Radiocarbon flux into labile and stable soil organic matter pools in the Enriched Background Isotope Study

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Introduction

Carbon stabilization in soil organic matter (SOM) occurs concurrently with destabilization, and large changes in the resident carbon in SOM may appear as only small net changes in bulk carbon values. Using carbon isotopes as tracers is an effective way to reveal the subtleties of SOM carbon dynamics, especially if combined with organic matter fractionation techniques. A large release of radiocarbon-labeled CO_2 from an incinerator at Oak Ridge Reservation (Oak Ridge, Tennessee, USA) in 1999 provided the opportunity to trace the ^{14}C-label through the forest vegetation and into SOM on an unprecedented scale. Senescent leaves were collected from ^{14}C-labeled and unlabeled trees and then plots were established alternatively in labeled and unlabeled stands in a factorial design. Thus, the primary source of elevated ^{14}C could be traced from roots or litter. Soils from these plots were collected and physically separated into carbon reservoirs of differing stability. 'Free' light fractions (fLF) contain organic matter with high C turnover rates and typically found in soil macropores. Occluded light fractions (oLF) are chemically similar to the fLF, but are isolated inside soil aggregates and have correspondingly slower C turnover rates. Heavy fractions (HF) are primarily organo-mineral complexes forming the matrix of soil microaggregates, and have the slowest C turnover rates.

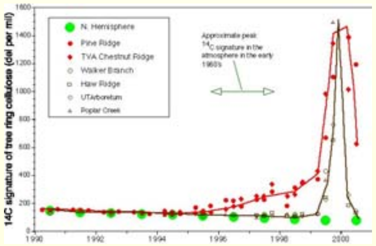
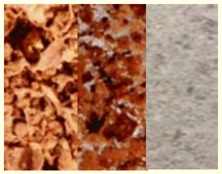


Fig. 1. ^{14}C concentrations in cellulose of trees in Oak Ridge Reservation and surrounding areas.



Density fractions, magnified 50X.

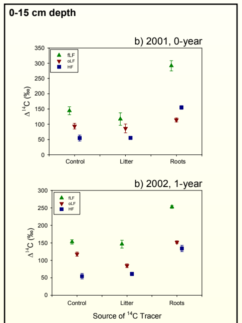


Fig. 4. Δ^{14}C of density fractions in 0-15 cm depth class in a) 2001 and b) 2002. Error bars are ±1 SE.

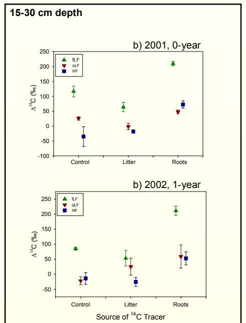


Fig. 5. Δ^{14}C of density fractions in 15-30 cm depth class in a) 2001 and b) 2002. Error bars are ± 1 SE.

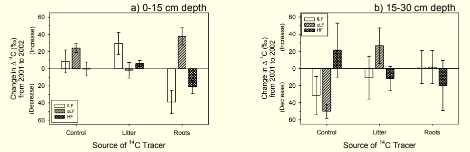


Fig. 6. The change in Δ^{14}C in density fractions from 2001 to 2002 in the a) 0-15 cm, and b) 15-30 cm depth classes. Error bars are ±1 SE.

Table 1. Mass recovery and C concentrations of density fractions.

Source		Mass Recovery (% of soil fractionated)	Free Light Fraction		Occluded Light Fraction		Heavy Fraction	
			Mass (% of soil)	Carbon (%)	Mass (% of soil)	Carbon (%)	Mass (% of soil)	Carbon (%)
Control	0-15 cm	99.0	2.2 (0.3)	24.9 (0.8)	1.0 (0.09)	38.5 (1.3)	96.9 (0.3)	1.4 (0.1)
	15-30 cm	97.3	0.4 (0.01)	33.9 (2.0)	0.2 (0.02)	45.2 (0.5)	99.5 (0.02)	0.3 (0.04)
Litter	0-15 cm	99.3	2.4 (0.3)	26.6 (0.3)	1.1 (0.1)	41.1 (1.9)	96.5 (0.4)	1.2 (0.1)
	15-30 cm	97.7	0.6 (0.2)	32.2 (3.1)	0.3 (0.07)	45.4 (1.8)	99.0 (0.3)	0.3 (0.07)
Roots	0-15 cm	98.8	1.9 (0.2)	26.5 (0.8)	0.8 (0.08)	38.1 (2.3)	97.2 (0.3)	1.1 (0.07)
	15-30 cm	98.5	0.4 (0.07)	30.1 (0.8)	0.3 (0.04)	41.8 (1.8)	99.3 (0.1)	0.4 (0.04)

SE in parentheses.

The Enriched Background Isotope Study (EBIS)

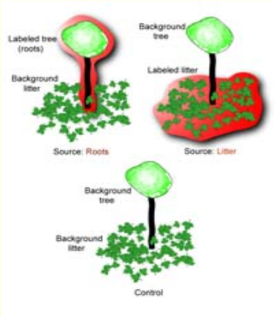


Fig. 2. Sources of enriched ^{14}C.

EBIS takes advantage of an extraordinary opportunity: tracing a large pulse of radiocarbon through an entire forest ecosystem. The largest atmospheric release of radiocarbon from the incinerator at Oak Ridge (June/July 1999) was comparable in Δ ^{14}C to the bomb curve at its peak (Fig 1). The ^{14}C was fixed by plants and was present in leaves, roots, and litter by the fall of 1999. Senescent leaves were collected in the fall of 2000 from the most labeled forest stands and from nearby stands that were at near-background levels. In a classic 'litter swap', labeled leaves were placed in plots inside background stands, and vise versa (Fig 2). Ideally, this design allows the source of the ^{14}C label to be identified in any given plot. Numerous aspects of the C cycle are being studied by EBIS collaborators (Fig. 3); this poster considers ^{14}C fluxes through three soil organic fractions. The data at '0-year' represent soil values at the beginning of the study, when the litter was first transplanted. The '1-year' data represent soils value after one year of litter or root treatment.

Collection of senescent leaves.

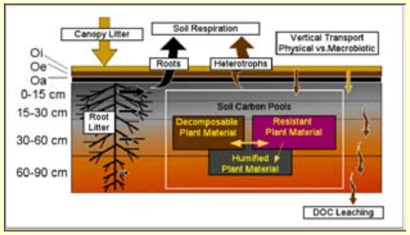


Fig. 3. Carbon cycle studies within EBIS.

General Methods

Density fractionation: soils were physically separated into active, intermediate, and stable organic fractions by sequential floatation in a dense (1.65 g mL^{-1}) liquid medium. The first fraction to float, after only very gentle agitation, is the free light fraction (fLF). The second, after mixing and sonication, is the occluded light fraction (oLF). The remaining sediment is the heavy fraction.

Measuring radiocarbon: samples were combusted in sealed tubes with CuO and Ag, then reduced to graphite using the H-reduction method. The ^{14}C concentration of the graphite was measured on a Van de Graaff FN accelerator at the Center for Accelerator Mass Spectrometry, LLNL.

Accelerator mass spectrometer at CAMS, LLNL

Initial Findings

The preliminary results from this ongoing study indicate:

- The treatment plots contain similar masses of density fractions (Table 1).
- Density fractions from different treatment plots have similar C concentrations (Table 1).
- The free light fraction in all treatments and depths contained the highest concentrations of ^{14}C.
- The source=Roots treatment plots had apparently received smaller, but substantial, inputs of enriched ^{14}C before the large spike in 1999 (Fig. 1). Thus, the source=Roots treatment appears disproportionately labeled at 0-year, and again at 1-year (Fig. 4 & 5).
- The Δ^{14}C of the occluded light fraction was typically between that of the free light fraction and the heavy fraction. The exception was in the source=Roots treatment in 0-year, when the oLF was less then the HF (Fig. 4 & 5).
- The heavy fraction typically showed the least change in Δ^{14}C from 0-year to 1-year.
- The source=Litter treatment appeared to move ^{14}C preferentially into the free light fraction in the 0-15-cm depth class, and into the occluded light fraction in the 15-30-cm depth class (Fig. 6). Incorporation of ^{14}C-label into the LF in the upper soil probably included substantial mixing of the litter and soil layers. Transport of ^{14}C into the lower soil and oLF was probably as dissolved organic carbon (DOC).
- The Δ^{14}C in the source=Roots treatment showed dilution in the free light fraction and heavy fraction in the 0-15-cm depth class, probably from the background litter application. Concurrently, Δ^{14}C in the occluded light fraction increased, possibly from accumulating degradation products as DOC from the previous years roots and LF (Fig. 6).

Concluding Remarks

Succeeding applications of litter will allow for the continued enrichment of the source=Litter treatment and the continued dilution of the source=Roots treatment. The density fractions have proven to be sensitive to ^{14}C flux through this system. We expect the free light fraction to remain the most responsive to ^{14}C inputs, although the occluded light fraction will probably become more enriched as labeled organic matter releases dissolved organic C during decomposition.

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