Enriched Background Isotope Study (EBIS): Analysis of ^{14}C-Enriched Carbon Cycle in Soils and Litter at Forested Oak Ridge and AmeriFlux Sites, 2001-2011

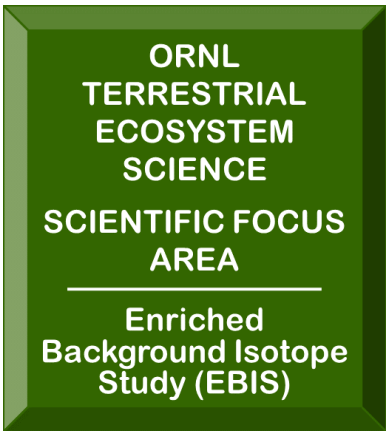

Table of Contents:

1. Data Set Overview:

Summary:

These data provide a record of the multi-year, multi-institutional Enriched Background Isotope Studies (EBIS) projects that ran from 2000 through 2011. Elevated levels of ^{14}C enriched CO_2 in the air and soil atmosphere as well as leaf, stem, and root tissues were observed on the Oak Ridge Reservations (ORR) during the summer of 1999, and were attributed to local incinerator activities on and/or near the ORR (Trumbore et al. 2002).

The isolated enrichment of the background levels of ^{14}C in local forest ecosystem represented a unique opportunity to study unresolved carbon cycling processes such as the contribution of leaf versus root litter contributions to soil carbon accumulation, the rate of vertical transport of carbon into deep soil storage pools, and the differential contribution of physicochemical versus faunal driven processes to soil carbon cycling and sequestration.

Leaf litter from the local enriched forest was transplanted to selected sites on the ORR and to selected AmeriFlux study sites to study soil C cycling across a range of soils and climates.

The EBIS research projects provide data on C flux from litter sources to mineral soil sinks for United States eastern hardwood forests necessary for testing process hypotheses and judging efficacy of soil C cycling models. Experimental results from this study are being used to parameterize and refine existing carbon dynamics models, the quantification of the long-term fate of ecosystem carbon inputs and as a means to judge the potential for ecosystem carbon sequestration via enhance litter inputs to soil.

EBIS observations support conclusions that intra- and inter-annual soil carbon cycling in hardwood forest soils should be characterized as a least a two-compartment system where surface leaf-litter and belowground root turnover represent primary carbon sources for organic-layer and mineral-soil carbon cycles, respectively.

EBIS experiments were conducted to complete enriched litterfall maniplations in upland forests on Ultisol and Inceptisol soils of the Oak Ridge Reservation, Oak Ridge, Tennessee. We also collected additional ^{14}C-enriched materials for new experimental applications, and applied those materials to multiple AmeriFlux sites over a range of climatic, edaphic and biological conditions.

The research provided data for addressing DOE's goal of understanding mechanisms controlling C flux, and for the improvement of models to be applied to policy discussions regarding the safe levels of greenhouse gases for the earth's system.

There are 5 data files provided in comma separated (*.csv) format for vegetation, field litter, soil and air [C] and C isotope data from the EBIS studies and associated environmental data.

Related Publications:

Portions of these have been reported in the following publications:

Cisneros-Dozal, LM, SE Trumbore, and PJ Hanson. 2007. Effect of moisture on leaf litter decomposition and its contribution to soil respiration in a temperate forest. Journal of Geophysical Research 112. https://doi.org/10.1029/2006JG000197

Cisneros-Dozal, LM, S Trumbore, And PJ Hanson. 2005. Partitioning sources of soil-respired CO2 and their seasonal variation using a unique radiocarbon tracer. Global Change Biology 12:194–204. https://doi.org/10.1111/j.1365-2486.2005.001061.x

Fröberg, M, PJ Hanson, SE Trumbore, CW Swanston, and DE Todd. 2009. Flux of carbon from 14C-enriched leaf litter throughout a forest soil mesocosm. Geoderma 149:181–188. https://doi.org/10.1016/j.geoderma.2008.11.029

Gaudinski, JB, MS Torn, WJ Riley, C Swanston, SE Trumbore, JD Joslin, H Majdi, TE Dawson, And PJ Hanson. 2009. Use of stored carbon reserves in growth of temperate tree roots and leaf buds: analyses using radiocarbon measurements and modeling. Global Change Biology 15:992–1014. https://doi.org/10.1111/j.1365-2486.2008.01736.x

Hanson, PJ, CW Swanston, CT Garten, DE Todd, and SE Trumbore. 2005. Reconciling Change in Oi-Horizon Carbon-14 with Mass Loss for an Oak Forest. Soil Science Society of America Journal 69:1492–1502. https://doi.org/10.2136/sssaj2004.0300

Heckman, KA, CW Swanston, MS Torn, PJ Hanson, LE Nave, RC Porras, U Mishra, and M Bill. 2021. Soil organic matter is principally root derived in an Ultisol under oak forest. Geoderma 403:115385. https://doi.org/10.1016/j.geoderma.2021.115385

Kramer, C, S Trumbore, M Fröberg, LM Cisneros Dozal, D Zhang, X Xu, GM Santos, and PJ Hanson. 2010. Recent (<4 year old) leaf litter is not a major source of microbial carbon in a temperate forest mineral soil. Soil Biology and Biochemistry 42:1028–1037. https://doi.org/10.1016/j.soilbio.2010.02.021

McFarlane KJ, Torn MS, Hanson PJ, Porras RC, Swanston CW, Callaham MA Jr., Guilderson TP (2013) Comparison of soil organic matter dynamics at five temperate deciduous forests with physical fractionation and radiocarbon measurements. *Biogeochemistry* 112:457-476, https://doi.org/10.1007/s10533-0212-9740-1

Parton, WJ, PJ Hanson, C Swanston, M Torn, SE Trumbore, W. Riley, and R. Kelly. 2010. ForCent model development and testing using the Enriched Background Isotope Study experiment. Journal of Geophysical Research 115. https://doi.org/10.1029/2009JG001193

Porras, RC, CE Hicks Pries, KJ McFarlane, PJ Hanson, and MS Torn. 2017. Association with pedogenic iron and aluminum: effects on soil organic carbon storage and stability in four temperate forest soils. Biogeochemistry 133:333–345. https://doi.org/10.1007/s10533-017-0337-6

Trumbore, S, JB Gaudinski, PJ Hanson, and JR Southon. 2002. Quantifying ecosystem-atmosphere carbon exchange with a 14C label. Eos, Transactions American Geophysical Union 83:265. https://doi.org/10.1029/2002EO000187

Data Citation:

Cite this data set as follows:

Hanson, PJ, DE Todd, JR Phillips, CT Garten, CW Swanston, KJ McFarlane, & J Le Moine. 2024. **Enriched Background Isotope Study (EBIS): Analysis of 14C-Enriched Carbon Cycle in Soils and Litter at Forested Oak Ridge and AmeriFlux Sites, 2001-2011**. Oak Ridge National Laboratory, TES SFA, U.S. Department of Energy, Oak Ridge, Tennessee, U.S.A. https://doi.org/10.25581/ornlsfa.020/1638590.

2. Data Characteristics:

This data set contains 5 comma separated (*.csv) files:

- **EB_AMER_Environment_20240308.csv**
  - AmeriFlux site data for soil temperature and moisture, litter temperature. EBIS-AmeriFlux sites.
- **EB_TN_Environment_20240308.csv**

  - Oak Ridge sites data for air temperature and humidity, soil temperature and moisture profiles, and litter temperature. EBIS-Oak Ridge project sites.
- **EB_AMER_SoilLitter_Analyses_20240308.csv**
  - AmeriFlux sites data on organic and mineral soil mass, tissue C, N and C:N ratios and the 14C-isotopic signature of the soil horizons over time. EBIS-AmeriFlux sites.
- **EB_TN_SoilLitter_Analyses_20240308.csv**
  - Oak Ridge sites data on organic and mineral soil mass, tissue C, N and C:N ratios and the ^{14}C-isotopic signature of the soil horizons over time. EBIS-Oak Ridge project sites.
- **EB_TN_Vegetation_20240308.csv**
  - Oak Ridge plot vegetation data collected at the beginning of the project in 2001 and again in 2003 and 2005. The data provide documentation of the site vegetation closed canopy forest at the time of the study. One file for EBIS-Oak Ridge with annual resolution.

Spatial Coverage

EBIS sites were located at the Oak Ridge Reservation in East Tennessee and at four AmeriFlux tower sites.

Site	Associated Site Abbreviations	Current AmeriFlux Site Name	EBIS Site Name	State	Coordinates
Oak Ridge Reservation	Includes the subsites: WB = Walker Branch, TVA = Tennessee Valley Authority, PR = Pine Ridge, HR = Haw Ridge	N/A	Oak Ridge Reservation (ORR)	TN	35.962 N, -84.275 W
AmeriFlux	MI-UMBS and MI-UMBS FT	US-UMB: Univ. of Mich. Biological Station	Biological Station	MI	45.559 N, -84.714 W
AmeriFlux	MA-HF	US-Ha1: Harvard Forest EMS Tower (HFR1)	Harvard Forest	MA	42.535 N, -72.172 W
AmeriFlux	NH-BEF	US-xBR: NEON Bartlett Experimental Forest (BART)	Bartlett Forest	NH	44.065 N, -71.288 W

AmeriFlux	MO	US-MOz: Missouri Ozark Site	Missouri Ozark	MO	38.744 N, -92.200 W

Temporal Coverage

At AmeriFlux sites: 2010-11-12 to 2011-11-10
At Oak Ridge Sites: 2001-10-03 to 2005-12-31

Measurements were made in hourly intervals across the study period.

Data File Description

These data are considered at **Quality Level 1**. Level 1 indicates an internally consistent data product that has been subjected to quality checks and data management procedures.

Missing values numeric values are represented by '-9999' and missing text values are represented by 'N/A'.

Data dictionary for *EB_AMER_Environment_20240308.csv*

Column Name	Units	Additional Description
Order		Row order
Year	YYYY	Year
Lat	Decimal degrees	Latitude of the research site
Long	Decimal degrees	Longitude of the research site
Soil_type		Standard soil series names
Project		Name of the project
Site		Name of the site: NH-BEF, MA-HF, MI-UMBS, MO
YFOY	YYYY.xxxx	Fractional value of time of year
DOY	1 to 366	day of the year
HOD	0 to 23	Hour of the day (two digits, e.g. '12')
DFOY	DOY.xxxx	Fractional value of day of the year
T_Oi_Litter	Degrees C	Temperature of the Oi litter layer
TS_10cm	Degrees C	Soil temperature at – 10 cm
SW_10cm	percent	Soil water content at -10 cm represented as a percent

Data dictionary for *EB_TN_Environment_20240308.csv*

Column Name	Units	Description
Order		Row order
Year	YYYY	Year
Lat	Decimal degrees	Latitude of the research site
Long	Decimal Degrees	Longitude of the research site
Soil_type		Standard soil type name
Project		Name of the project
Site		Name of the site: WB = Walker Branch, TVA = Tennessee Valley Authority, PR = Pine Ridge, HR = Haw Ridge
YFOY	YYYY.xxxx	Fractional value of time of year
DOY		Sequential day of the year
HOD		Hour of the day (three or four digits, e.g., '1200')
DFOY	DOY.xxxx	Fractional value of day of the year
U_Air_T	Degrees C	Understory temperature at approx. 1 m
U_RH	percent	Understory relative humidity at approx. 1 m
T_Oi_Litter	Degrees C	Temperature of the Oi litter layer
TS_6cm	Degrees C	Soil temperature at – 6 cm
TS_31cm	Degrees C	Soil temperature at -31 cm
SW_6cm	percent	Soil water content at -6 cm
SW_31cm	percent	Soil water content at -31 cm
LWC	g H_2O g dry litter -1	Water content of the litter layer by DC Half Bridge

Data dictionary for *EB_AMER_SoilLitter_Analyses_20240308.csv*

Column Name	Units	Description
Order		Row order

Column Name	Units	Description
Year	YYYY	Year
Lat	Decimal degrees	Latitude of the research site
Long	Decimal degrees	Longitude of the research site
Soil_type		Standard soil type name
Project		Name of the project
Site		Name of the AmeriFlux site: MA-HF = Harvard Forest, NH-BEF = Bartlett Forest, MI-UMBS = Biological Station, MI-UMBS FT ,MO = Missouri Ozark
Plot		Plot number within site
Plot_type		Designation for the treatment plots. Litter or Humus
Date	YY-MMM	Date of sample collection
Soil_layer		Layer name: Litter YYYY, Oi>1Y = newest Oi layer, OeOa organic layer , 0-05 cm depth, 05-15 cm depth, 15-30 cm depth, 30-45 cm depth , 45-60 cm depth, 60-75 cm depth
Sampled_area	m2	Area sampled for the organic soil layers
Sample_volume	cm3	Volume of soil sampled
Organic_mass	g	Dry mass of the organic sample
Organic_mass_per_area	g m-2	Dry mass of organic matter by layer
Ref_soil_mass	g	Reference soil dry mass for analytical assessments
Rocks	g	Dry mass of rock material
Rock_vol	g cm-3	Volume of rocks not considered soil after 2 mm sieving
AD	g cm-3	Soil density of the samples sent for chemical analyses
BD	g cm-3	Traditional bulk density that ignores large rocks
Delta_14C	Per mil	Δ^{14}C-signature of the sieved sample.
Delta_13C	Per mil	δ^{13}C-signature of the sieved sample.
C	Percent	[C] percent of C in the sample by mass
N	Percent	[N] percent of N in the sample by mass
C_N_ratio	Ratio	Ratio of [C] to [N] in the sample
Notes		Various notes on sample status or handling

Column Name	Units	Description
Chem_sample_ID		Identifying code for chemical sample
Chem_sample_number		Number of the Chemical sample analysis for tracking

Data dictionary for *EB_TN_SoilLitter_Analyses_20240308.csv*

Column Name	Units	Description
Order		Row order
Year	YYYY	Year
Lat	Decimal degrees	Latitude of the research site
Long	Decimal Degrees	Longitude of the research site
Soil_type		Standard soil type name
Project		Name of the project
Site		Name of the site: WB = Walker Branch, TVA = Tennessee Valley Authority, PR = Pine Ridge, HR = Haw Ridge
Plot		Plot number within site
Treatment		Designation for the treatment plots. Ambient or Enriched.
Date		Date collected (month and year)
Soil_layer		Soil layer name: Oi = fresh litter, Oi>1Y = newest Oi layer, OeOa organic layer, 0-15 cm depth, 15-30 cm depth, 30-60 cm depth,60-90 cm depth, or Alternate final depth in cm
Mass	g	Raw dry mass collected
Sampled_area	m2	Area sampled for the organic soil layers
Sample_volume	cm3	Volume of soil sampled
Organic_mass_per_area	g m-2	Dry mass of organic matter by layer

Column Name	Units	Description
Ref_soil_mass	g	Reference soil dry mass for analytical assessments
Mass_per_vol	g cm-3	Dry mass of soil layer by volume
2mm_soil_mass	g	Dry mass of 2 mm sieved sample
Frac_2mm		Fraction of total soil mass that is in the 2mm size class or smaller
Rocks	g	Dry mass of rock material
C_ref_density	g cm-3	Soil density of the samples sent for chemical analyses
Trad_BD	g cm-3	Traditional bulk density that ignores large rocks
True_BD	g cm-3	True bulk density that includes large rocks
Rock_vol	g cm-3	Volume of rocks not considered soil after 2 mm sieving
Big_rock_vol	g cm-3	Volume of extra large rocks that were pulled from the sample prior to sieving
Delta_14C	Per mil	Δ^{14}C-signature of the sieved sample.
Delta_13C	Per mil	δ^{13}C-signature of the sieved sample.
C	%	[C] percent of C in the sample by mass
N	%	[N] percent of N in the sample by mass
C:N	Ratio	Ratio of [C] to [N] in the sample

Data dictionary for *EB_TN_Vegetation_20240308.csv*

Column Name	Units	Description
Order		Row order
Year	YYYY	Year
Lat	Decimal degrees	Latitude of the research site
Long	Decimal degrees	Longitude of the research site
Soil_type		Standard soil type name
Project		Name of the project

Column Name	Units	Description
Site		Name of the site: WB = Walker Branch, TVA = Tennessee Valley Authority, PR = Pine Ridge, HR = Haw Ridge
Plot		Fixed plot number at a site values range from 1 to 8
Plot_radius	m	Radius of the plot in meters
Tag_num		Tree tag number to identify individual trees measured in 2001, 2003 and 2005
Spc		Species designations: Buck = Buckthorn, Cercis = Cercis canadensis, DG = dogwood, GB = Gum black, H = Hickory, MR = maple red, OC = oak chestnut, OR = oak red group, OW = oak white, SW = Sourwood, YP = Yellow Poplar
Diam_cm	cm	Tree diameter at 1.3 meters
Tree_BA	m2 tree-1	Tree basal area in m2
Plot_area	m2 plot-1	Area of the surveyed forest plot.
Plot_BA	m-2 ha-1	Basal area contribution to the plot
Notes		Various notes on individual observations.

3 Applications and Derivation

These data aid in improving our understanding mechanisms controlling C flux, and for the improvement of models to be applied to policy discussions regarding the safe levels of greenhouse gases for the earth's system.

4. Quality Assessment:

These data are considered at **Quality Level 1**. Level 1 indicates an internally consistent data product that has been subjected to quality checks and data management procedures. Established calibration procedures were followed.

5. Data Acquisition Materials and Methods:

The EBIS projects litter transplant manipulation to study soil C cycling across a range of soils and climates.

EBIS-Oak Ridge Layout and Sampling Protocol

At four sites on the ORR encompassing two soil types and two levels of ^{14}C exposure in 1999, we established 8 replicated permanent plots for the manipulation of forest litter through reciprocal transplants of enriched versus near back ground litter among sites. Annual sampling of soils enabled us to investigate C transport throughout the soil horizons. By replicating the litter transplant study on two soil types (Inceptisol, Ultisols) we addressed the influence of soil chemical and physical properties on all these issues.

Sampling plan -- Eight 7m x 7m plots were destructively sampled for organic and mineral soil horizons annually in 2000 (time zero), 2001 (1-year), 2002 (2-year), 2003 (3-year) and 2004 (4-year). Three enriched litter cohorts (500 g m^{-2}) were added in early 2001, 2002 and 2003 following that year's sampling. Organic layers sampled included collected current year litterfall or the prepared substitutes, an Oi layer >1 year of age isolated beneath landscape cloth, and the subtending OeOa layer. Mineral soil depths sampled included 0-15, 15-30, 30-60 and 60-90 cm or as deep as could be reached at a given coring location. Each year 3 randomly selected coring locations were sampled within the interior 6m x 6m area of each defined plot area. These subsamples were pooled for analyses. Over the entire destructive sampling sequence only 4.1% of the organic layer and <0.4% of the mineral soil useable sample area within each plot (6m x 6m) was sampled.

Environmental monitoring – A single monitoring stations was located at each of the 4 sites for the EBIS-Oak Ridge study at which was measured understory air temperature and relative humidity at approximately 1m, Oi litter layer temperature, mineral soil temperatures at -6 and -31 cm, and soil water content at -6 and -31 cm. Litter layer water content was also assesses using DC half bridge techniques (Hanson et al. 2003).

EBIS-AmeriFlux Layout and Sampling Protocol

At each of the four new sites (Table 1) 5 randomly distributed 2m x 2m plots were established as replicated permanent plots for the manipulation of forest litter (i.e., litter plots). An additional 1m x 1m plot was collocated with each of these 5 plots for assessment of enriched humus transfers into the subtending soil horizons (Humus plots). Annual sampling of soils enabled us to investigate C transport into the soil horizons.

Soil sampling plan – The five 2m x 2m Litter and 1m x 1m humus plot locations were destructively sampled annually in 2007 (time zero sampling adjacent to plot area), 2008 (1-year), 2009 (2-year), 2010 (3-year) and 2011 (4-year). Three enriched litter cohorts (500 g m^{-2}) were added to the litter plots in 2007, 2008 and 2009 following that year's sampling. Only a single addition of enriched humus was added to the Humus plots after time zero sampling in 2007.

Organic layers sampled included collected current year litterfall or the prepared substitutes, an Oi layer >1 year of age isolated beneath landscape cloth, and the subtending OeOa layer. Mineral soil depths sampled included 0-15, 15-30, 30-60 and 60-90 cm or as deep as could be reached at a given coring location. A single randomly selected coring locations was sampled within the interior 2m x 2m Litter and 1m x 1m Humus plots. Over the entire destructive sampling sequence from 2008 through 2011 only 5.7% of the organic layer and 0.8% of the mineral soil area was sampled in the Litter plots, and only 9% of the organic layer and 3.2% of the mineral soil area of the Humus plots.

Environmental monitoring – A single monitoring stations was located at each of the 4 sites for the EBIS-AmeriFlux study. At each of these locations we measured litter layer temperature, soil temperature at a depth of -10 cm and soil water content from approximately 0 to -10 cm.

6. Related References:

Hanson, PJ, EG O'Neill, MLS Chambers, JS Riggs, JD Joslin, and MH Wolfe. 2003. Soil Respiration and Litter Decomposition. North American Temperate Deciduous Forest Responses to Changing Precipitation Regimes:163–189. https://doi.org/10.1007/978-1-4613-0021-2_10

7. Data Access:

Get Data

For public access to data from the US Department of Energy Terrestrial Ecosystem Science Scientific Focus Ares (TES-SFA) please visit: **https://tes-sfa.ornl.gov/node/80**