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

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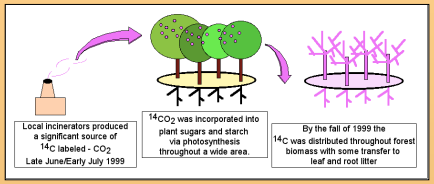
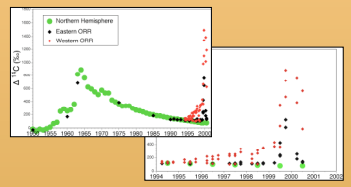
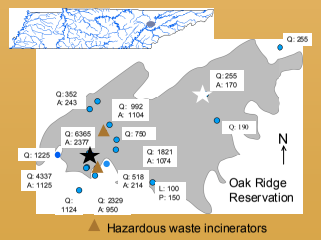
A Unique Opportunity



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.

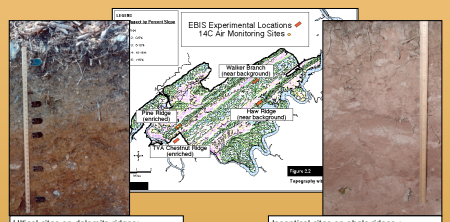


Sampling of *Quercus alba (Q)* or *Acer rubrum* (A) leaves for $\Delta^{14}C$ (‰) during the 2000 growing season showed greatest enrichment on the west end of the ORR.

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

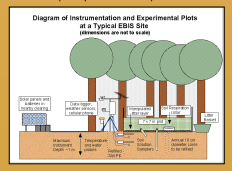
Sufficient enriched (west end) and near-background (east end) litter was collected in the fall of 2000 to conduct a plot-level litter manipulation study (3 years of litter additions). The experiment is being conducted in replicated upland-oak forest plots representing two different soil types and either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



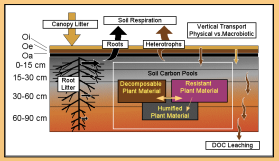
Ultisol sites on dolomite ridges:
Walker Branch (WB)
TVA

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).

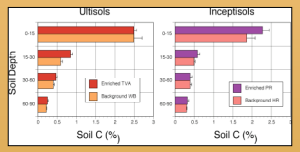


Research Objectives and Some Initial Results

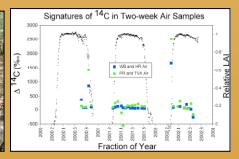


Objectives

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.

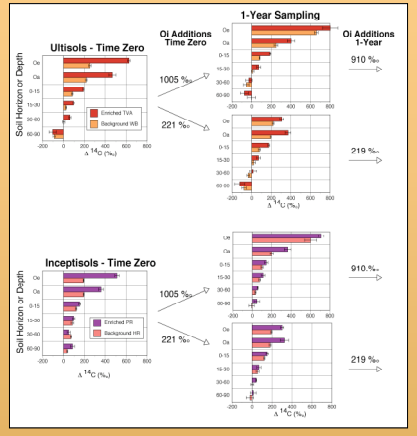


Soil Carbon (Garten)
Initial soil C levels are highest in the ultisol surface soils, but similar to the inceptisols at depth. The ^{14}C-signatures indicate that the deep soil C of the ultisols is older.



Air Sampling (Cisneros-Doll, Hanson, 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 levels of $^{14}CO_2$ have been observed since 1999, but they are not a problem because they did not overlap the active photosynthetic period.



Calculated Contribution of Oi litter to the Oe horizon after 1-year

% = (Y1-Y0)/(Oi -Y0)*100

Y0 = Oe ^{14}C signature at time zero

Y1 = Oe ^{14}C signature at 1-year

Oi = ^{14}C signature of added litter

^{14}C Enrichment

(1005 ‰ Oi added to Oe layers)

TVA	=	46 ± 50%
WB	=	54 ± 8%
PR	=	40 ± 20%
HR	=	50 ± 25%

^{14}C Dilution

(221 ‰ Oi added to enriched Oe layers)

TVA	=	78 ± 16%
PR	=	71 ± 18%

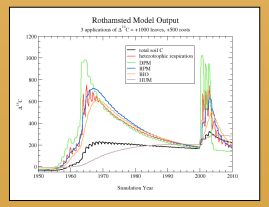
Values are mean % ± 95% c.i.

Bulk Horizon Analysis (Hanson, Todd, Swanston, Southon)

Time zero bulk ^{14}C analyses by soil horizon show clear differences due to location on the Oak Ridge Reservation as expected, and subtle differences by soil type.

After one year of enriched or background Oi litter applications there is little evidence of new C movement below the Oe horizon.

Estimates of the fractional contribution of Oi litter to the Oe layer after 1-year were not the same for enriched vs.. background Oi additions suggesting differential rates of litter cohort decomposition within the Oe layer.



Modeling (Post)

An example an *a priori* prediction from the Rothamsted Model showing the influence of 3 years of enriched litter additions. Testing and improvement of such models is a key anticipated output of the EBIS project.

An Invitation

Limited quantities of enriched and background litter from the 2000 collection will remain unused. The material is primarily leaf litter from a mixture of deciduous species, and the approximate bulk ^{14}C-signatures are known (enriched ~ 1000 ‰; background ~220 ‰). Contact P. Hanson (hansonpj@ornl.gov) if you have an interest in developing projects that might utilize this material.

Acknowledgement

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