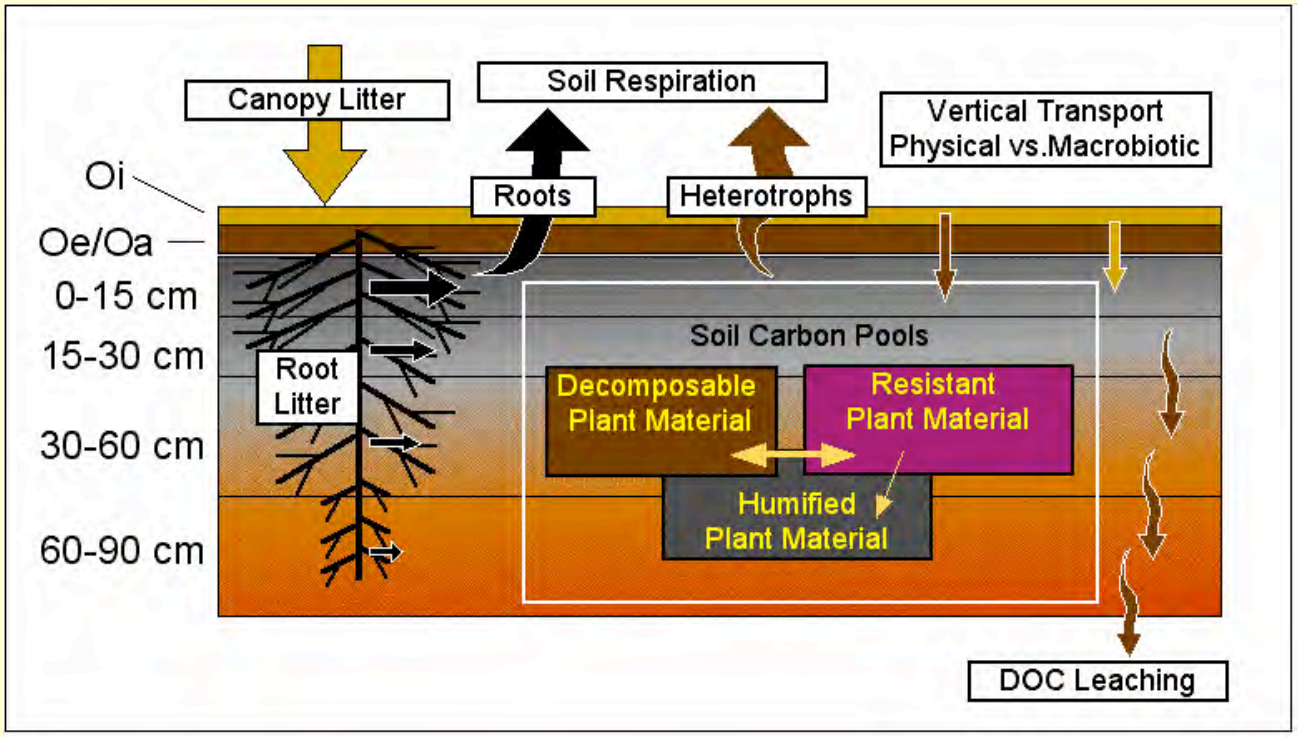
Enriched Background Isotope Study (EBIS)

A litter reciprocal transplant study to understand sources, transport, and fate of carbon in soils

Oak Ridge National Laboratory
Lawrence Livermore National Laboratory-CAMS
Argonne National Laboratory
Lawrence Berkeley National Laboratory
University of California - Irvine
University of California - Santa Barbara
Belowground Forest Research
USDA-Forest Service, Southern Research Station

Sponsor: U.S. Department of Energy, Office of Science, Biological and Environmental Research (BER), Terrestrial Carbon Processes Program (TCP).

Experimental Goals



- **Distinguish between above- and belowground C sources**
- **Quantify pathways and rates of transfer from plant carbon sources to soil carbon sinks (e.g., DOC transport)**
- **Partition soil respiration to autotrophic or heterotrophic sources**
- **Evaluate the longevity and turnover time of fine roots**
- **Measure bioturbation: earthworm C movement**

EBIS and the NACP

- The EBIS project seeks to improve our understanding of and ability to model the fate and accumulation of carbon within organic and mineral soils of deciduous oak-dominated forests that comprise 46 to 60 million hectares of North America east of the Mississippi River.
- EBIS project goals are related to program elements 3a and 4 of the implementation plan for the NACP dealing with terrestrial measurements and modeling of the land biosphere and biosphere-atmosphere interactions.
- The ^{14}C-tracer-enhanced studies of the EBIS project provide a uniquely robust means to quantify rates of soil carbon inputs, turnover and accumulation for both short (years) and long (decades to century) timescales within a time span of 3-10 years.
- Such data provide the means for constraining and enhancing bottom-up models of soil carbon accumulation that represents the long-term storage pool of carbon within terrestrial ecosystems.

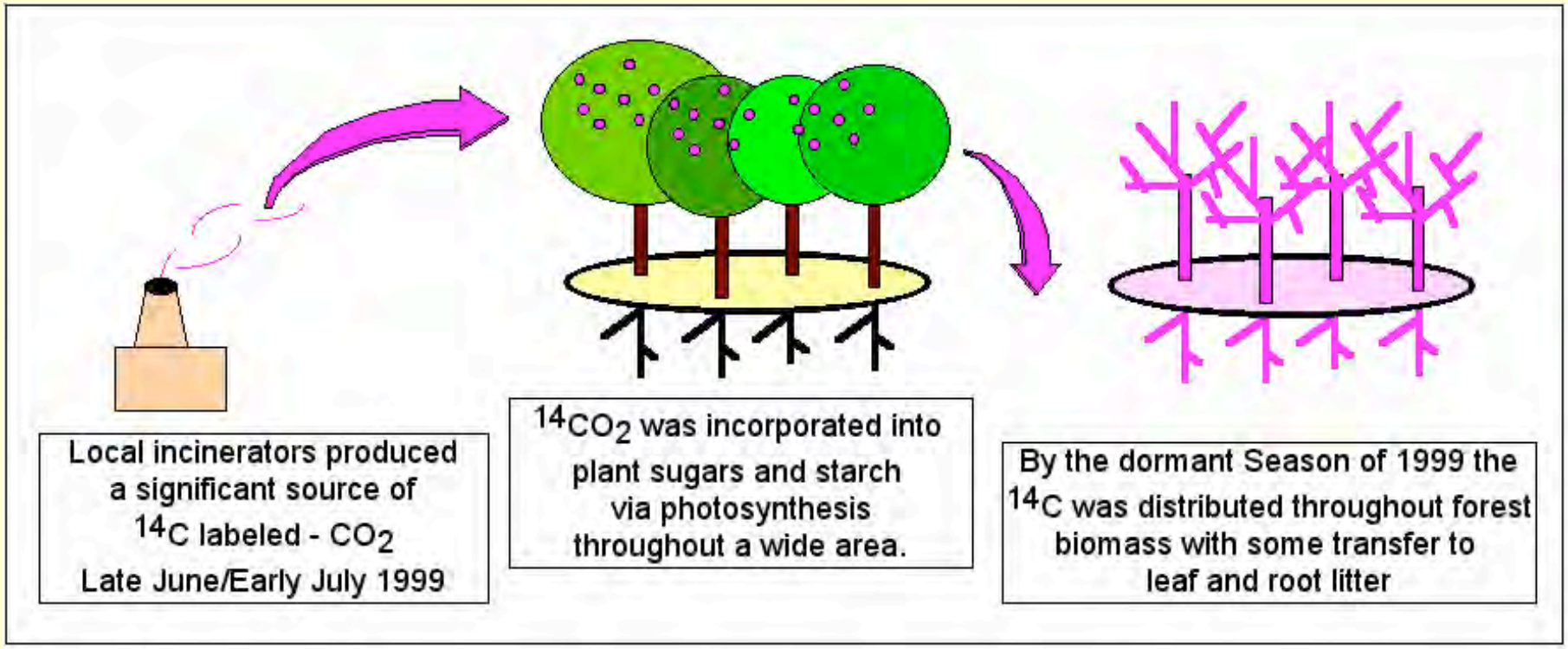
Not Quite Eureka!

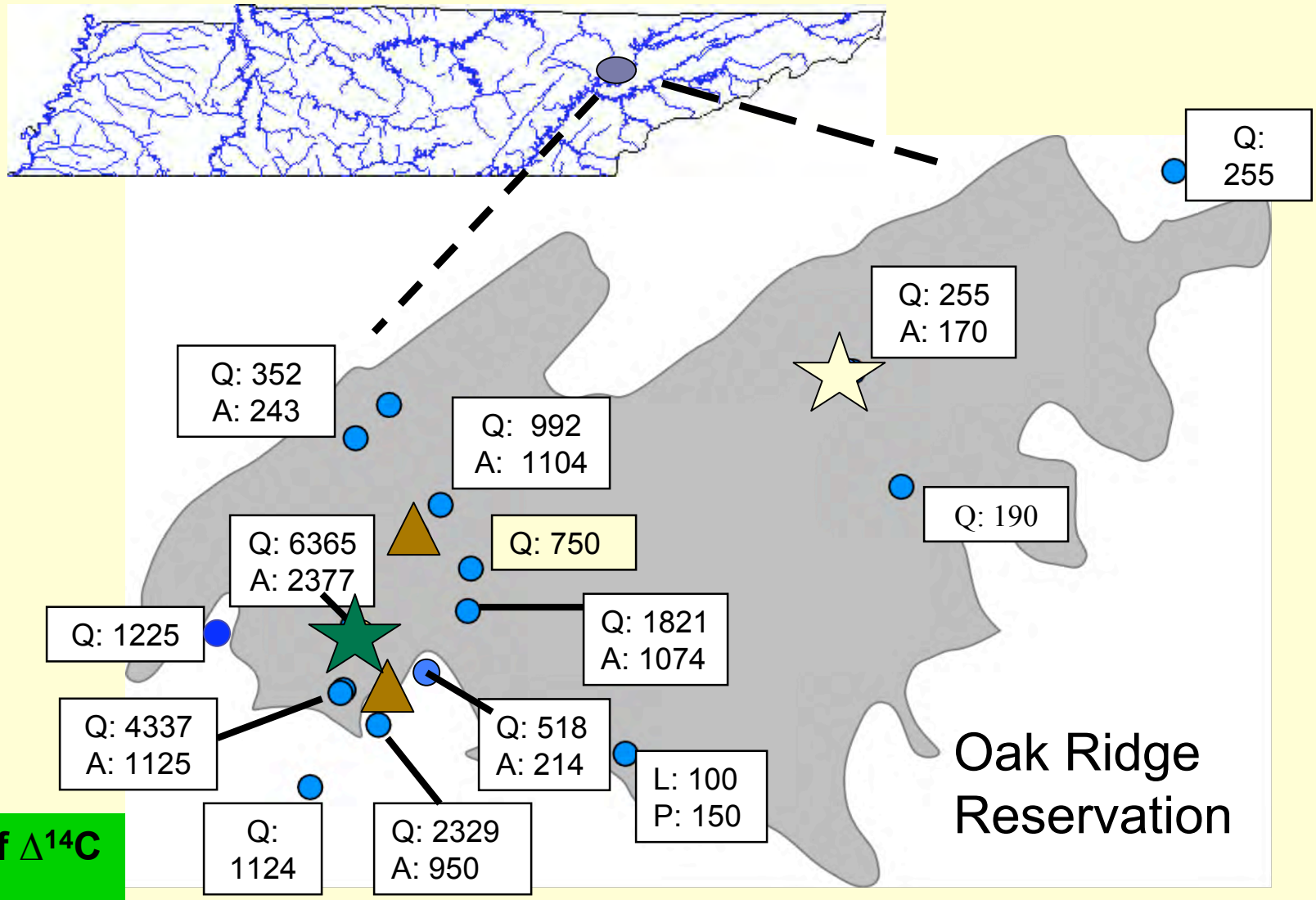
Date: Mon, 20 Sep 1999 16:53:53 -0800
From: Julia Gaudinski <gaudinsk@uci.edu>
Subject: Hot Data
X-Sender: gaudinsk@ea-pop.oac.uci.edu
To: hansonpj@ornl.gov
Cc: setrumbo@uci.edu

Hi Paul,

……..” I have attched an excel file with my most recent data from July and August plotted up. All the data are seriously contaminated with 14C!!…….So I think we definitely have something NOT natural going on here……. this is potentially disastrous for a lot of the work I have already done……However, there may be a silver lining to this dark cloud…”

The 1999 ^{14}C Event





Green-leaf $\Delta^{14}C$

A = *Acer*

Q = *Quercus*

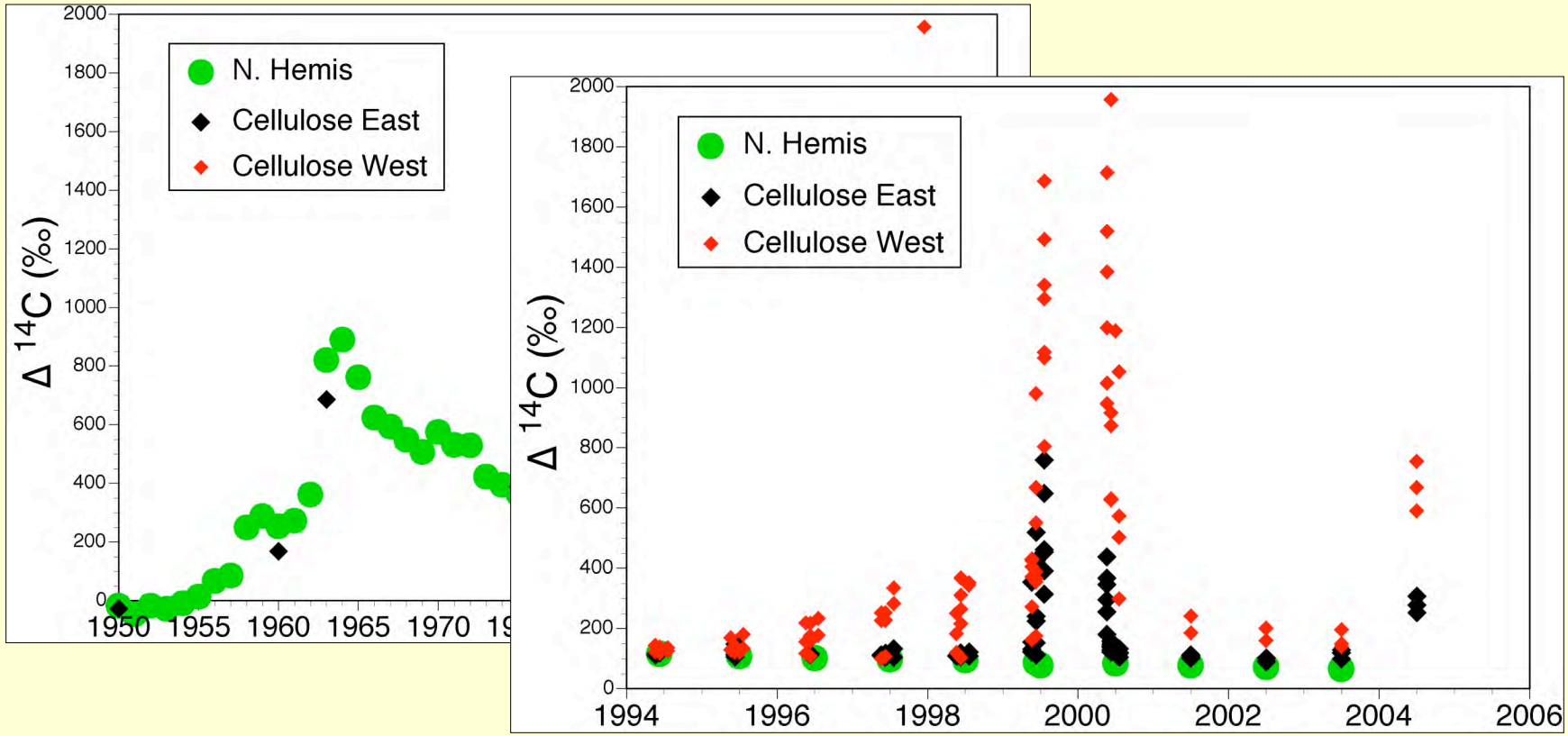
L = *Liquidambar*

P = *Platanus*

Hazardous waste incinerators

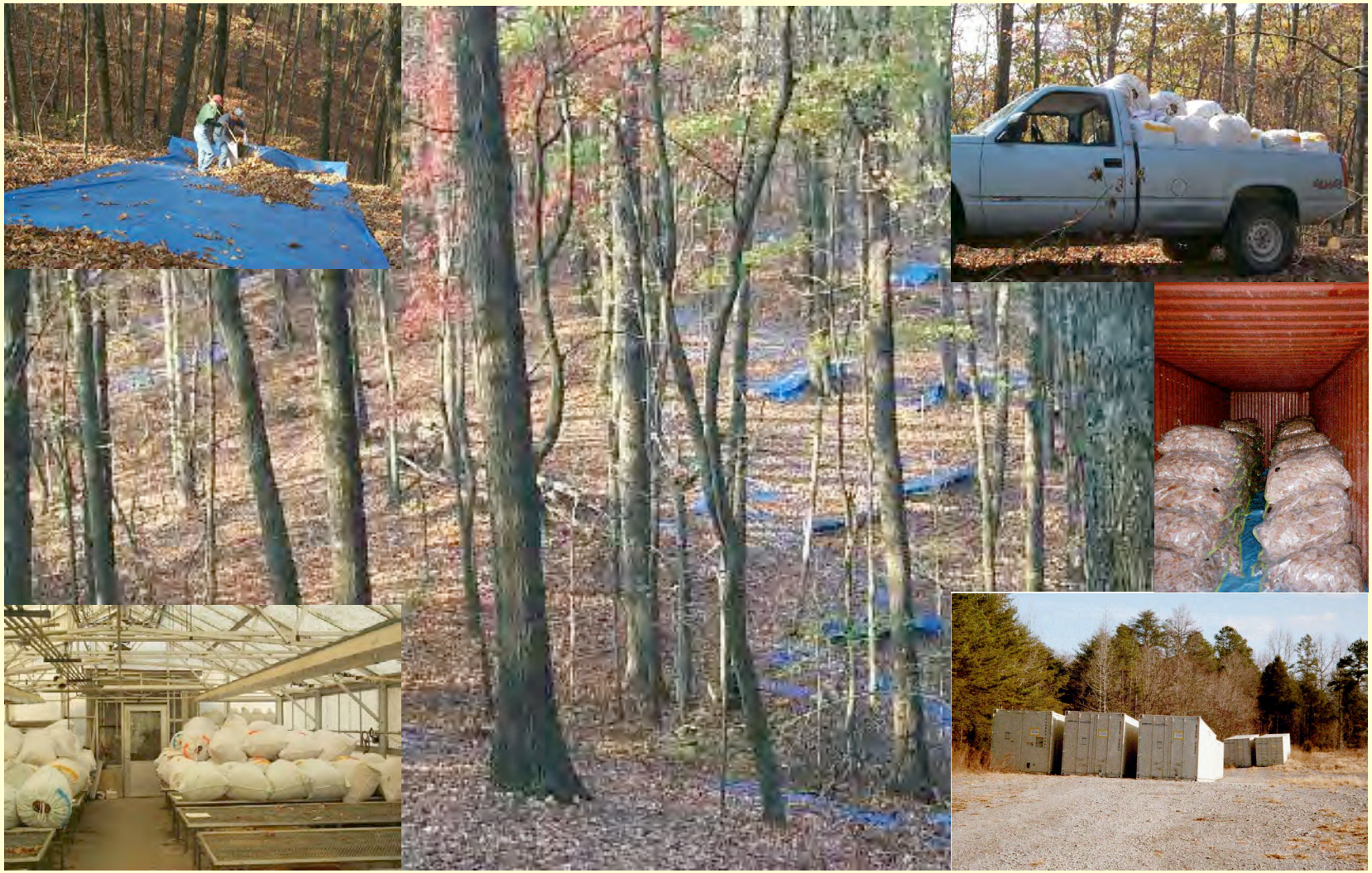
Trumbore et al. 2002

The 1999 ^{14}C Event

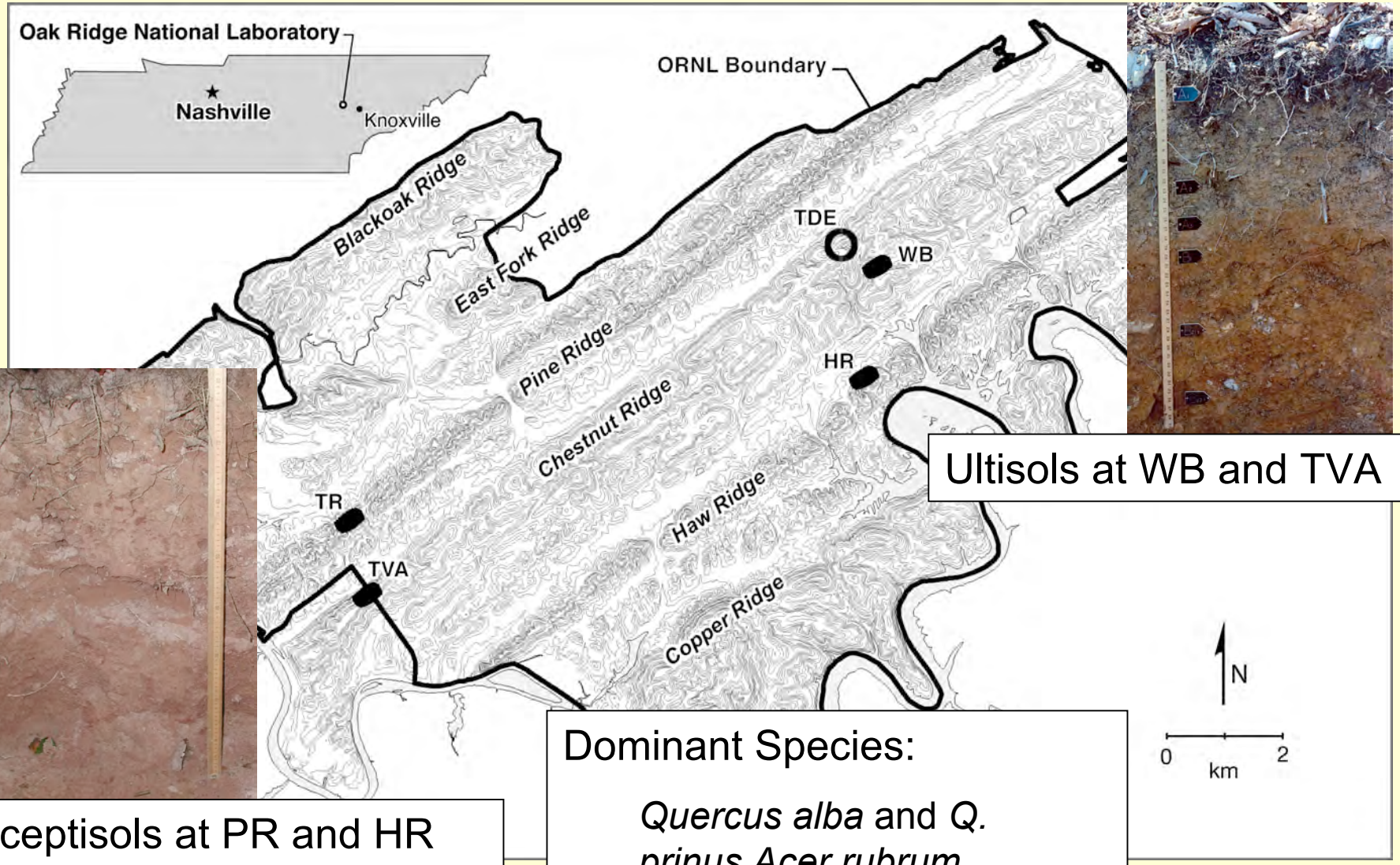


- ^{14}C signatures in the local tree ring record demonstrated the unique and unprecedented nature of the 1999 event.
- ^{14}C in 2000 expanding foliage and buds confirmed the 1999 whole-ecosystem label and suggested that the ecosystem signature could be exploited for other studies.
- A new ^{14}C-pulse in 2004 will allow us to take another look at root C sources.

^{14}C Enriched and Near-Background Litter were Archived in 2000



Two Soil Types are Being Studied



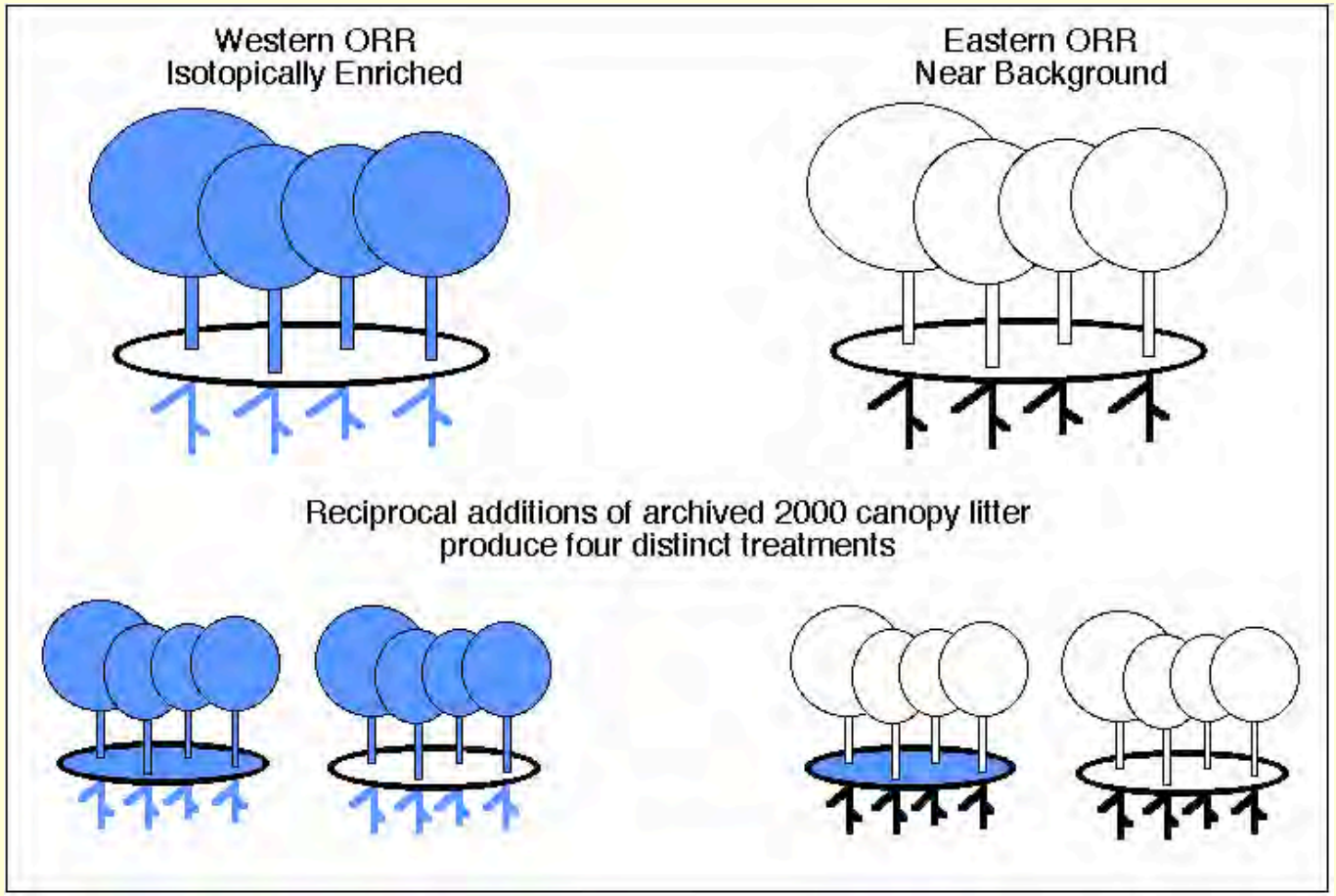
Ultisols at WB and TVA

Inceptisols at PR and HR

Dominant Species:

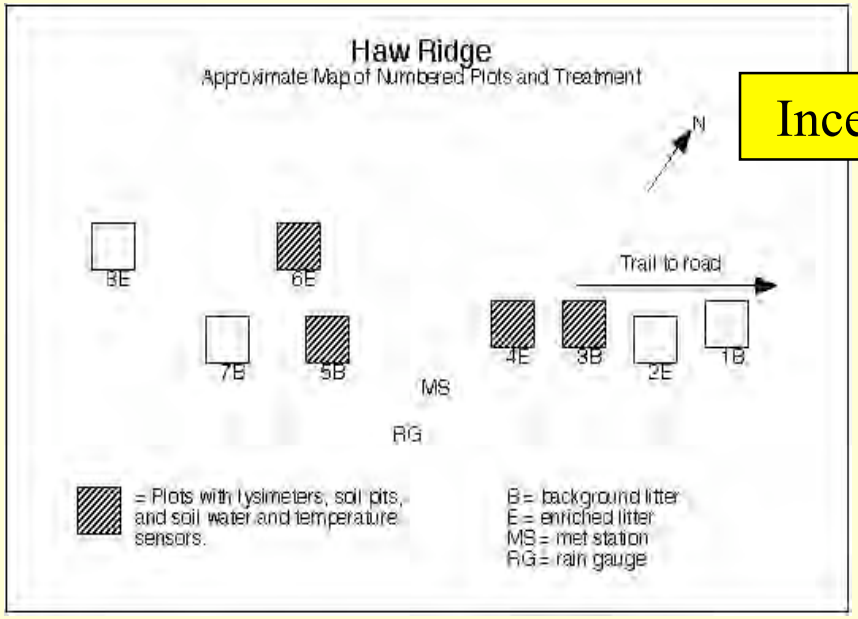
Quercus alba and *Q. prinus Acer rubrum*

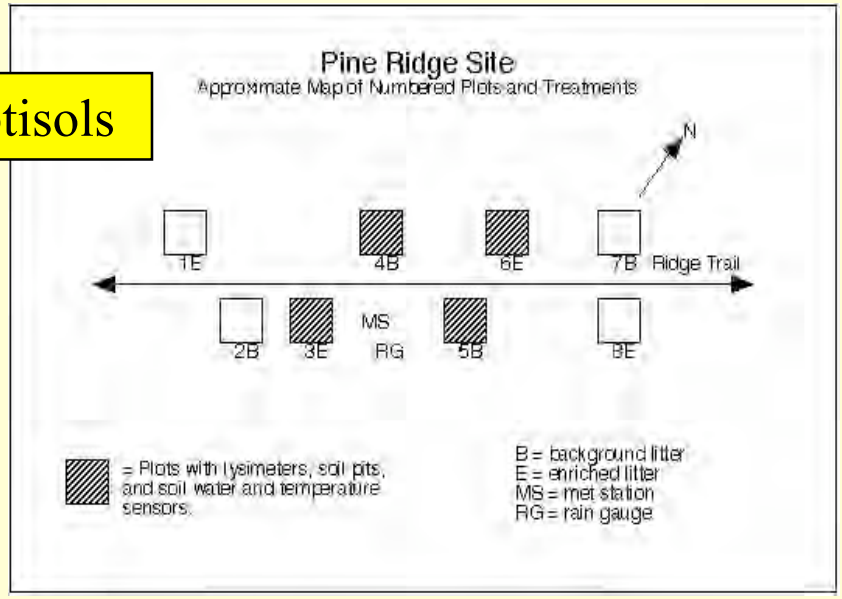
Experiment Design



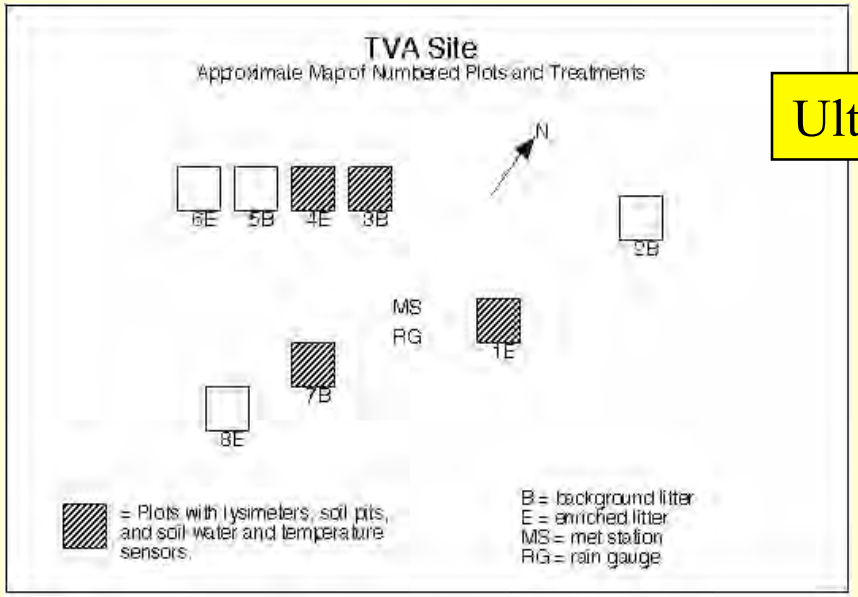
- **Multi-year, litter-replacement experiment repeated for Ultisol and Inceptisol Soils**
  - **Enriched vs. background sites**
  - **3-year application of archived 2000 litter (500 g m^{-2} y^{-1})**

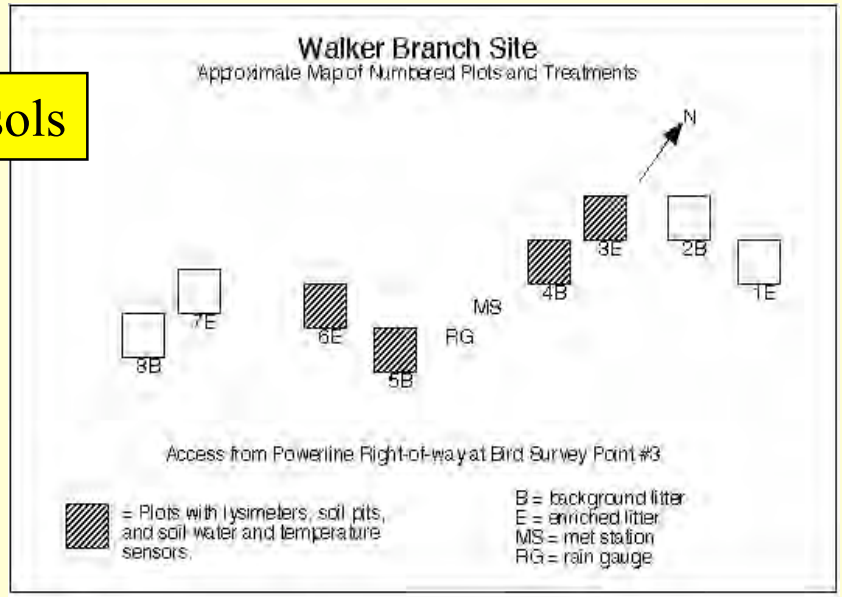
Inceptisols



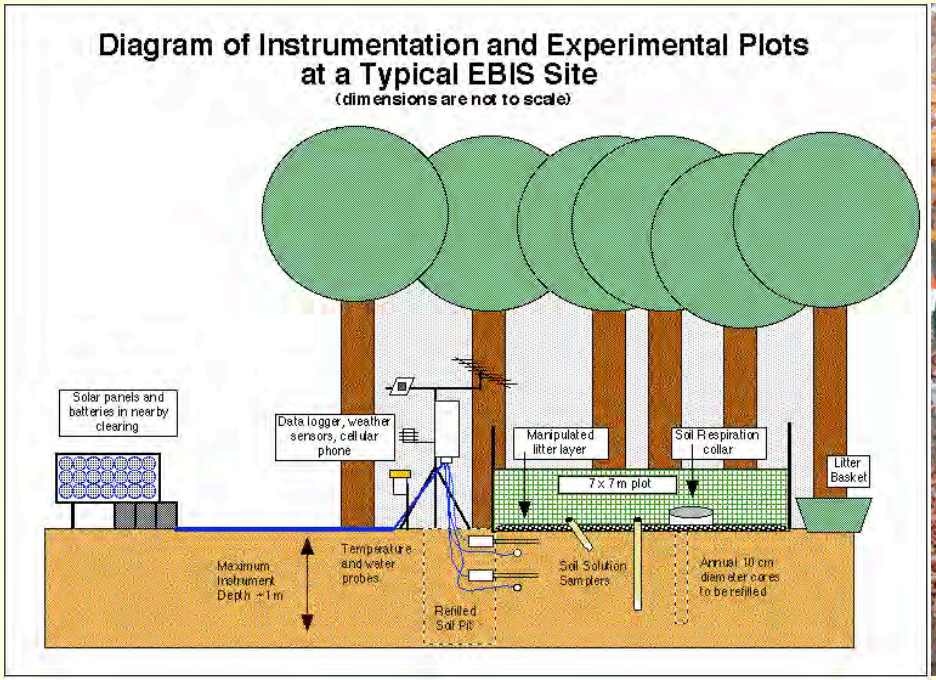


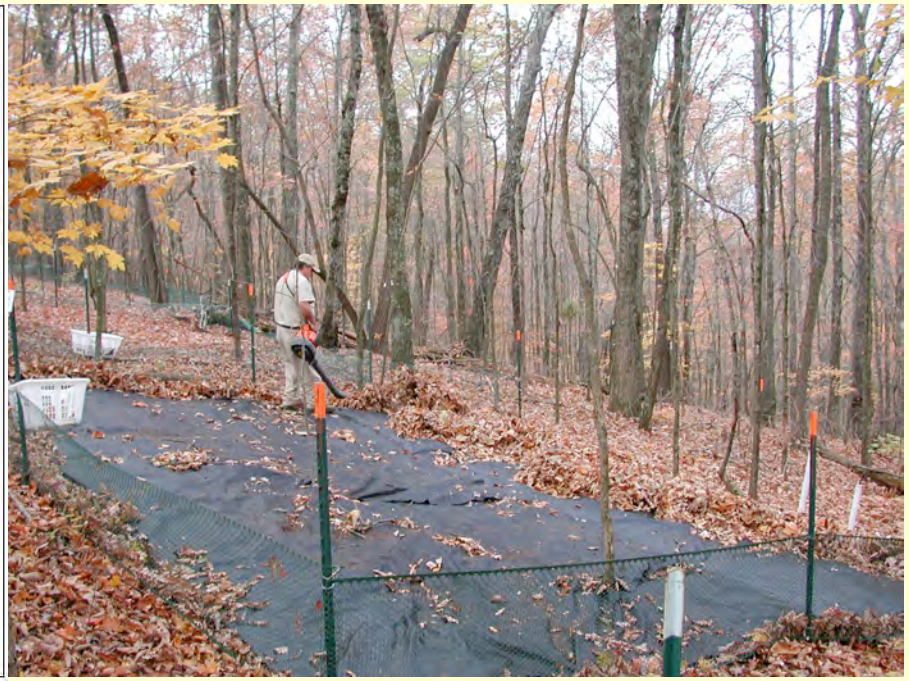
Ultisols





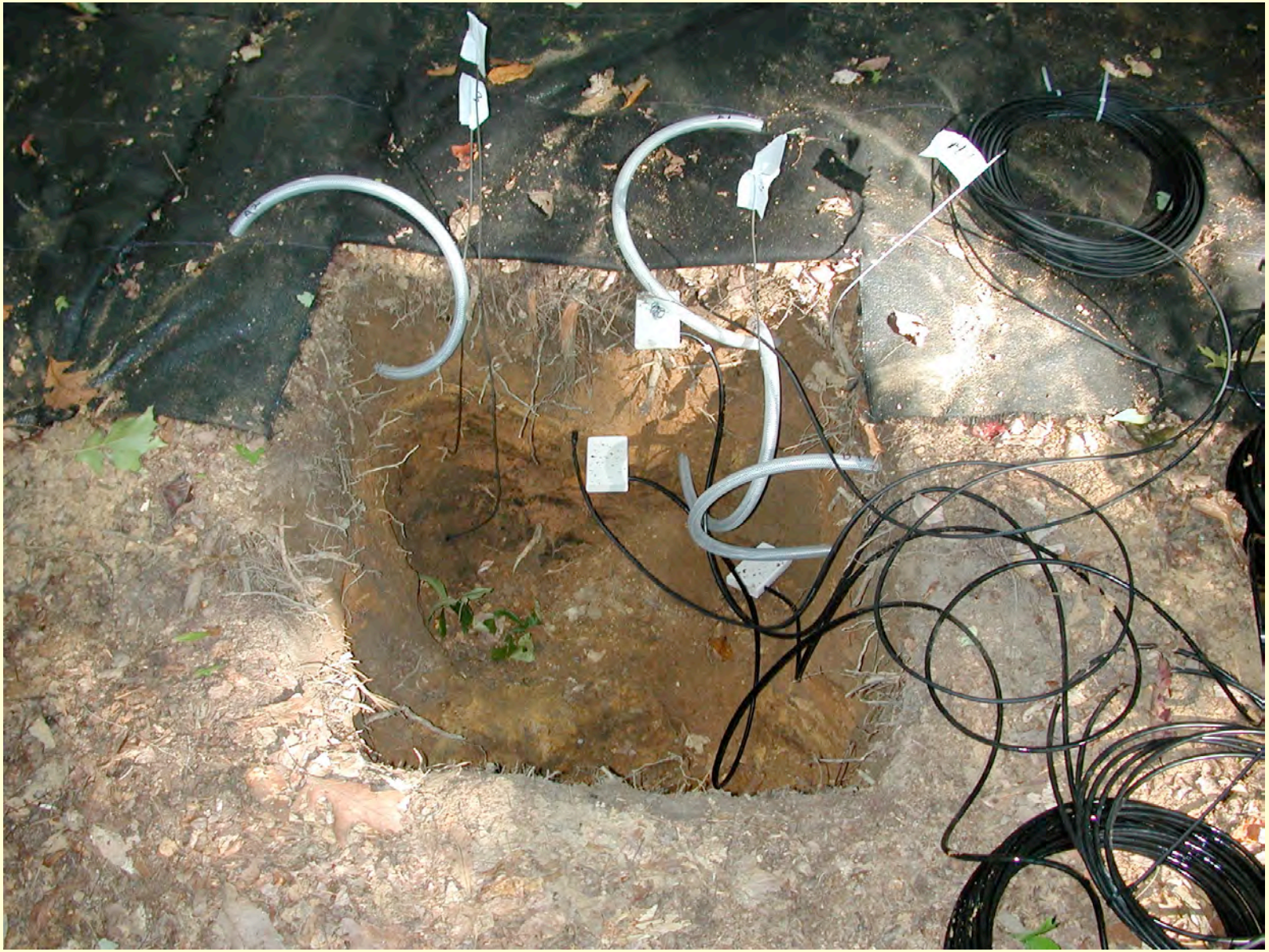
Replicate 7x7 m Plots Were Established at 4 Sites





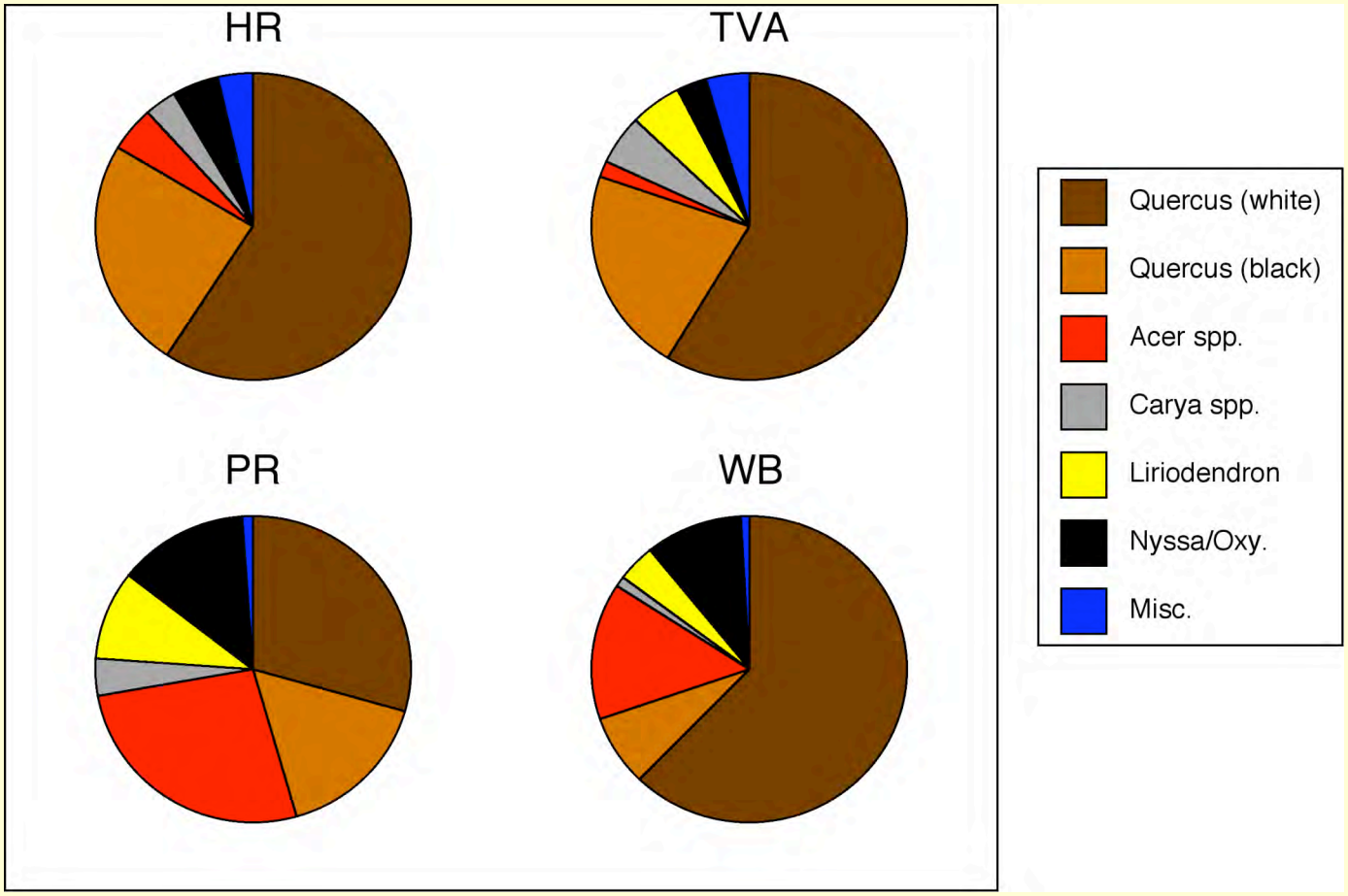
- **Eight plots were established at each site. Half receive enriched litter each year and the other half receive background litter. Ambient litterfall is excluded from all plots (see photo).**

PP



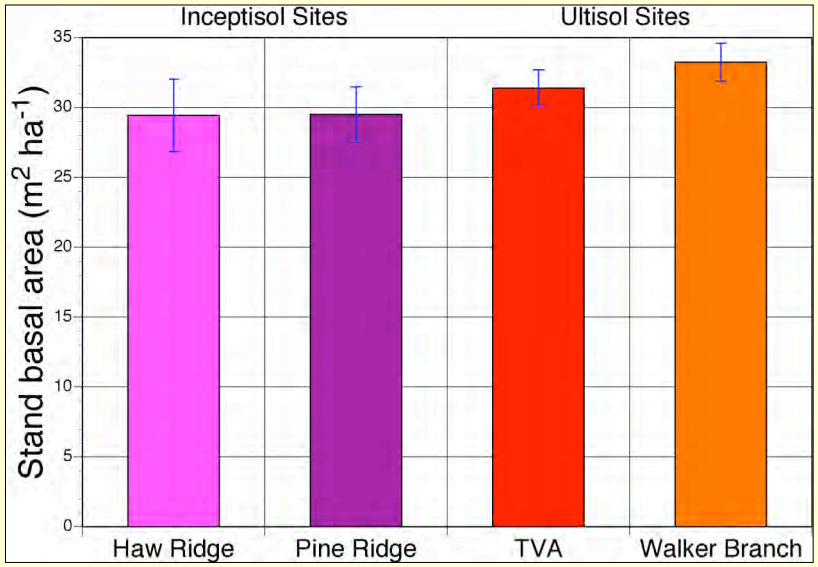
Quercus (oak) Dominated Forests

[*Acer* litter contributions on Pine Ridge could impact decomposition]

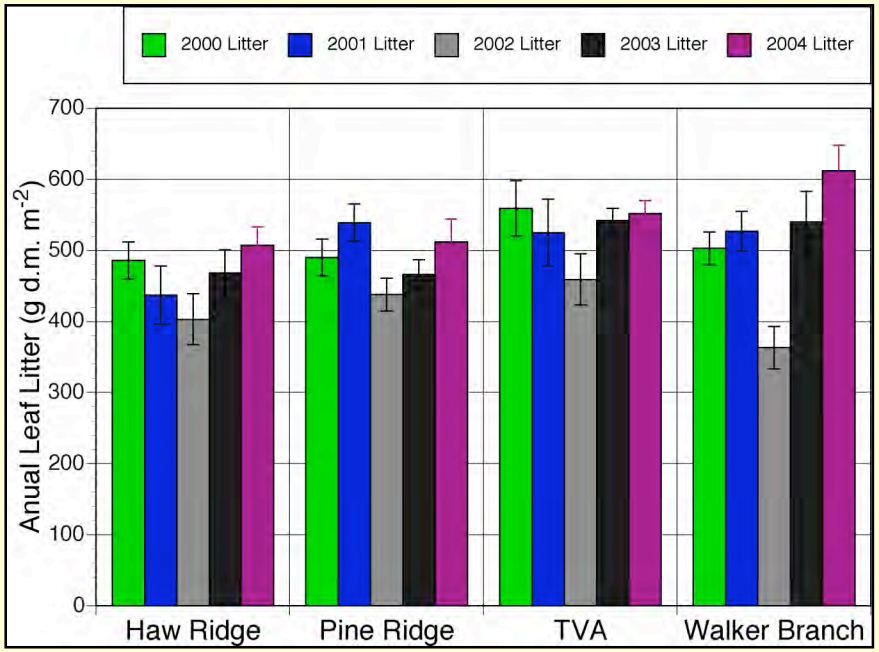


Similar Vegetation

Basal areas of all sites covered a limited range from 28 to 34 m^2 ha^{-1}

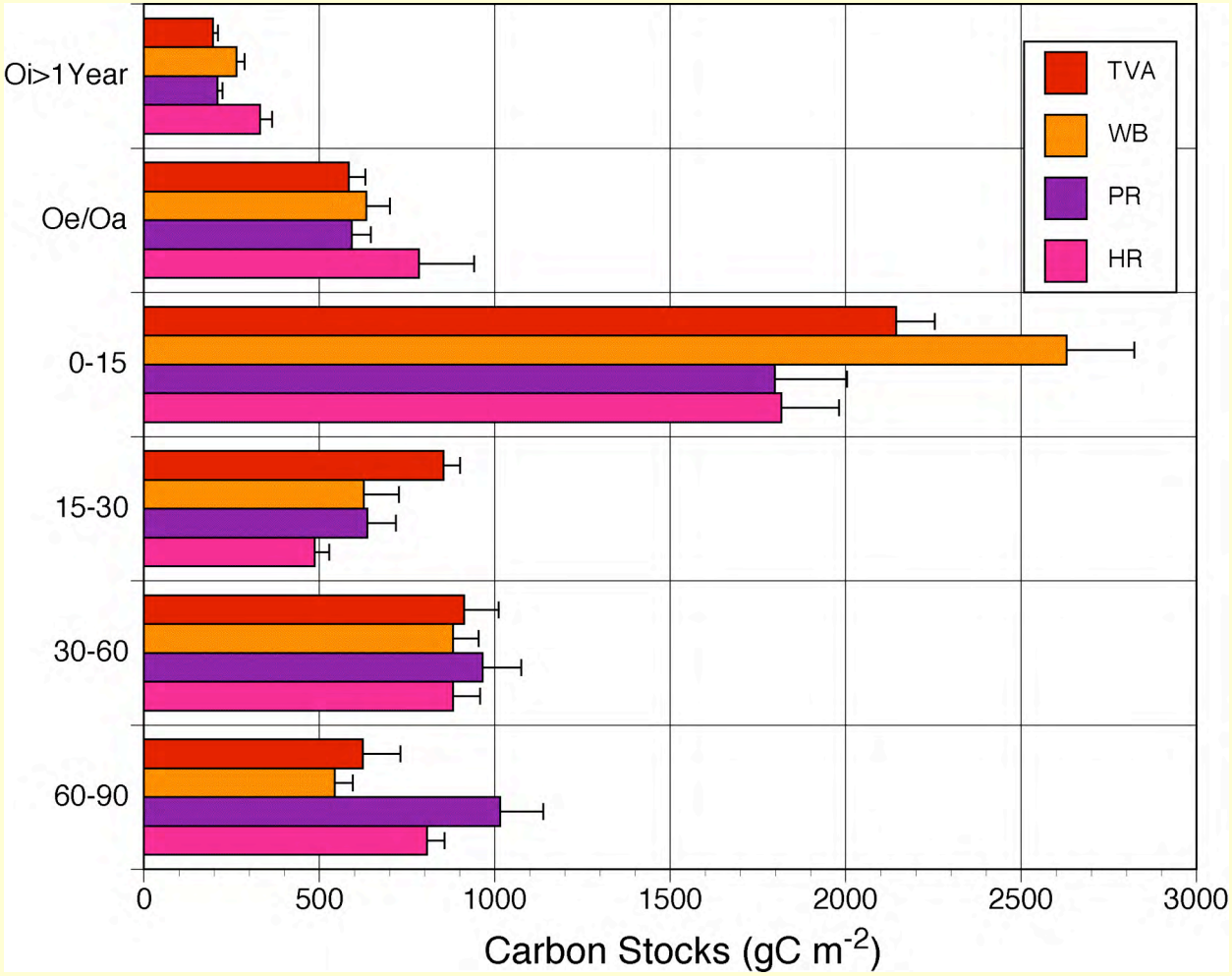


Foliar litter production at all sites is ~500 g m^{-2} y^{-1}



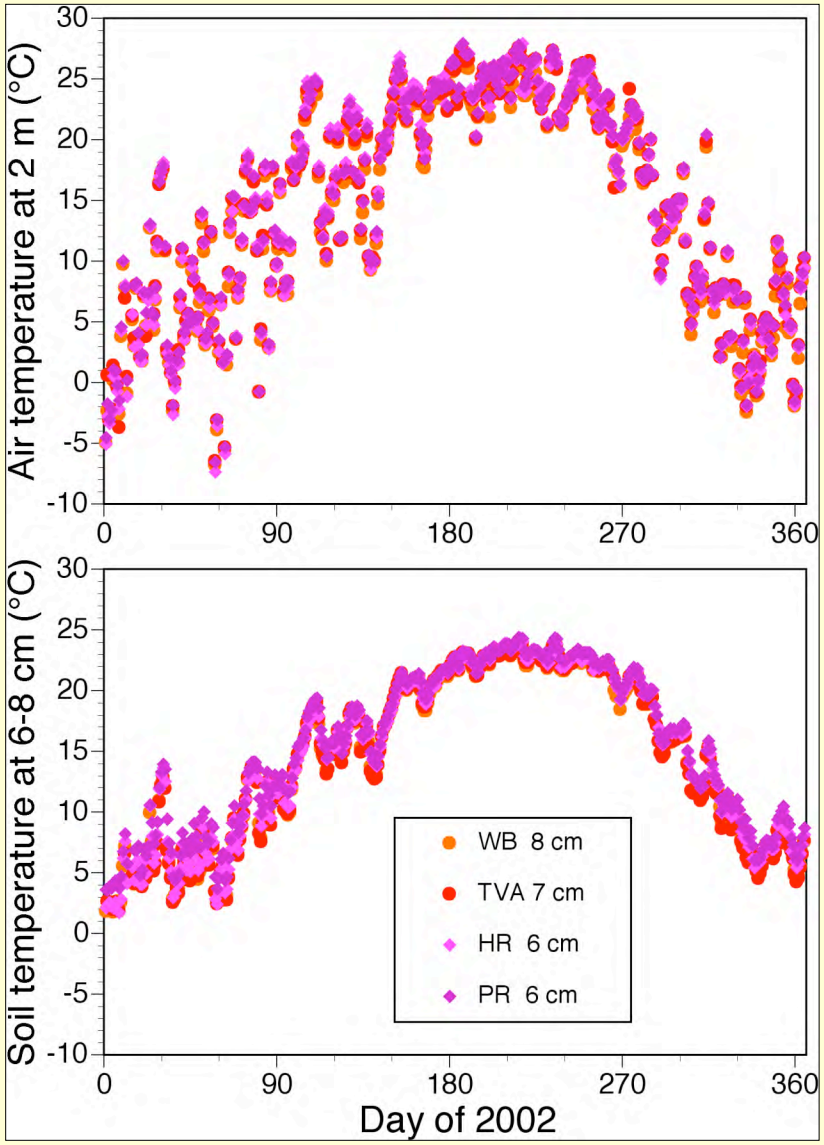
Site Bulk C Stocks

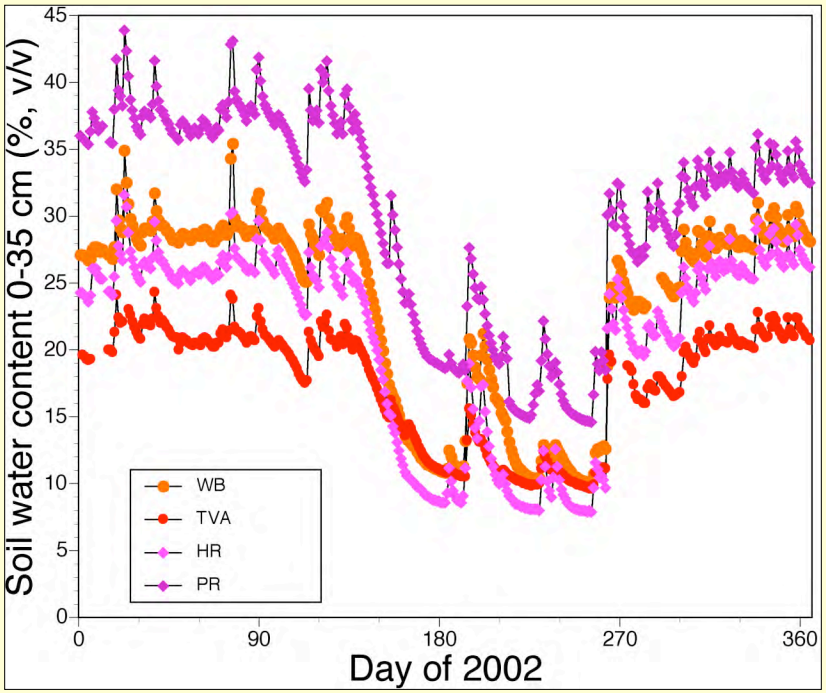
C.T. Garten, D. Todd and P.J. Hanson



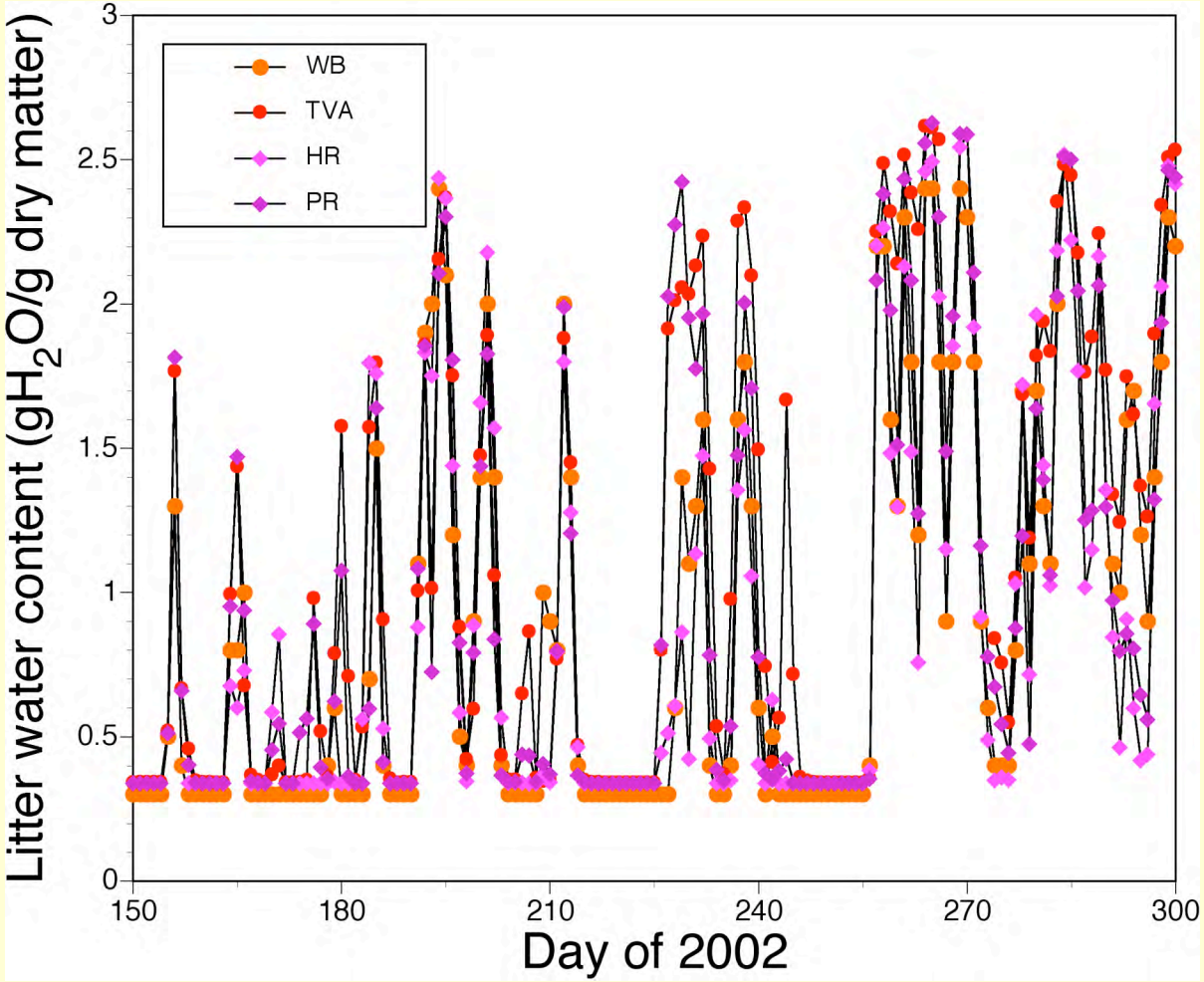
Environment

- **Similar air, litter and soil temperatures were found at all 4 sites.**
- **Water status of the soil and litter layer is also consistent among sites, but isolated summer rains can yield minor differences.**





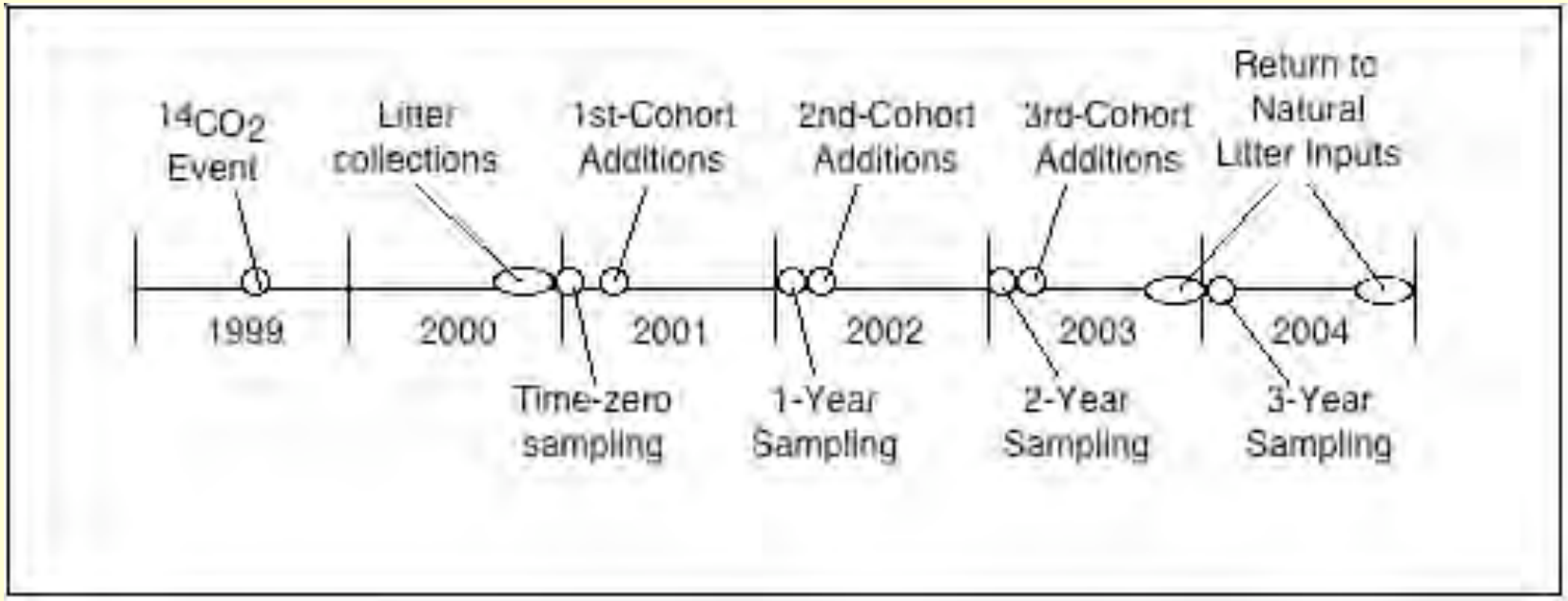
Litter-layer Water Content



EBIS Tasks and Responsible Institutions

- Operation of the experiment - ORNL
  - Field manipulations and environmental observations
  - Annual sampling for bulk changes - ORNL/LLNL
- ^{14}C Analyses - CAMS/LLNL
  - CAMS is accommodating more samples
  - Approximately 2500 samples run so far
- Components of soil respiration - UC-Irvine
  - Soil respiration and gas wells
- Fine root turnover - UC-Santa Cruz and BGFR
- Vertical transport
  - Dissolved organic carbon - ORNL
  - Macrobiota mediated - USFS/UGA
- Fate of mineral soil C in protected and unprotected forms
  - Aggregate-based separations - ANL
  - Density-based separations - LBNL/LLNL
- Integration and modeling
  - Rothamsted model - ORNL
  - Root turnover - LBNL, UC-Santa Cruz
  - Organic layer decomposition - ORNL, LLNL

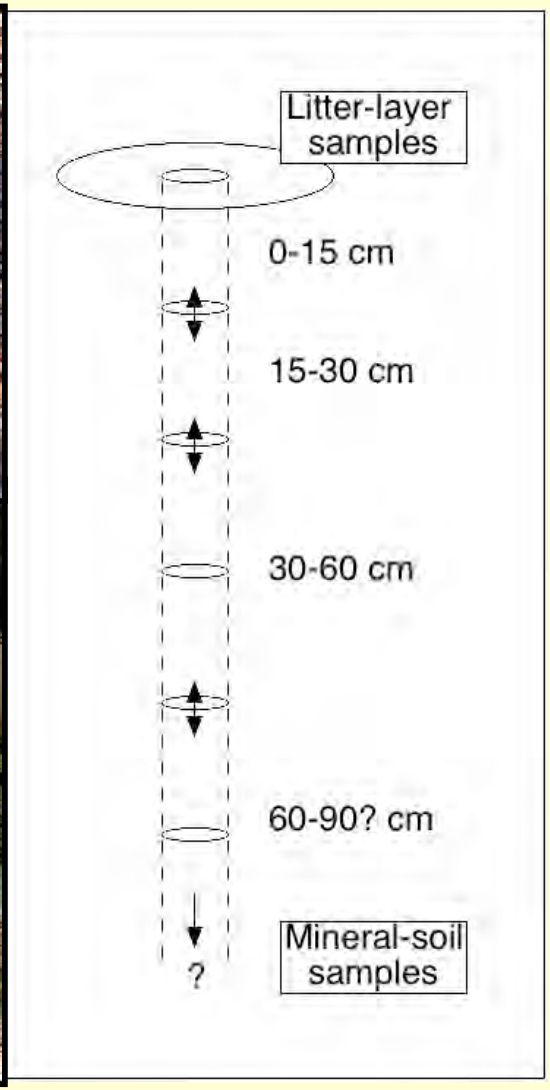
EBIS Experimental Activities to Date

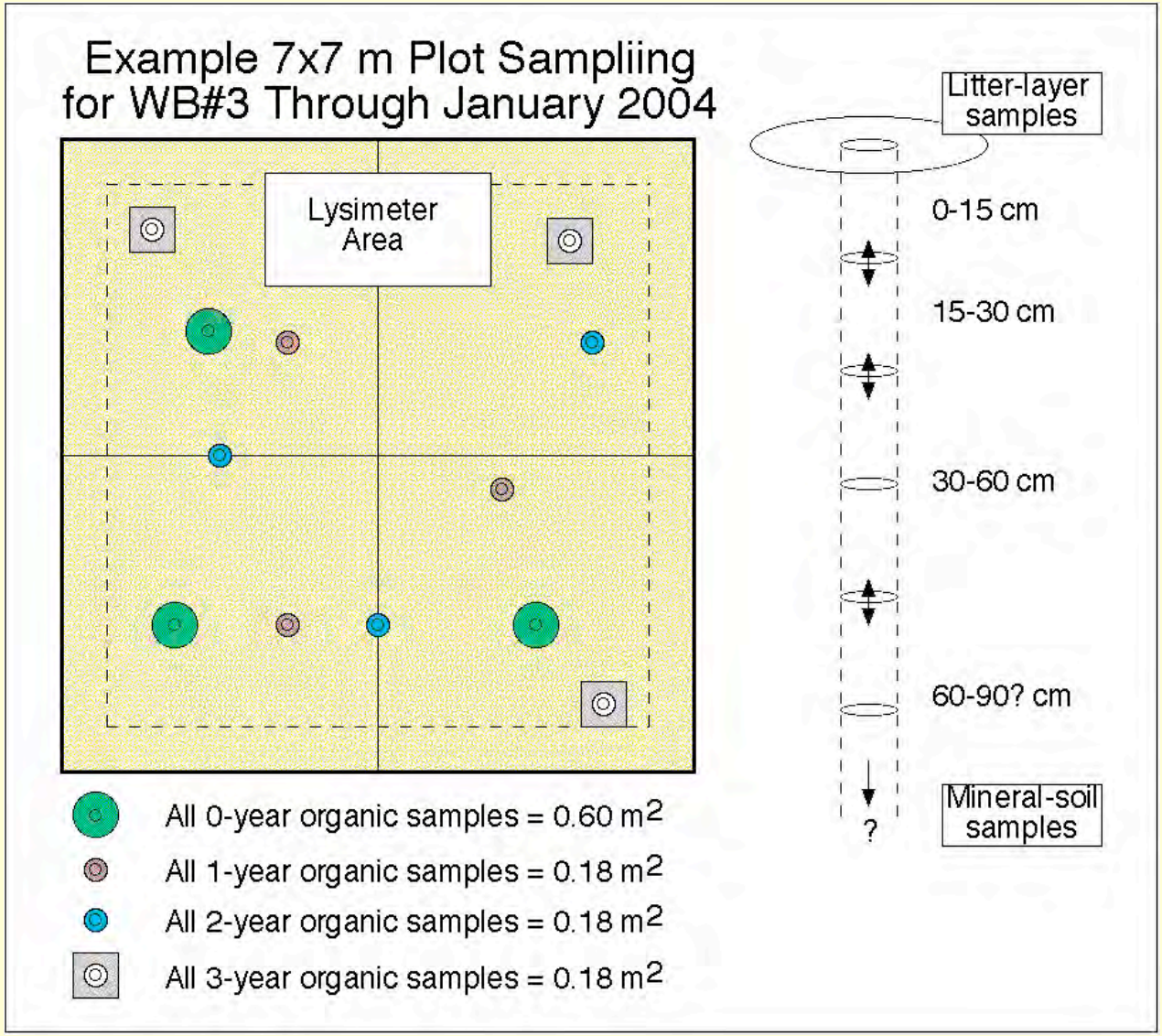


- **Startup funds obtained from DOE 2000/2001**
- **Experimental plots established Fall 2000**
- **DOE multi-institution science funding began Oct 2001**
- **Initial publication -- June 2002 Trumbore et al. EOS 84:265,267-8.**

Annual Sampling

(2000 Litter additions, O_i>1Y, O_e/O_a and Mineral Soils)





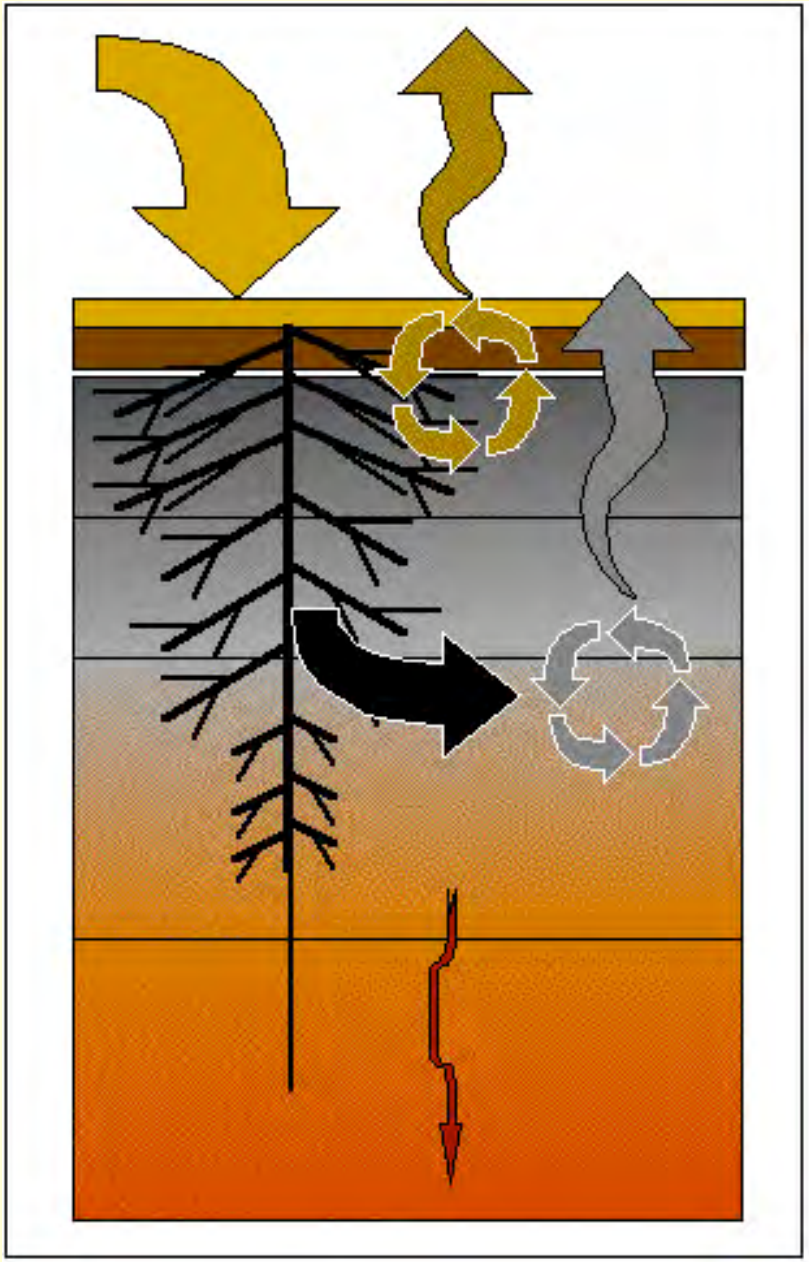
O_e horizon is minimal
0-15 cm is > A horizon

Depth of B horizon is highly variable

- **<4% of the organic and <0.3% of the mineral ground area have been sampled.**

EBIS: Recap

- Experimental progress
  - ^{14}C-Enrichment and ^{14}C-dilution experiments are being conducted at 4 sites on two soils.
  - Three annual cohorts of enriched or background litter have been added to the experimental plots.
- Conclusions
  - Black-box models of soil C flux are inadequate
  - Updated models of soil carbon loss and turnover will require additional layers of complexity to capture the fate of leaf and root litter inputs
    - Litter layers
    - Labile vs. recalcitrant mineral soil carbon pools
    - Root turnover
    - Vertical transport
  - Semi-independent organic and mineral soil C cycles might be considered.



Gaithersburg Follow-Up

- Post-workshop deliverables:
  - Posting of Irvine and Gaithersburg workshop presentations on the project web site – Completed January 2004.
  - Submission of Gaithersburg EBIS workshop report to DOE
  - Posting of EBIS core data sets on the EBIS project web sites for internal use by all project investigators – Password protected space made available, but not populated with data yet.
  - Submission of 6 new manuscripts on EBIS research to peer-reviewed journals by June 1, 2004.
  - Completion of a multi-authored EBIS project synthesis manuscript for submission to a high profile journal detailing the nature of soil carbon cycling under eastern deciduous hardwood forests and key hypotheses remaining to be tested – In progress
  - Prepare a renewal proposal for work in FY2006 and beyond – Deadline March 1, 2005.

Gaithersburg Follow-Up

- Follow-up Research Activities:
  - Complete the retrospective analysis of atmospheric 14C from an analysis of tree ring cellulose for all four EBIS research sites, and archived litter collections available for Walker Branch (1993 to date) and for each EBIS research site (2000 to date).
  - Conduct additional leaf and root litter leaching studies to further characterize differences in 14C-signatures between bulk-tissue and leachable C compounds.
  - Consider redesigning the 14C-air monitoring protocol to better sample daytime periods and canopy-level air to improve correlations with 14C in current photosynthate.
  - Develop an online project data archive to improve communication of results among project participants, and provide a mechanism for future data dissemination to the public.
  - Proceed with the necessary measurements and data synthesis to allow the use of full C, N, and 14C mass balance in the interpretation of EBIS results.
- Other issues mentioned
  - Analyze 0-15 cm mineral soil C for Y1, Y2, and Y3 (Garten)
  - Ditto for root tissues. Do we have older root tissues to serve as a reference?
  - Fractionation of Oe/Oa material**
  - Change air ^{14}C monitoring to capture canopy-level values**
  - Characterize throughfall C-inputs and ^{14}C-signatures** (not a big deal, but….)
  - N cycling and mass balance
  - Get Ameriflux CO_2 diurnal data set from the profile system for future use.

EBIS Publications

- Completed Publications (Project start date: October 1, 2001):
  - Trumbore S, Gaudinski JB, Hanson PJ, Southon JR (2002) A whole-ecosystem carbon-14 label in a temperate forest. EOS 83:265,267-268.
  - Swanston CW, Torn MS, Hanson PJ, Southon JR, Garten CT, Hanlon EM, Ganio L (2005) Initial characterization of processes of soil carbon stabilization using forest stand-level radiocarbon enrichment. Geoderma (in press).
  - Cisneros-Dozal LM, Trumbore SE, Hanson PJ (2005) Estimating sources of soil respired CO2 and their seasonal variation using a unique radiocarbon tracer. Global Change Biol (in press).
  - Hanson PJ, Swanston CW, Garten CT Jr., Todd DE, Trumbore SE (2005) Reconciling Change in Oi-Horizon 14C With Mass Loss for an Oak Forest. Soil Sci Soc Amer J (accepted pending minor revisions).
- In Review:
  - Joslin JD, Gaudinski JB, Torn MS, Riley WJ, Hanson PJ (2004-5) Unearthing live fine root turnover times in a hardwood forest: the roles of root diameter, soil depth, and root branching order. Biogeochemistry (submitted).
- Manuscripts in preparation:
  - Gaudinski JB, Riley WJ, Torn MS, Joslin JD, Trumbore SE, Majdi H, Hanson PJ (2005) Quantification of stored carbon reserves to new root and leaf growth in forested ecosystems using radiocarbon data. To be submitted to Ecological Applications jointly with MS below.
  - Riley WJ, Gaudinski JB, Torn MS, Swanston C, Hanson PJ (2005) Quantification of root lifespan in a forested ecosystem using a numerical model tested with locally released radiocarbon. To be submitted to Ecological Applications jointly with MS above.
  - Jardine PM, Todd DE, Palmer JA, Swanston C, Hanson PJ. Hydrogeochemical controls on the fate and transport of dissolved organic C in subsurface environments.