Enriched Background Isotope Study (EBIS): Application of an Ecosystem-scale ^{14}C Tracer to Soil-Carbon-Cycle Studies

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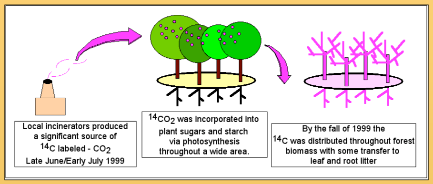
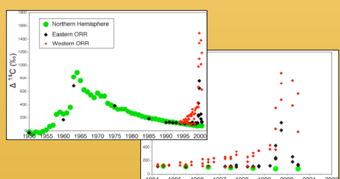
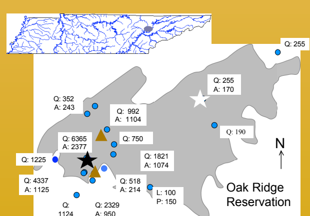
A Unique Opportunity



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.

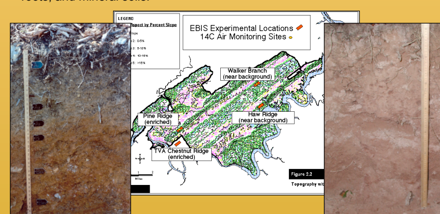


Sampling of *Quercus alba* (Q) or *Acer rubrum* (A) leaves for $\Delta^{14}C$ (‰) during the 2000 growing season showed greatest enrichment on the west end of the ORR.

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.

The Experiment

Sufficient enriched (west end) and near-background (east end) litter was collected in the fall of 2000 to conduct a plot-level litter manipulation study (3 years 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.



Ultisol sites on dolomite ridges:

Walker Branch (WB)

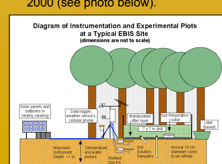
TVA

Inceptisol sites on shale ridges :

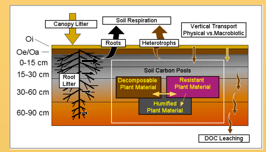
Haw Ridge (HR)

Pine Ridge (PR)

Eight experimental plots were established in 2000 at each of the four sites shown above. Time-zero sampling of organic and mineral horizons was done in Jan/Feb 2001. All plots received either enriched litter (4 plots/site) or background litter (4 plots/site) in March of 2001 from the 2000 collections. The second litter addition was made in February 2002 following 1-year sampling. Final litter additions will be made in February 2003. Ambient litterfall was excluded from all plots starting in the fall of 2000 (see photo below).

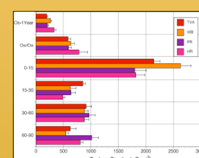


Research Objectives and Bulk C Pool Analyses



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.

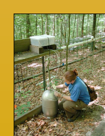


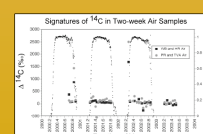
Year-0 ^{14}C	Background		Enriched	
Horizon	WB	HR	TVA	PR
Oi>1Y	252	193	627	515
Oe/Oa	218	194	466	361
0-15cm	84	121	192	163
15-30cm	24	72	95	92
30-60 cm	7	72	62	40
60-90 cm	-90	35	-104	58

Soil Carbon (C. Garten, P. Hanson, and C. Swanston)

Soil C stocks are highest in the ultisol surface soils (0-15 cm), similar for both soil types at intermediate depths (15 - 60 cm), and highest for the inceptisol soils deep in the soil profile (60-90 cm).

As expected, the time zero bulk ^{14}C analyses by soil horizon show the influence of the 1999 ^{14}C-pulse, but additional subtle differences by soil type are evident. The ^{14}C-signatures show that deep soil C of the ultisols is older than the C of the inceptisols (more negative $\Delta^{14}C$ signature).

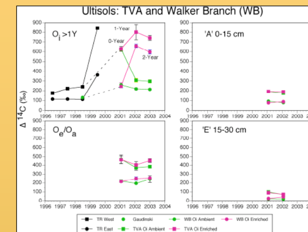


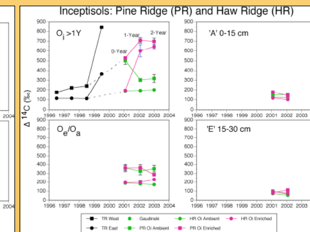


Air Sampling (M. Cisneros-Doll, P. Hanson, and S. Trumbore)

^{14}C in ambient air is being monitored throughout the study to allow corrections to our analyses in the event of future ^{14}C emissions. Elevated spikes of $^{14}CO_2$ observed since 1999 are not a problem because they do not overlap the active photosynthetic period.

Higher ambient air ^{14}C levels at the western research plots (PR and TVA) demonstrate the potential for ecosystem of carbon recycling (S. Trumbore).



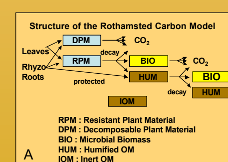


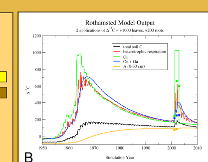
Bulk 14C Analysis by Horizon (P.J. Hanson, C. Swanston, D.E. Todd, and J.Southon)

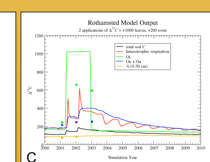
These graphs contrast ^{14}C-signature of pre-study tree ring sapwood rings (TR) for eastern and western trees with bulk ^{14}C data for organic layers (Oi, Oe/Oa) or mineral soil depths/horizons (A,E). Time zero measurements for the experiment are the 2001 data.

After one year of enriched (1005‰) or background (221‰) litter additions (2002 data points), recognizable litter greater than 1-year of age (Oi>1Y) showed the expected patterns of enrichment or dilution. There was little evidence of new C movement below the Oi horizon after one year

Surprisingly, after the second year of enriched litter additions (910‰) Oi and Oe/Oa ^{14}C signatures did not continue to increase in the 'enriched' treatment plots. Differential decomposition of individual litter cohorts and/or differential labeling of soluble/labile litter components are being investigated as the reasons for this outcome.







Soil Carbon Modeling (Mac Post)

A. Rothamsted model carbon pools and processes. Their approximate equivalents for the EBIS sample processing scheme: Oi ~ DPM+part of RPM; Oe/Oa ~BIO+part of RPM; 'A' ~ HUM+IOM.

B. A 58-year spin up of the Rothamsted model for the ultisol soils showing the influence of two annual enriched litter additions starting in 2001.

C. An expanded view of the model simulations for the experimental period (2001 and beyond). Observed ^{14}C-signatures of the Oi>1Y layer, the Oe/Oa layer, and the 'A' soil horizon show that model improvements need to be made to capture observed soil carbon cycling and transport processes.

Testing and improvement of soil carbon cycling models is a key anticipated output of the EBIS project.

Acknowledgement

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