Quantifying Soil Carbon Cycle Mechanisms and Flux Using ^{14}C-Enriched Leaf Litter Manipulations: Implications for Modeling Carbon In Soil

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The Project

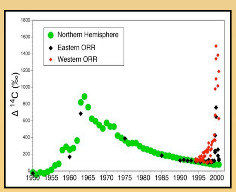
Near-background releases of $^{14}CO_2$ from waste incinerators on or near the Oak Ridge Reservation (N 35° 58'; W 84°16') provided the opportunity for observations of the soil carbon (C) cycle at ecosystem scales. Multi-year and seasonal manipulations of enriched litter additions were undertaken as a part of the Enriched Background Isotope Study (EBIS) to resolve carbon flow paths through the soils of a representative eastern upland oak forest.

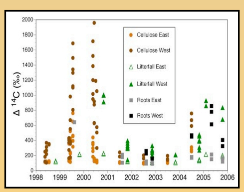
The EBIS experiments:

(1) a multi-year, enriched-leaf-litter addition study for tracking annual movement of labeled C for a full range of soil depths and chemical forms, and

(2) a mesocosm-based study with intra-annual resolution to follow the fate of leaf-litter-derived ^{14}C-enriched material to dissolved organic C, organic and soil C pools, and CO_2 release.

During the summer of 1999, incinerator emissions added a large pulse of ^{14}C-CO_2 to the local atmosphere that was subsequently fixed by photosynthesizing vegetation and incorporated into leaves, stems, roots, and carbohydrate storage pools. Those materials were collected, dried and archived for use in future studies.





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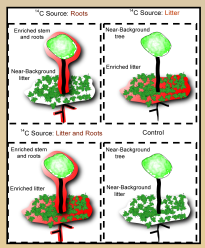
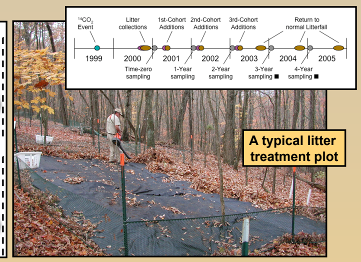
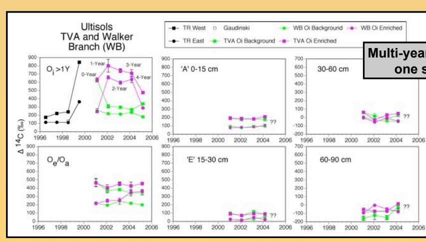
Multi-Year, Litter-Cohort Addition Experiment

Leaf litter collected in Fall 2000 from the ^{14}C-enriched and near-background areas of the Oak Ridge Reservation were used in a reciprocal litter transplant study. Highly enriched leaves were placed in background-^{14}C stands, while background-^{14}C leaves were placed in highly enriched stands. This arrangement allowed us to trace enriched litter from known sources (leaves, roots) into soil organic fractions with differing potentials for SOM stabilization.



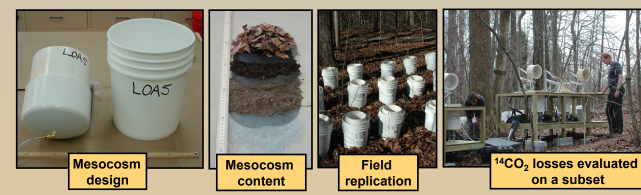


After one year of enriched (1005‰) or background (221‰) litter additions there was little evidence of new C movement below the Oi horizon. Enrichment or dilution patterns did develop within the Oe/Oa horizon after three years of sustained ^{14}C additions, and continued to develop as the enriched cohorts migrated downwards. Five years after the initial leaf-litter cohort additions, there was little evidence for a net change in the ^{14}C-enrichment of bulk mineral soils. Large soil C stocks and unenriched root turnover C sources may mask small changes from enriched litter additions. Annual time step resolution litter-manipulations revealed that dissolved organic carbon (DOC) was a rapid mechanism for transferring surface C deep into the mineral soils. However, the annual net amount of DOC retained between 15 and 70 cm was quite small (1.5-6 g m^{-2} y^{-1}).

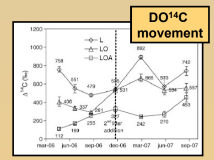


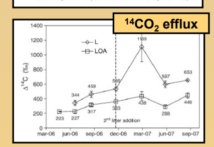
Mesocosm Study of Seasonal Soil-C Dynamics

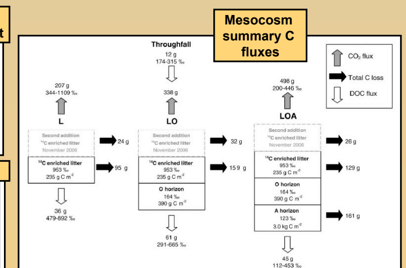
Fröberg, Hanson, Trumbore, Swanston and Todd 2009 *Geoderma* (in press)



At odds with the previous conclusion, the mesocosm observations demonstrated extensive short-term retention of DOC in the A horizon confirming the DOC leaching pathway as a driver from C movement from litter to mineral soils. The majority of the DOC carbon was, however, rapidly respired back to the atmosphere within an annual cycle allowing us to reconcile the mesocosm and cohort-addition results.







Modeling the Soil Carbon Cycle

Simplistic models of soil respiration (i.e., one box) common to stand-level interpretation of carbon fluxes are inadequate for capturing the complex dynamics of soil C fluxes and pools at sub-annual to annual time steps. A multi-layered, cohort-based analysis including dynamic carbon pools was needed to interpret the path, rate and fate of isotopically labeled materials in these upland forest soils.

At multi-year time-steps such detail may not be required, but improved layering of models such as (DayCent) to account for litter vs. root C inputs to soils is warranted and are in progress.