Carbon Loss in Mineral Soil Horizons: The Effects of 120 Years of Forest Harvesting in New England

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1) Introduction
   i) New England forests
   ii) The soil carbon budget
   iii) How forest harvesting disrupts the soil carbon budget

2) Objectives

3) Study Site

4) Methods

5) Results

6) Significance
New England Forests

Should we manage New England Forests:

• As a Carbon Sink?

• As an Energy Source?
New England Forests: Carbon Storage

Introduction | Objectives | Study Sites | Methods | Results | Significance

Image from the USDA Natural Resources Conservation Service
Benefits of bioenergy:

• energy independence
• replacement of fossil fuels
• may improve local economy
• carbon neutral???

Large-Scale Bioenergy Production: Biogas Conversion at Middlebury College

http://www.middlebury.edu/sustainability/energy-climate/biomass
The Soil Carbon Budget

**Organic Horizon:** 525 Gt C

**Mineral Horizons:** 1975 Gt C

**Total Soil Carbon Pool:** 2,500 Gt C

Soil is a major global carbon reservoir

- Atmosphere: 800 Gt C
- Plant Biomass: 500 Gt C
- Organic Horizon: 525 Gt C
- Mineral Horizons: 1975 Gt C

**Introduction** | **Objectives** | **Study Sites** | **Methods** | **Results** | **Significance**
Forest harvesting disrupts the soil carbon budget

Result: increased soil respiration $\rightarrow$ increased $\text{CO}_2$ output to the atmosphere

How much?
For how long?
From where?
Forest Harvesting and the Soil Carbon Budget

**Introduction** | **Objectives** | **Study Sites** | **Methods** | **Results** | **Significance**

15 yrs | 64 yrs

**Forest Floor**

**Mineral Horizons**

How does this compare with New England?

New Hampshire

Nova Scotia (northeastern red spruce)

Diochon and Kellman (2009, Fig. 1)
1. Determine the rates of depletion and recovery of carbon over time since harvesting for New England forest soils
Objectives

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1. Compare results with other studies to determine the extent of the applicability of soil carbon loss and recovery models
Bartlett Experimental Forest, Bartlett, NH

- 1050 ha mixed northern hardwood forest
- Soils: spodosols underlain by granitic glacial till
- History: extensive harvesting 120 yrs ago for railroad, subsequent harvests for fuel and wood products
Methods

Chronosequence: reconstructing the past

• 3 quantitative soil pits per site:
  • Sample to 60 cm depth below O horizon

• Analysis:
  • Total C and N
  • δ^{13}C and δ^{15}N
Results: 1. Carbon Loss and Recovery

Total Carbon by Depth Interval
Results: 2. Evaluate the Mechanisms

Increased microbial respiration
Results: 3. Comparison to Other Studies

![Graph showing comparison of total C (Mg/ha) across different stand ages for Bartlett, NH and Nova Scotia.](graph.png)
Significance

• Mineral soil carbon depletion occurs for 70+ years after harvesting

• Trends are similar to Nova Scotia study, but indicate regional variation

• Increasing forest harvesting could increase the net CO$_2$ flux from mineral soil horizons to the atmosphere for over 100 years after harvest
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The Dartmouth College Earth Sciences Department
C/N Ratio

Depth Below Organic Horizon (cm)

C/N Ratio

- Old Growth
- 75-yr
- 50-yr
- 25-yr
- 3-yr
\[ \delta^{13}C \text{ and } \delta^{15}N: \]

\[ \delta(\%) = \left( \frac{R_{\text{sample}}}{R_{\text{standard}}} - 1 \right) \times 1000 \]

Where:

\[ R = \frac{^{13}C}{^{12}C} \text{ or } \frac{^{15}N}{^{14}N} \]
Causes of $^{13}$C variation in soils:

1. Microbial fractionation (decomposition) $\Rightarrow$ $^{13}$C enrichment
2. Variations in atmospheric $^{13}$C
3. Variations in vegetation ($C_3$ vs. $C_4$ plants)
4. Preferential preservation of biochemical constituents
5. Changes in plant water-use efficiency (long-term)
6. In-situ translocation of organic C