Beyond REDD+

What management of land can and cannot do to help control atmospheric $CO_2$

R.A. Houghton
Woods Hole Research Center
Outline

- Introduction: Climate Change
- The Global Carbon Cycle
- What can we do?
Global Warming is a **not** a scientific controversy!

- There is a natural greenhouse effect; we know the gases responsible.
- The concentrations of these gases are increasing.
- Mean global temperature is increasing.
Recent weather disasters

In the 1990s
• 200 natural weather-related disasters per year

In the last decade
• 350 natural weather-related disasters per year
And all of these disasters happened with an average global warming of less than 1°C.
Recent AAAS report on climate

Climate scientists agree: climate change is happening here and now.
Recent AAAS report on climate

- Climate scientists agree: climate change is happening here and now.
- We are at risk of pushing our climate system toward abrupt, unpredictable, and potentially irreversible changes with highly damaging impacts.
Recent AAAS report on climate

- Climate scientists agree: climate change is happening here and now.
- We are at risk of pushing our climate system toward abrupt, unpredictable, and potentially irreversible changes with highly damaging impacts.
- The sooner we act, the lower the risk and cost. And there is much we can do.
Outline

- Introduction: Climate Change
- The Global Carbon Cycle
- What can we do?
What is the **global carbon cycle**?

The exchanges of carbon within and among four reservoirs:

- Atmosphere
- Oceans
- Land (terrestrial ecosystems)
- Fossil fuels
Perturbation of Global Carbon Budget (1850-2006)

Le Quéré, unpublished; Canadell et al. 2007, PNAS
Perturbation of Global Carbon Budget (1850-2006)

CO\textsubscript{2} flux (Pg C y\textsuperscript{-1})

Time (y)

Le Quéré, unpublished; Canadell et al. 2007, PNAS
Perturbation of Global Carbon Budget (1850-2006)

CO$_2$ flux (Pg C y$^{-1}$)

Sink

Source

fossil fuel emissions
deforestation

“SINKS”

Time (y)

1850 1900 1950 2000

2000-2006 7.6 1.5

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CO₂ flux (PgC y⁻¹)

Sink

Source

fossil fuel emissions
deforestation
atmospheric CO₂
ocean

Time (y)

1850
1900
1950
2000
2000-2006
7.6
1.5
4.1
2.2

Le Quéré, unpublished; Canadell et al. 2007, PNAS
Perturbation of Global Carbon Budget (1850-2006)

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atmospheric CO$_2$

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Two terrestrial processes
Carbon sources and sinks on land result from two processes

1. Direct human effects (management)
   - Croplands, pasturelands
   - Forestry
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2. Indirect and natural effects
   - Environmentally induced changes in metabolism (e.g., CO2, N deposition, changes in climate)
Perturbation of Global Carbon Budget (1850-2006)

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Le Quéré, unpublished; Canadell et al. 2007, PNAS
Changes in Land Use (management)
Changes in carbon from management

A bookkeeping model
10% - 15% of the problem.
This terrestrial source from management (or land-use change) is a net source, composed of both sources and sinks, for example, logging and forest regrowth.
Carbon sources and sinks on land result from two processes

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Le Quéré, unpublished; Canadell et al. 2007, PNAS
Over the last 5 decades the land and ocean sinks have increased in proportion to emissions.

It’s remarkable.

Nature’s been on our side.
Today the terrestrial sink (nature) is 3 times larger than the terrestrial source (management).

2.8 PgC/yr versus 0.9 PgC/yr
And this natural terrestrial sink is composed of both sources and sinks.
What’s causing the natural sink?

Hypotheses:
• CO₂ fertilization
• Nitrogen deposition
• Changes in climate
Will the carbon sinks on land and in the ocean continue?

Will they keep up with emissions?
Tipping Points in the Carbon-Climate System?

If the natural sinks on land and ocean are beginning to **decline**:

1. more of the carbon emitted stays in the atmosphere,
Tipping Points in the Carbon-Climate System?

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3. it is more difficult to manage the carbon cycle,
**Tipping Points in the Carbon-Climate System?**

If the natural sinks on land and ocean are beginning to **decline**:

1. more of the carbon emitted stays in the atmosphere,
2. the rate of climatic disruption increases,
3. it is more difficult to manage the carbon cycle,
4. the carbon cycle is not behaving as the projections assumed.
Tipping Points in the Carbon-Climate System?

Perhaps the only way to avoid declining natural sinks is to limit the rate and extent of global warming.
Outline

- Climate Change
- The Global Carbon Cycle
- What can we do?
To stop the warming, we need to stabilize the CO$_2$ concentration in the atmosphere...
...and there are two ways to do that:

- Reduce emissions
- Increase uptake by land, oceans
First, management...

1. Direct human effects (management)
   - Deforestation
   - Croplands, pasturelands
   - Forestry: harvests and use of products
Can we reduce emissions?

![Graph showing emissions over time]

- Land-use change
- Fossil fuels
We could stabilize the concentration of $\text{CO}_2$ in the atmosphere quickly by:

- reducing emissions by 4 PgC/yr (about 50%)
### Global Carbon Budget 2000-2010

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We could stabilize the concentration of $CO_2$ in the atmosphere quickly by:

• reducing emissions by 4 PgC/yr (about 50%)

And we could do that by:

• managing forests
Three land management mechanisms for the near term

- Stop deforestation (1 PgC/yr)
- Allow existing forests to grow (1-3 PgC/yr)
- Expand the area of forests (1 PgC/yr)

Total CO$_2$ reduction: 3-5 BMT C yr$^{-1}$
## Global Carbon Budget 2000-2010

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Managing land will not be simple

- Forests don’t accumulate carbon indefinitely
- Fossil fuel emissions must decline
- Natural land and ocean sinks must continue
- Carbon in forests is vulnerable
- Suitable land areas must be identified
- Much will depend on the price of carbon
- There will be intense competition for land
- Rights and equity must be protected
Second, natural processes...

1. Direct human effects (management)
   - Croplands, pasturelands
   - Forestry

2. **Indirect and natural effects**
   - Environmentally induced changes in metabolism (e.g., CO2, N deposition, changes in climate)
Review

Direct human effects
(management)
versus
Natural effects
Review

Direct human effects (management) and natural effects

Today
0.9 PgC/yr source

Tomorrow’s Potential
2-4 PgC/yr sink
Review

Direct human effects (management) and Natural effects

Today

0.9 PgC/yr source and 2.8 PgC/yr sink

Tomorrow’s Potential

2-4 PgC/yr sink and ???
Review - climate governance

Direct human effects (management) versus Natural effects

How do we account for these sources and sinks? (debits and credits)
Climate governance

Direct human effects (management)
- REDD+
- Kyoto Protocol

Natural effects
- No credits or debits
Climate governance

Direct human effects (management)
- REDD+
- Kyoto Protocol

Natural effects
- No credits or debits

Private, National
Public, Common property, Global
Climate governance

We need a global agreement for dealing with the common property of natural sources and sinks of carbon.

For example, reducing sources even more in response to large atmospheric CO$_2$ increases; and allowing greater sources in response to small atmospheric CO$_2$ increases (i.e., more management).
In conclusion...
Conclusions

Highest priority is reducing fossil fuel use.

…but that’s only part of the solution.
Conclusions

Highest priority is reducing fossil fuel use.

…and it will take some decades.

In the meantime…

Forest and land management could reduce emissions of carbon by 3-5 PgC/yr, and stabilize the CO₂ concentration.
Conclusions

Highest priority is reducing fossil fuel use.

Forest and land management could change from 10-15% of the problem to 50% of the solution.
Conclusions (continued)

Highest priority is reducing fossil fuel use.

The urgency:

Global warming could increase sources of carbon (the natural terrestrial sink could disappear)... and make carbon management insignificant.
The urgency:

Global warming could increase sources of carbon (the natural terrestrial sink could disappear)… and make carbon management insignificant… with harsh consequences:

- extreme weather: floods, droughts, fires
- crop failures
- sea level rise
- forest die-off

Highest priority is reducing fossil fuel use.
To stop further climatic disruption...

...we must stabilize the concentrations of greenhouse gases in the atmosphere (\(CO_2\) especially).

But when?
At what concentration?
How much warming is safe?

A 2°C warming has been set as a limit or goal.

-- the cut-off between safe and dangerous.

-- a compromise between what’s needed (science) and what was seen as possible (politics). But it may be too much.
The average global warming so far has been \(~ 0.75^\circ C\).

We are committed to a warming of almost another \(0.75^\circ C\) \textit{if all emissions stopped now.} (That’s almost \(1.5^\circ C\))
2°C ??

A closing window

- Area of unachievability

Climate target (°C)

Starting year of emissions reduction

T F Stocker Science 2013;339:280-282
A closing window

![Graph showing climate target vs. starting year of emissions reduction]

- Climate target (°C)
- Starting year of emissions reduction

Area of unachievability

2°C ??
$2^\circ C$ ?

A closing window

[Graph showing climate target (°C) vs. starting year of emissions reduction with an area of unachievability highlighted.]
A closing window

![Graph showing climate targets vs. starting year of emissions reduction. The graph indicates an area of unachievability beyond a certain temperature and emissions reduction timelines.](image)
$2^\circ C$ ??

A closing window

![Graph showing climate targets and emissions reduction years with area of unachievability highlighted.](image-url)

T F Stocker Science 2013;339:280-282
Therefore ...

...if we want to limit the warming to 2°C, we have about 25 years to do it ...

...if we start now.
We are almost certainly going to exceed a warming of 2°C, safe or not.

We’ll have to take carbon out of the atmosphere.

And we can do that at the same time we restore the biosphere.
Must stabilize concentration

**Sources**
- Fossil fuels: $7.9 \pm 0.5$ (PGC/yr)
- Land-use change: $1.0 \pm 0.7$ (PGC/yr)

**Sinks**
- Atmosphere: $4.1 \pm 0.2$ (PGC/yr)  
- Oceans: $2.4 \pm 0.5$ (PGC/yr)
- Residual terrestrial: $2.4 \pm 1.0$ (PGC/yr)

2000-2010 with management:
- Fossil fuels: 7.9
- Land-use change: -2 to -4
- Atmosphere: 4 to 6
**Must reduce emissions...**

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...and start taking CO$_2$ out of the atmosphere

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Thank you
Using land to transition from fossil to renewable fuels

R.A. Houghton
Woods Hole Research Center
Gross sources are \(~3x\) greater than net sources.