Incorporation of a Whole Ecosystem Radiocarbon Label into Unprotected and Protected Soil Carbon Pools

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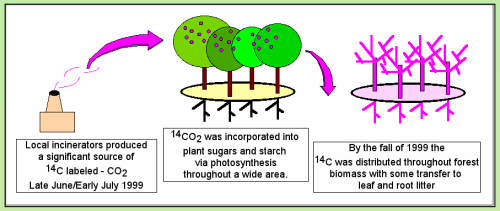
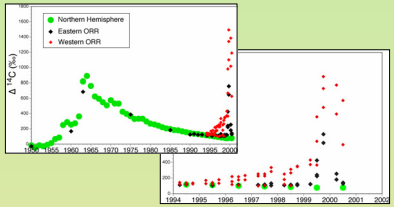
A Unique Opportunity



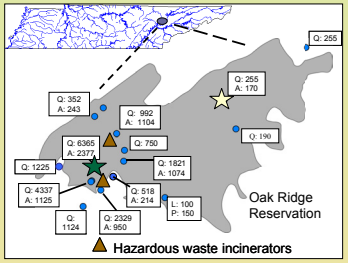
During the summer of 1999, emissions from local waste-incinerators added ^{14}C-CO_2 to the atmosphere of the Oak Ridge Reservation (ORR). Subsequent photosynthetic incorporation produced enriched vegetation (leaves, stems, roots) and carbohydrate storage pools.



The ^{14}C signature in tree ring cellulose demonstrated the unique and unprecedented nature of the 1999 event. Notwithstanding the unusual nature of the 1999 event, the ^{14}C-enrichment event was a permitted emission and not a safety hazard.

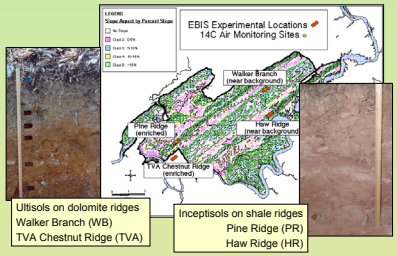
Sampling of *Quercus alba (Q)* or *Acer rubrum* (A) leaves for $\Delta^{14}C$ (‰) during the 2000 growing season showed greatest enrichment on the west end of the ORR.

Reference: Trumbore S, Gaudinski JB, Hanson PJ, Southon JR, 2002, A whole-ecosystem carbon-14 label in a temperate forest. EOS 83:265,267-268.

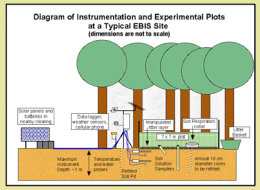


Enriched Background Isotope Study (EBIS): The Experiment

Sufficient enriched (west end) and near-background (east end) litter was collected in fall 2000 to conduct a plot-level litter manipulation study (3 yr of litter additions). The experiment is being conducted in replicated upland oak forest plots representing two different soil types and either enriched or near-background initial conditions with respect to ^{14}C in litter, roots, and mineral soils.

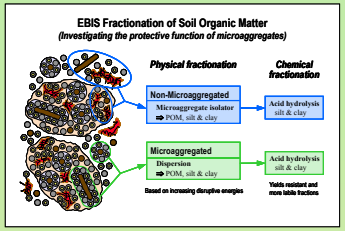


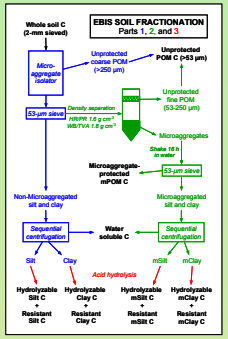
Eight experimental plots were established in 2000 at each of the 4 sites above. Study year-zero sampling of organic and mineral horizons occurred in Jan/Feb 2001. All plots received either enriched or background litter (4 plots of each per site) in March 2001, from the 2000 collections. Second and final litter additions were made in Feb 2002 and 2003 following 1-yr and 2-yr samplings, respectively. Yearly mineral soil samples consist of 3 cores (10 cm diameter) taken to 90 cm and pooled by depth increments (0-15, 15-30, 30-60, 60-90 cm) for each plot. Soil samples were dried and sieved through a 2-mm sieve.



Ambient litterfall was excluded from all plots starting in fall 2000.

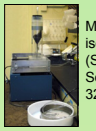
Fractionation of Surface Mineral Soils (0-15 cm depth)



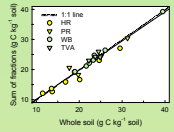


Soil fractionations (shown conceptually above and procedurally to right). Fraction definitions (Parts 1 & 2):

- POM = unprotected particulate organic matter (POM)
- mPOM = microaggregate protected POM
- SILT or CLAY = non-microaggregated silt or clay
- mSILT or mCLAY = microaggregated silt or clay



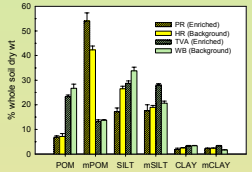
Microaggregate isolator (Six, J et al., 2000, Soil Biol. Biochem. 32:2099-2103)



Overall recovery of whole soil C from fractionation Parts 1 & 2 was 97.6 ± 0.2 %

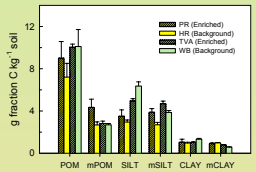
Initial Results: Year Zero (before litter manipulations)

Fig. 1. Weight distribution of fractions



The switch in distribution of POM vs. mPOM weights between soil types reflects differences in the size class of sand isolated with the POM

Fig. 2. Distribution of whole soil C across soil fractions



- 50-60% of whole soil C in POM fractions
- 30-40% of whole soil C in silt and ~10% in clay fractions

Fig. 3. Radiocarbon signatures in fractions and whole soil

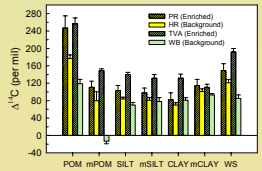
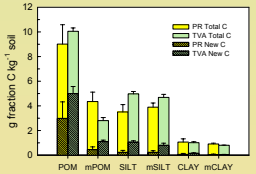


Fig. 4. Estimated new C derived from inputs during 1999 and 2000 growing seasons



- Negative $\Delta^{14}C$ for WB mPOM probably due to charcoal
- Significant ^{14}C enrichment mostly in unprotected POM for PR; some enrichment in all PR fractions (but not significant)
- TVA has significant ^{14}C enrichment in all fractions
- Acid hydrolysis (not completed yet) will give some indication whether rapid enrichment in mineral fractions is largely derived from microbial action on exudates and sloughed roots (hydrolyzable) or from root residues (acid resistant)

Estimated by mass balance using ^{14}C signatures for Year 0 sampling:

$$S_E = f\,(I_E) + (1 - f)\,S_B$$

or

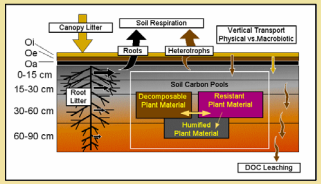
$$f = (S_E - S_B)/(I_E - S_B)$$

f = proportion new
S_E = enriched soil (PR or TVA)
S_B = background soil (HR or WB)
I_E = dead roots (<2 mm) from PR or TVA

- Absolute values questionable due to pulse labeling and many assumptions concerning I_E but relative comparisons between fractions and soils are more reliable
- Better estimates will result from following the dynamics of ^{14}C signatures in fractions over time and application of the data to modeling studies

Multi-Institution Collaborative Research:

EBIS researchers from eight different institutions make use of the whole-ecosystem isotopic label to collaboratively address several research objectives relevant to the C cycle in temperate deciduous forests.



EBIS Research Objectives

1. Quantify pathways and rates of bulk C transfer from carbon sources (leaf and root litter) to respiratory losses, leaching or accumulation in stable forms in the mineral soil.
2. Partition soil respiration into autotrophic and heterotrophic sources.
3. Distinguish between leaf-litter and root-litter C sources for heterotrophic respiration.
4. Measure the rate of C accumulation in soils having different chemical and/or physical protection from decomposition.
5. Evaluate the role of dissolved organic carbon (DOC) in vertical transport.
6. Measure macrobiotic (earthworm) vertical transfer of C from the litter layer to the mineral horizons.
7. Identify the longevity and turnover time of fine roots.