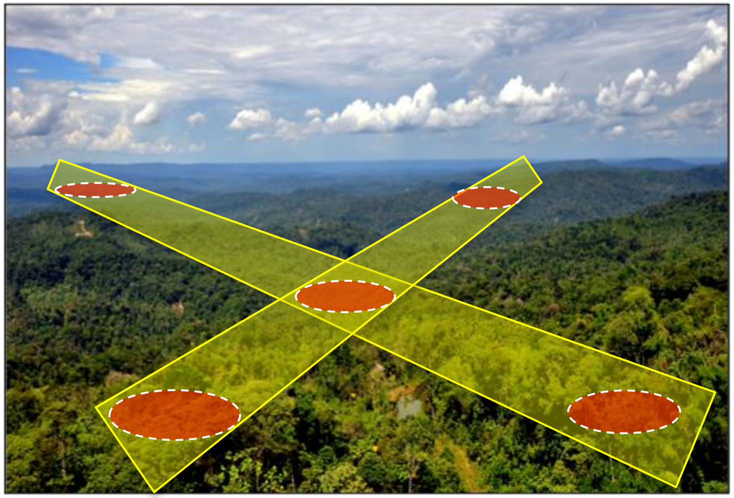
- Spaceborne LiDAR observations



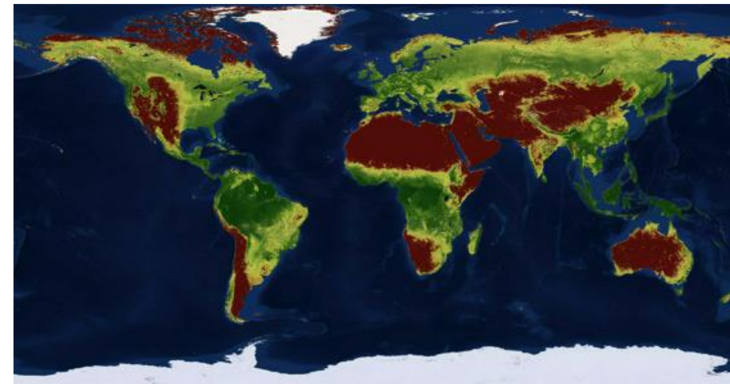
- Satellite derived image data
  - (500 m or 30 m)

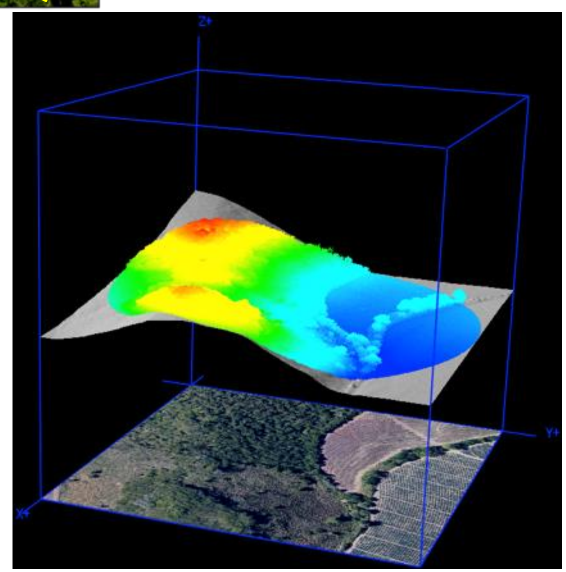
General Approach: Data Integration

WOODS HOLE RESEARCH CENTER
Ranked #1 climate think tank in the world.

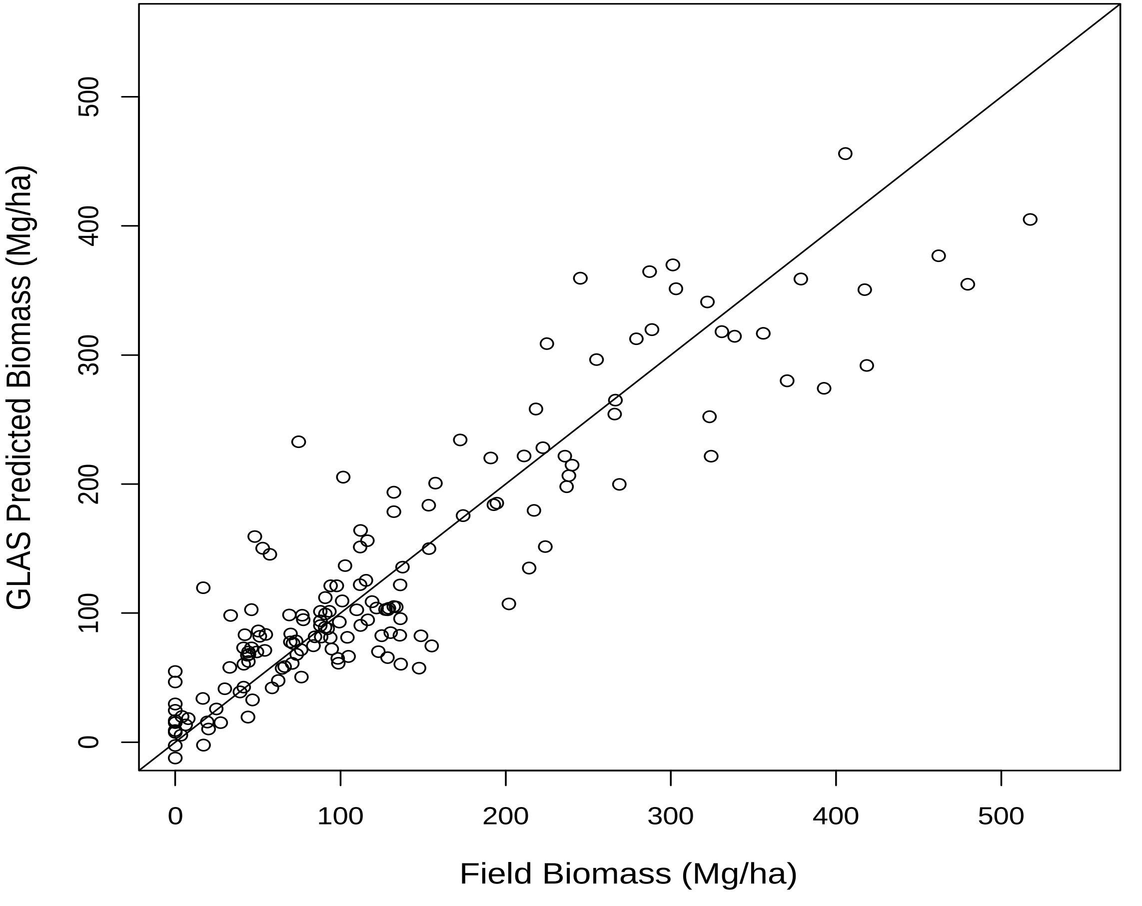


The Map



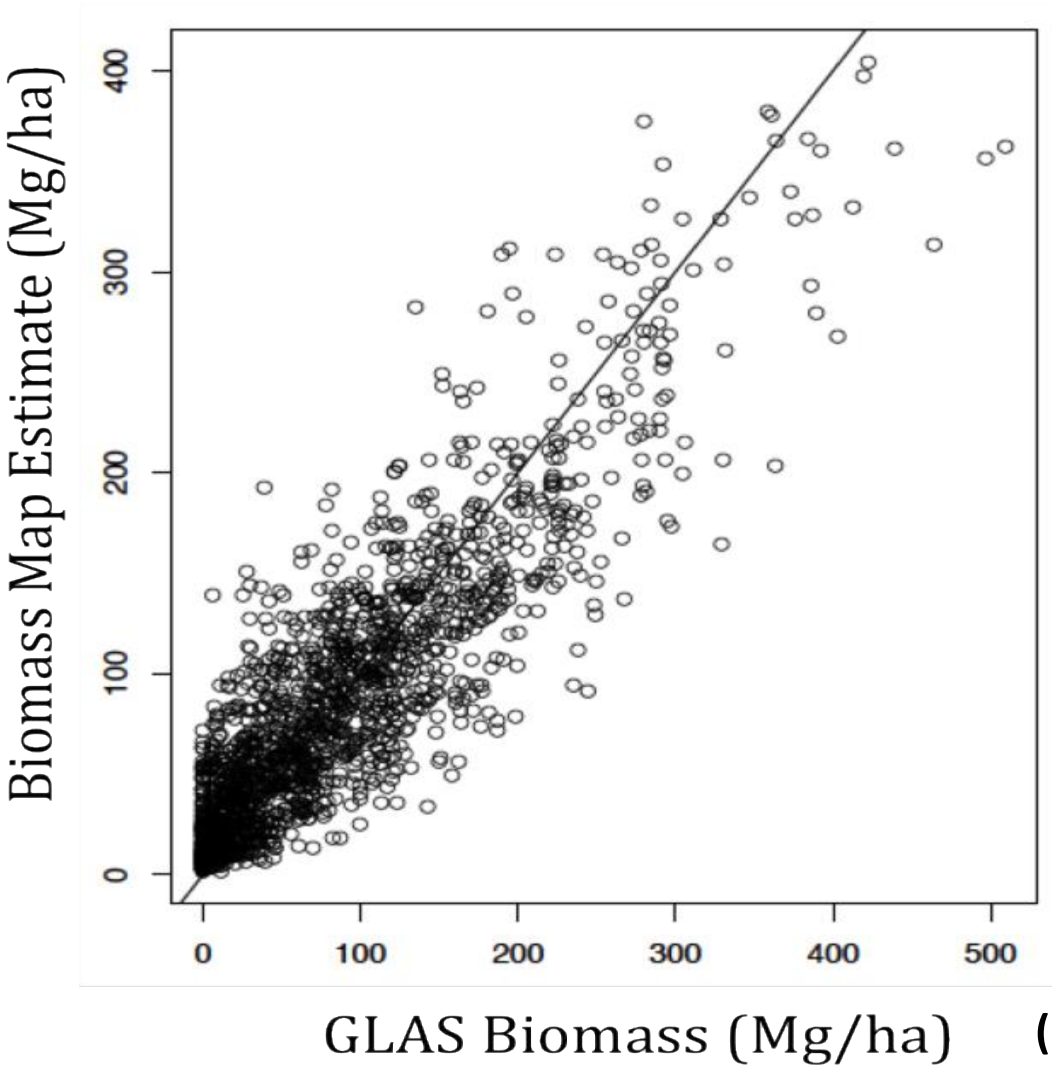


Field to LiDAR



GLAS predicted biomass versus field derived biomass .

LiDAR to MODIS



(LiDAR)

SRTM
NDII2
Evi2
LST var
LST
B7 var
B7
B6
B5
B4
B2
B1

Not 283 points, but 40,000

Mapping biomass change in the tropics

2003-2014

Percent of MODIS pixels (500 m) showing…

… No significant change	79%
… Loss of biomass	15%
… Gain in biomass	6%
	100%

Baccini et al., in press

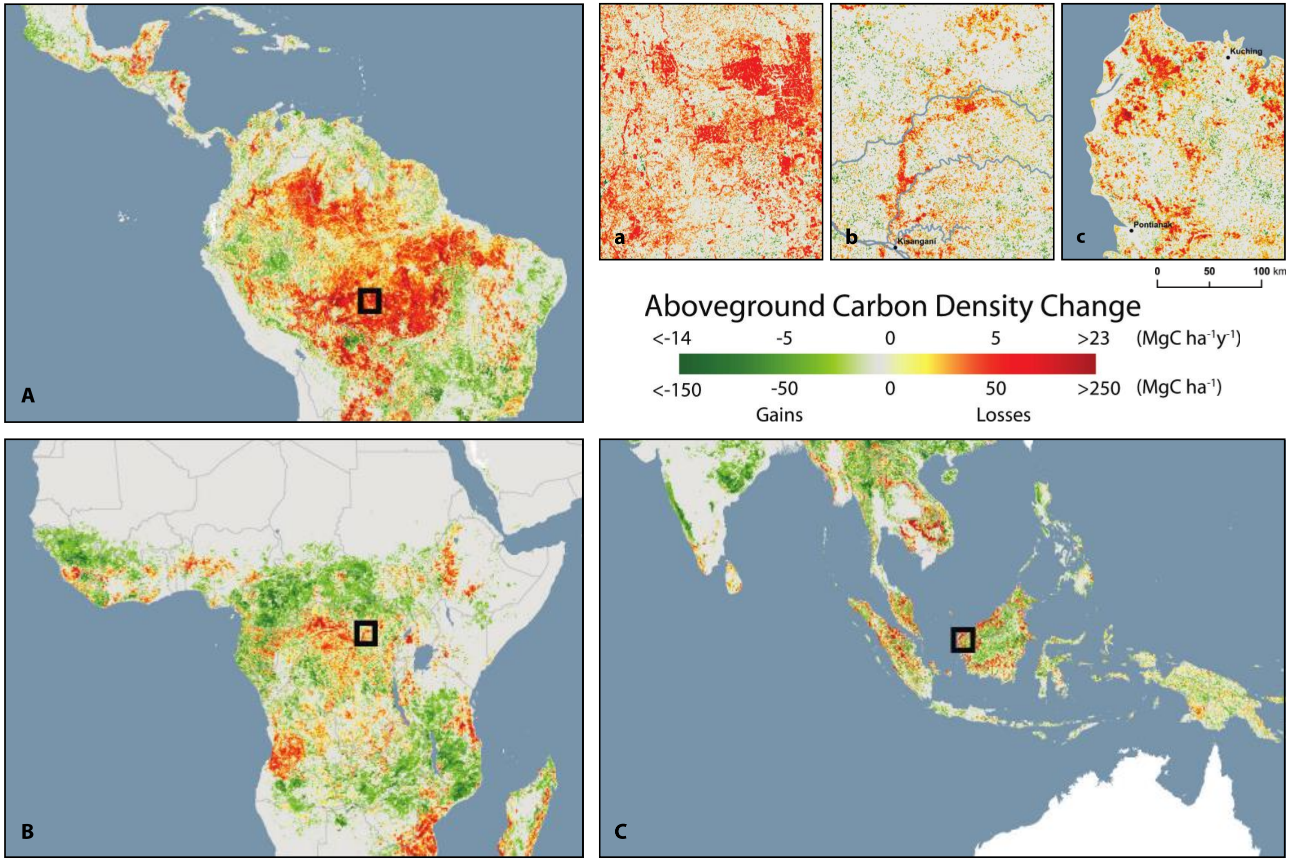


Figure 1: Geography of carbon density change. The figure depicts the spatial distribution of areas exhibiting gains, losses, and no change (stable). Values reported are the change from 2003 to 2014 within each 463 x 463 m grid cell. Changes with a p-value larger than 0.05 are identified as stable. Data in panels A-C have been aggregated to 5 km for display. Insets a-c are shown at full resolution and correspond to the black rectangles in A-C, respectively.

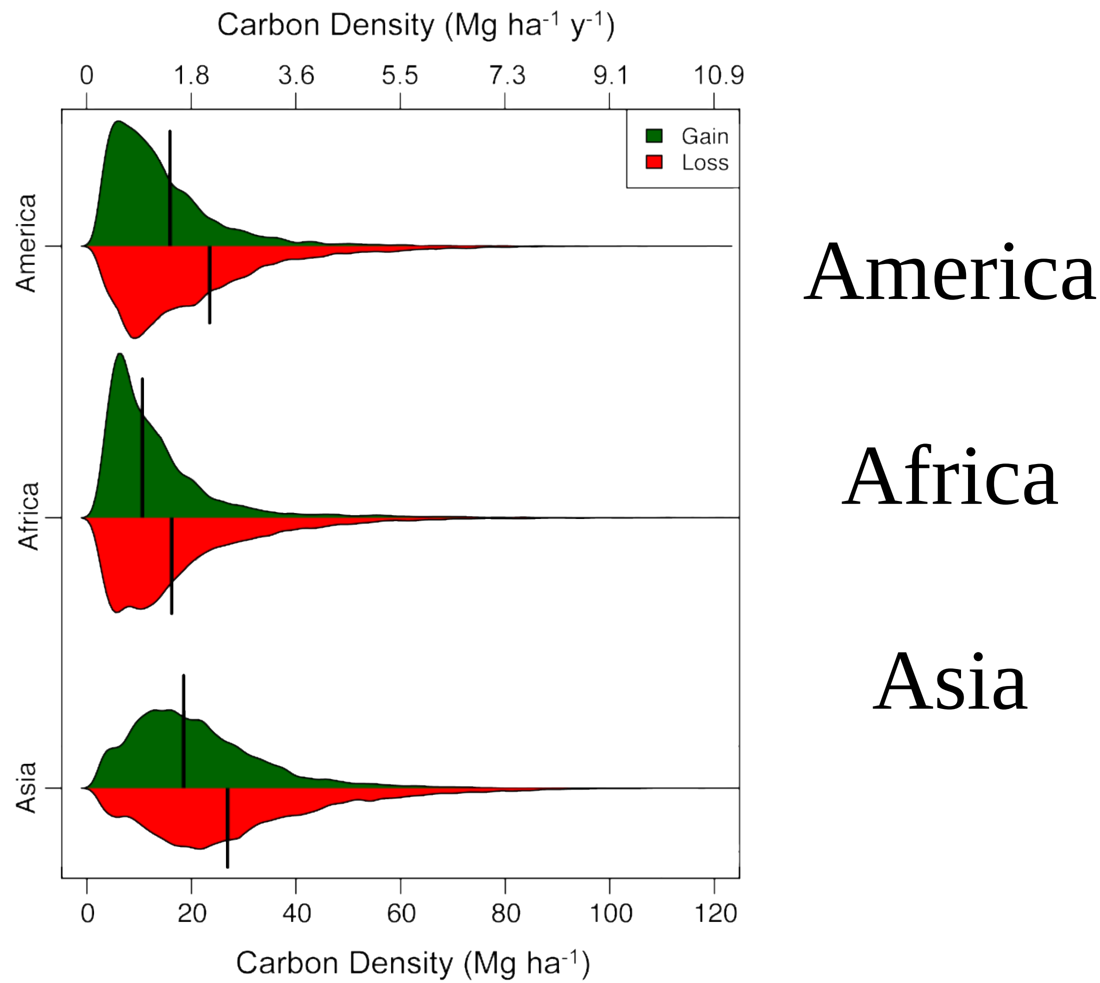


Figure 2: Frequency distributions based on pixel counts of net carbon density gains and losses from 2003 to 2014 for tropical America, Africa, and Asia. Mean values of gain/loss are indicated with vertical black bars.

Change in aboveground biomass

($TgC\ y^{-1}$)

(2003-2014)

	Loss	Gain	Net
America	516 (70)	191 (18)	325 (74)
Africa	205 (25)	133 (19)	72 (33)
Asia	141 (18)	112 (10)	28 (22)
Total	**862 (80)**	**436 (31)**	**425 (92)**

A new approach using satellite data

Previously…

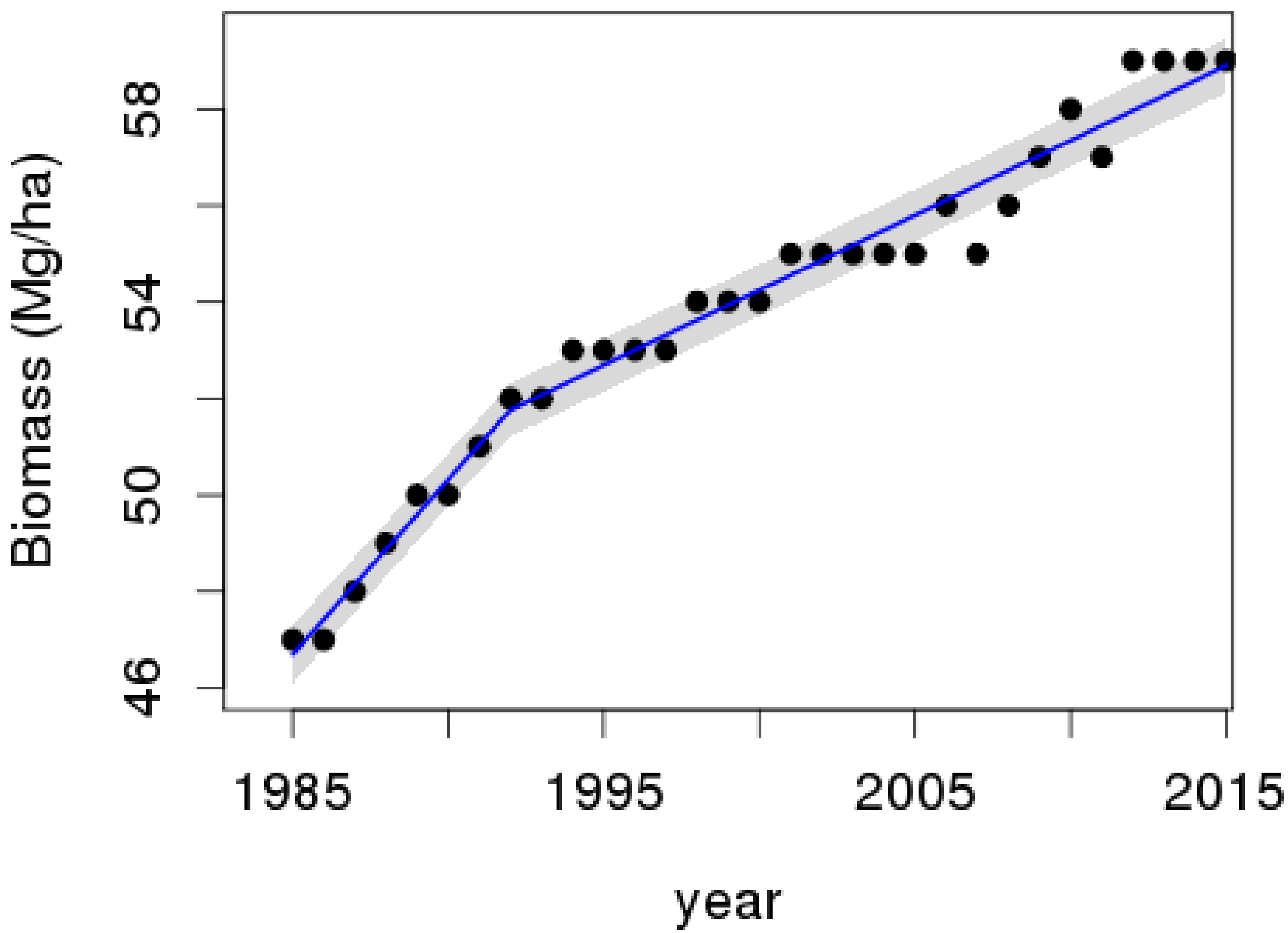
1. Loss in forest area x average biomass
2. Loss in forest area x spatially explicit biomass

This work…

3. Spatially explicit *change* in aboveground woody biomass
   - Carbon lost through deforestation
   - Carbon lost through forest degradation
   - Carbon gained through forest growth

A preview:

Landsat Pixel 8771878 (30 m x 30 m)



Conclusions

Carbon budget for the tropics (2006-2015):

LULCC: +1.4 PgC/yr source (Houghton & Nassikas 2017)

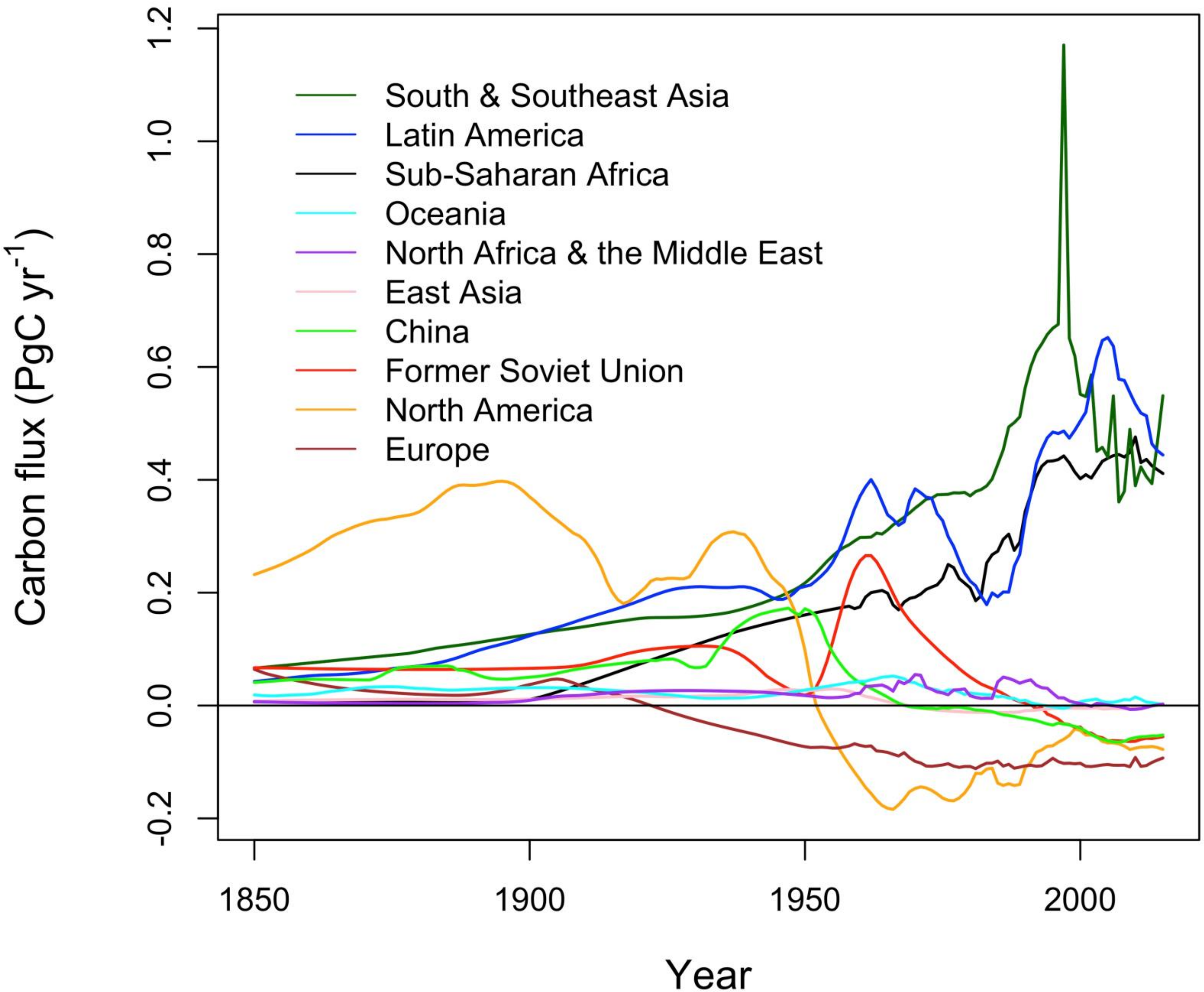
Net: +0.4 PgC/yr source* (Baccini et al., in review)

Residual: -1.0 PgC/yr sink

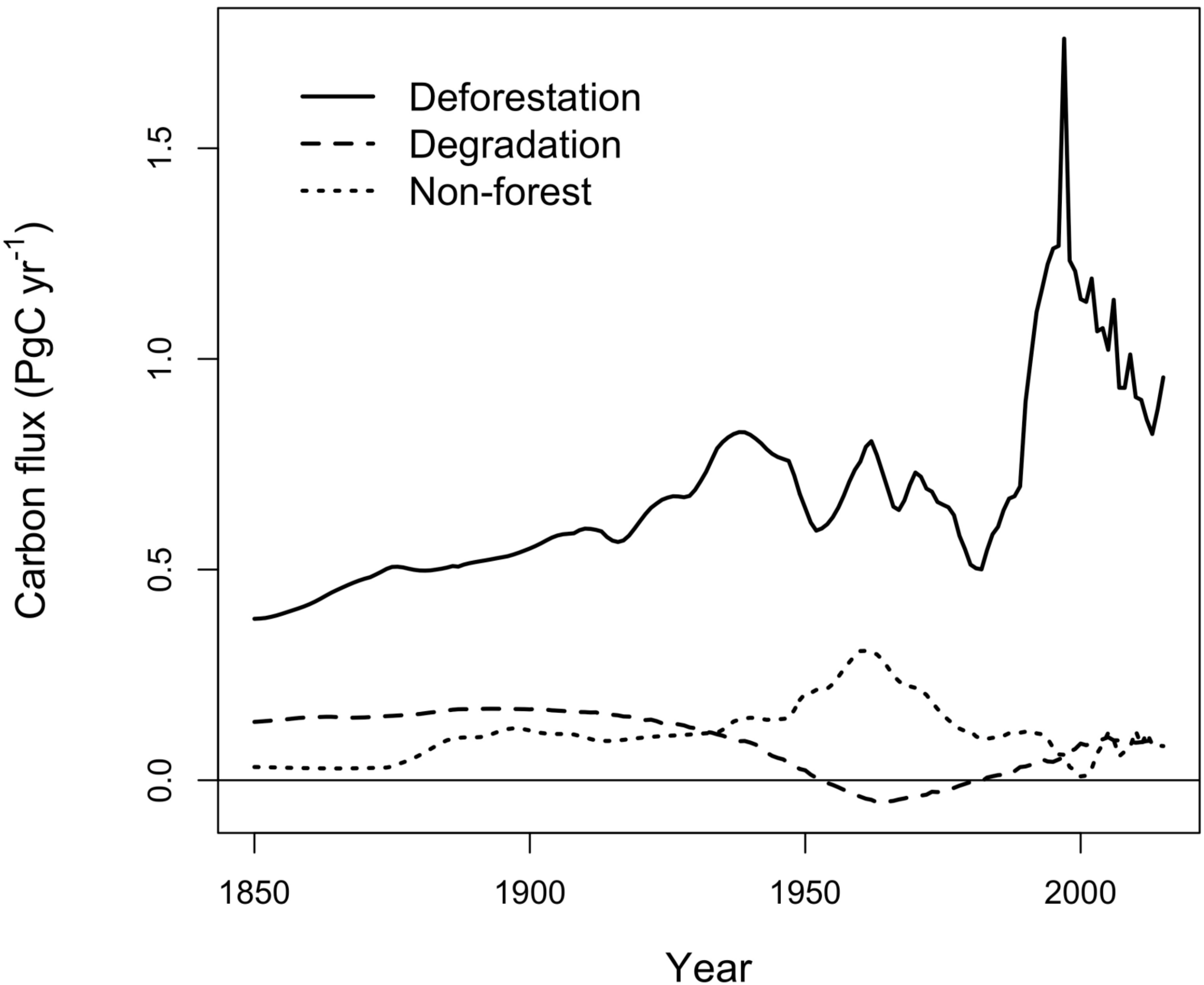
(about 1/3 of the residual terrestrial sink)

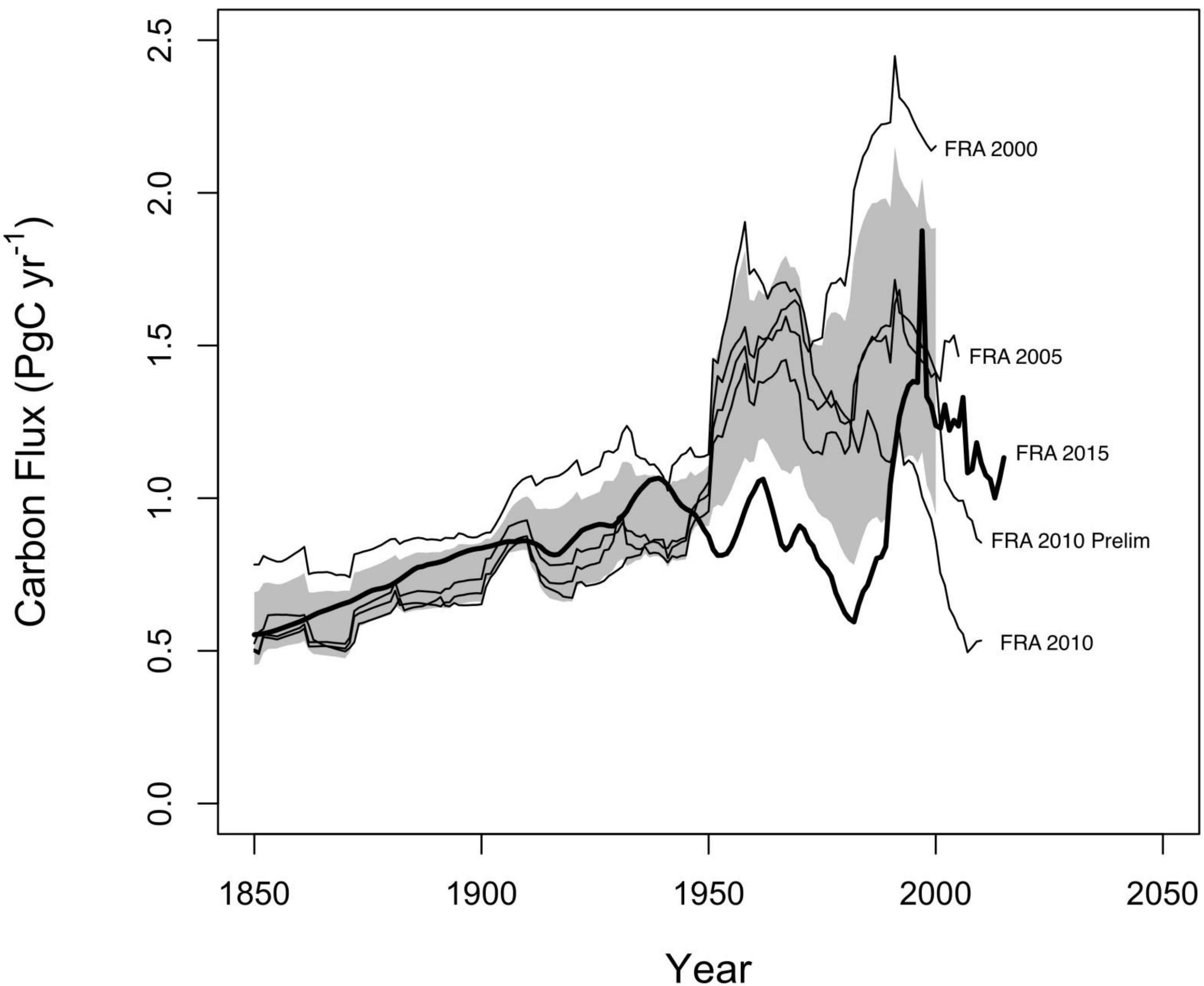
*Not counting soils, wood products, slash, etc.

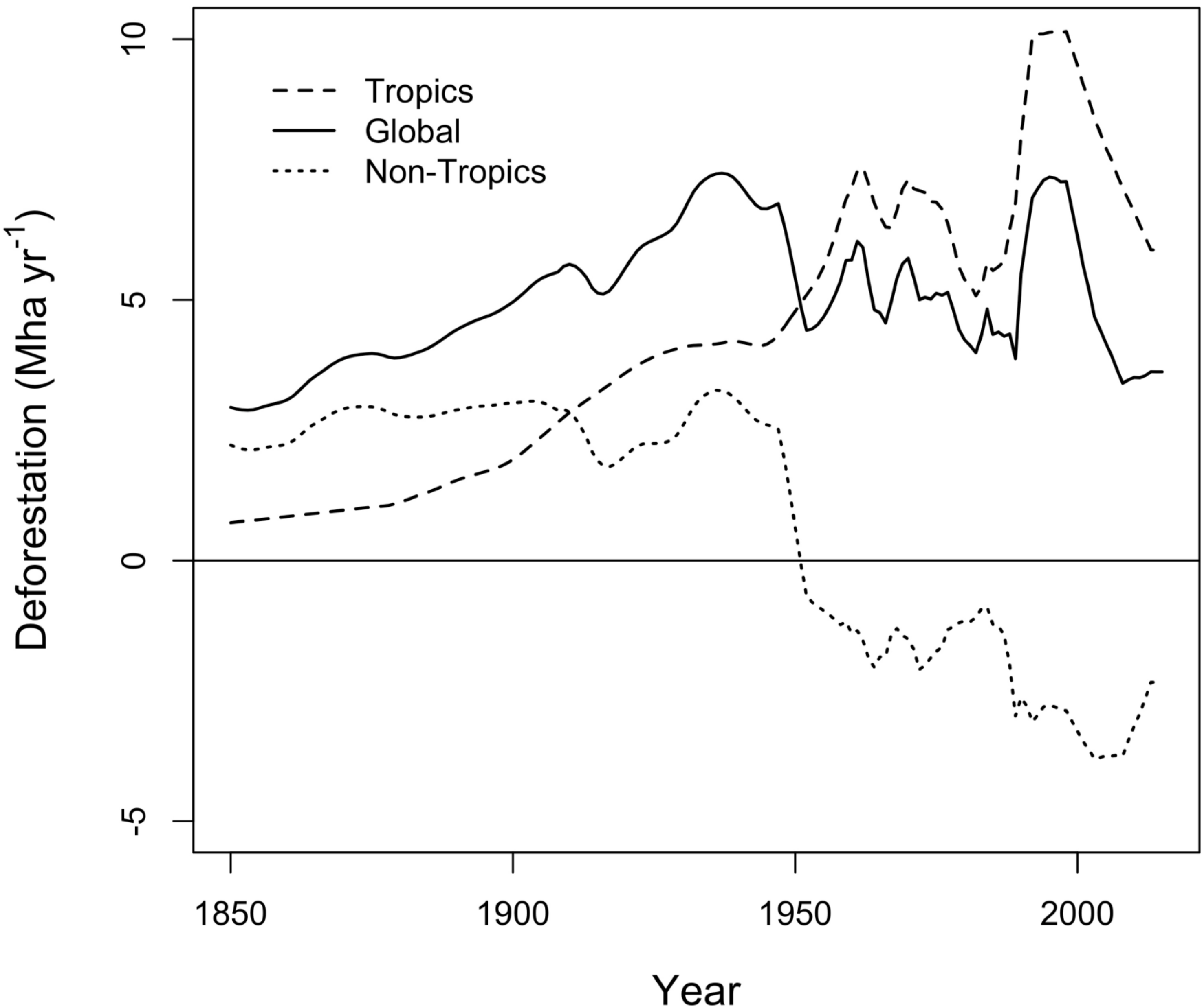
Thank you.



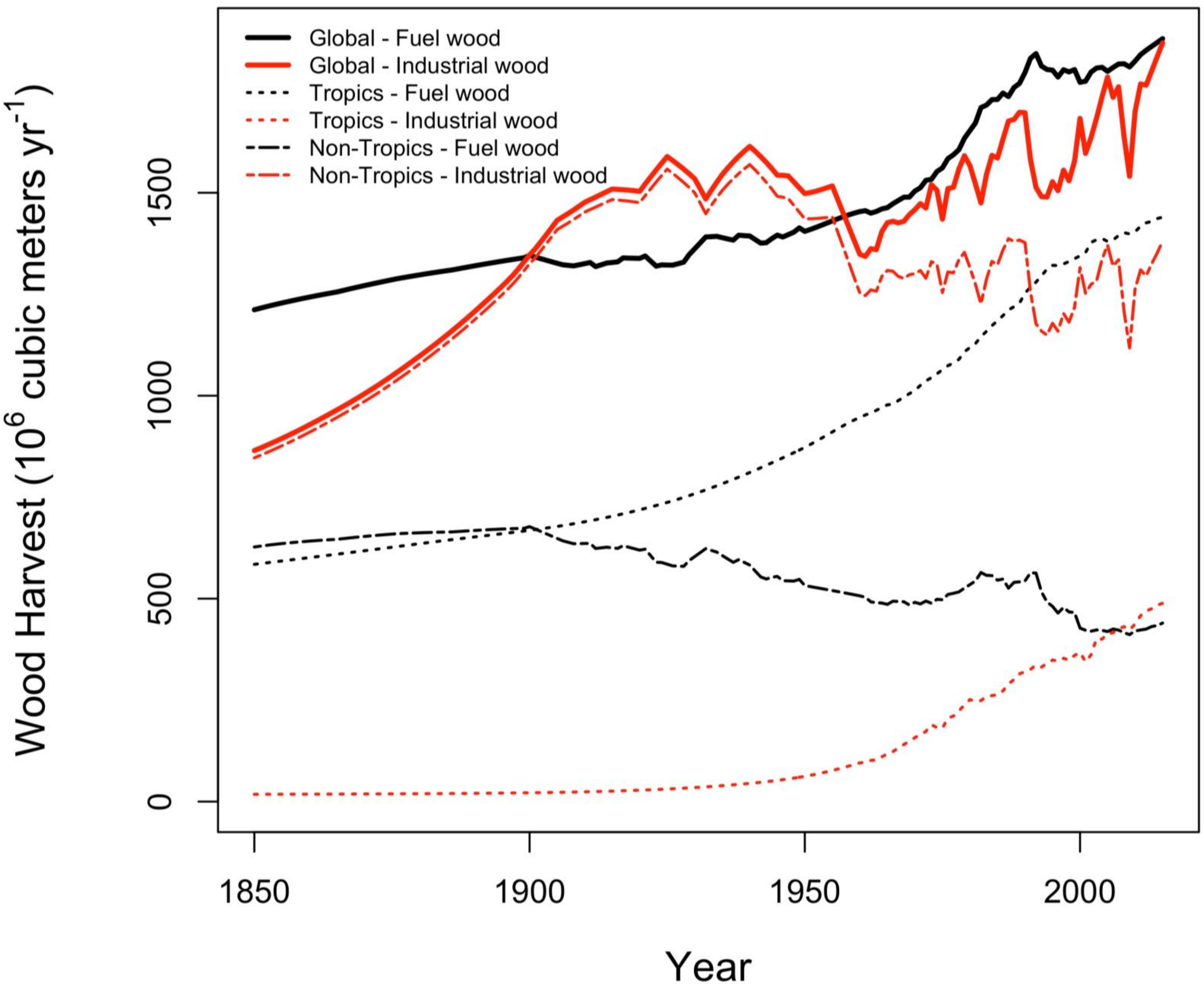
South & Southeast Asia
Latin America
Sub-Saharan Africa
Oceania
North Africa & the Middle East
East Asia
China
Former Soviet Union
North America
Europe
Carbon flux (PgC yr-1)
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1850
1900
1950
2000
Year


Deforestation
Degradation
Non-forest
Carbon flux (PgC yr-1)
0.0
0.5
1.0
1.5
1850
1900
1950
2000
Year

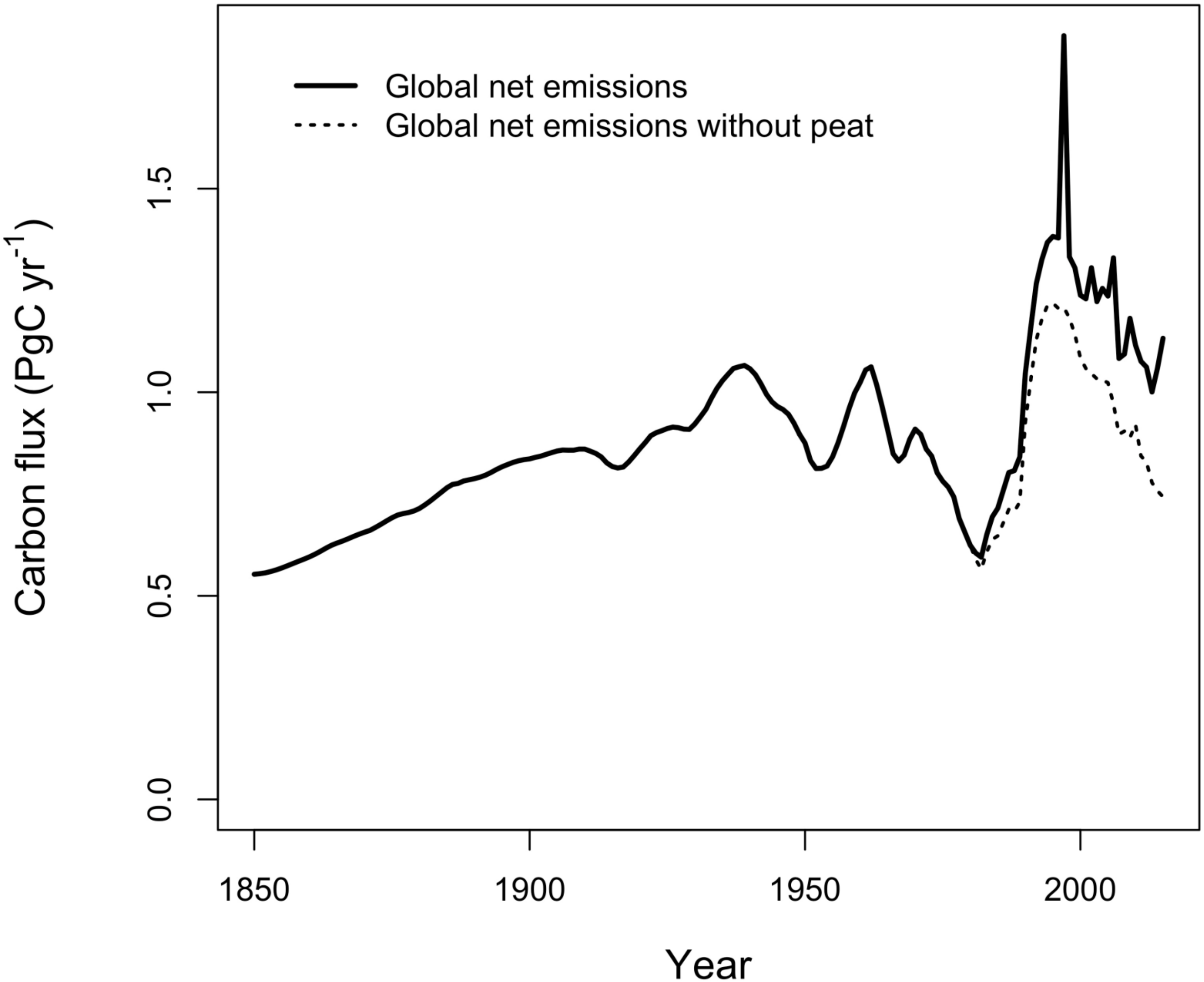

Carbon Flux (PgC yr-1)
2.5
2.0
1.5
1.0
0.5
0.0
FRA 2000
FRA 2005
FRA 2015
FRA 2010 Prelim
FRA 2010
1850
1900
1950
2000
2050
Year



Tropics
Global
Non-Tropics
Deforestation (Mha yr^{-1})
10
5
0
-5
1850
1900
1950
2000
Year



Global - Fuel wood
Global - Industrial wood
Tropics - Fuel wood
Tropics - Industrial wood
Non-Tropics - Fuel wood
Non-Tropics - Industrial wood
Wood Harvest (10^6 cubic meters yr^-1)
0
500
1000
1500
1850
1900
1950
2000
Year

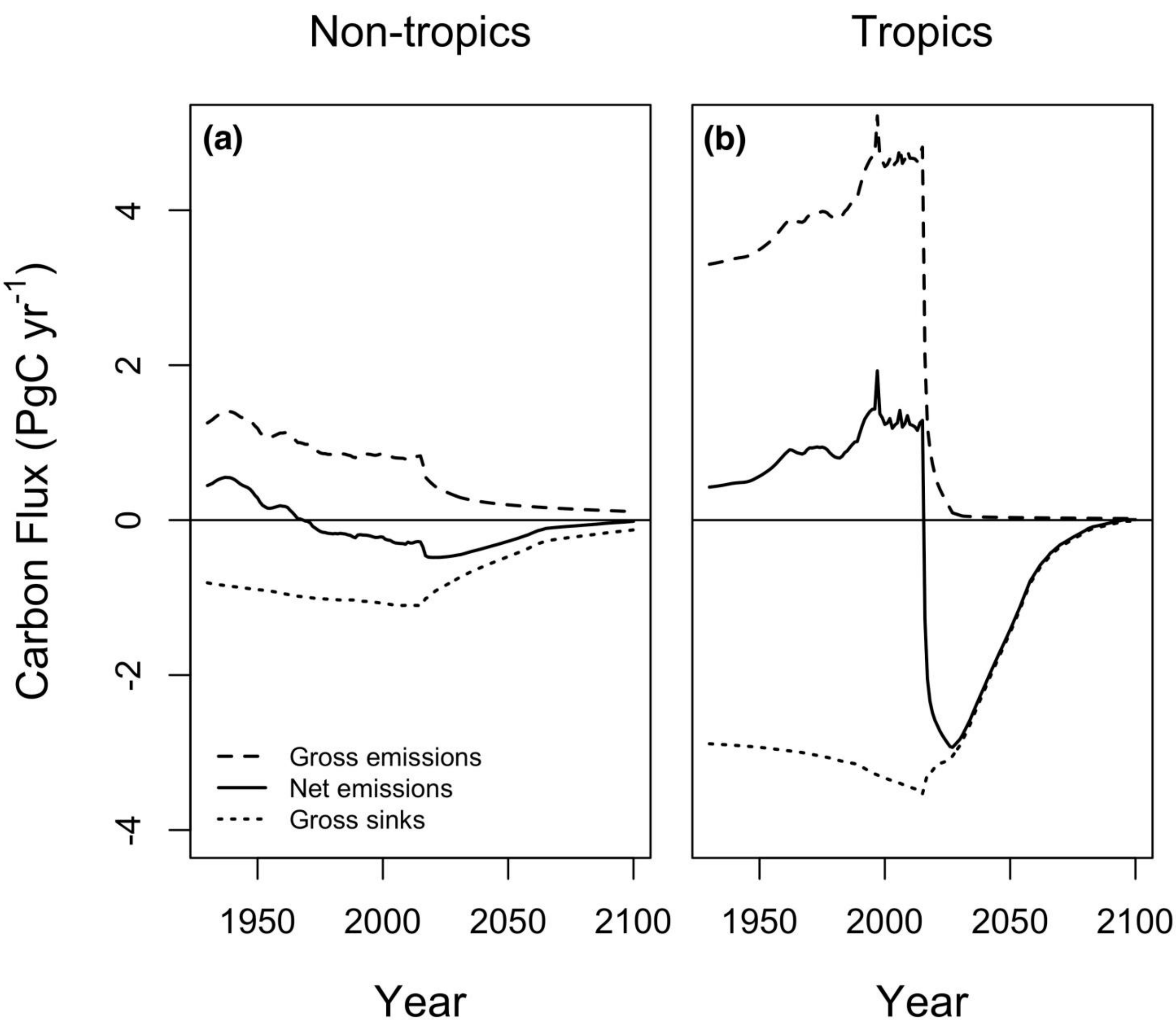


Global net emissions
Global net emissions without peat
Carbon flux (PgC yr^{-1})
0.0
0.5
1.0
1.5
1850
1900
1950
2000
Year

Future emissions from LULCC

Total amount of carbon (PgC) removed from the atmosphere between 2016 and 2100 according to different simulations

Simulation	Tropical forests	Temperate zone & boreal forests
#1 Business-as-usual (includes shifting cultivation in the tropics)	56	-10
#2A Stop all LULCC after 2015 (Conservative)	-15	-19
#2B Stop all LULCC after 2015 (Generous)	-98	-
#3 Stop deforestation only	-2	-8
#4 Enhance wood products	-8	-28



Non-tropics
Tropics
(a)
(b)
Carbon Flux (PgC yr-1)
4
2
0
-2
-4
1950
2000
2050
2100
Year
Gross emissions
Net emissions
Gross sinks

One last question:

How much of the residual terrestrial sink is in managed lands, and how much of it is in unmanaged lands?

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We don’t know.

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…because we don't know where the residual sink is. It's not necessarily in unmanaged/intact forests.

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We don't know…

…because we don't know where the residual sink is. It's not necessarily in unmanaged/intact forests.

Nevertheless, there's evidence that most of the residual sink is **in forests**.

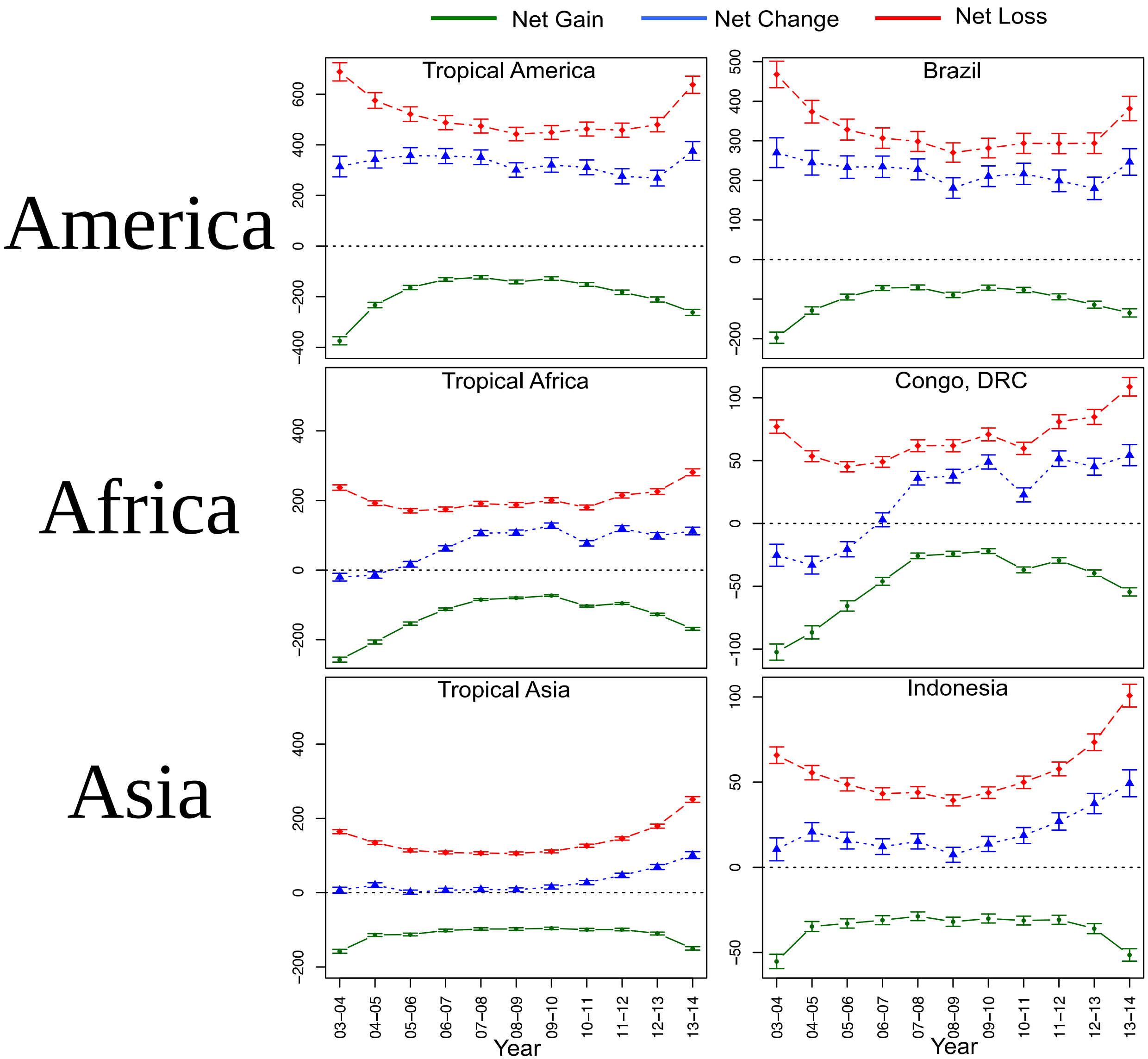

Figure 3: Annual net change (95% CI) in total carbon. Red lines indicate a loss in carbon density, green lines indicates a gain in carbon density, and blue lines reflect the difference between loss and gain. The standard error of the change value is indicated by the vertical bars.