Fine Root Production and Mortality From ^{15}N Tracer Studies

(and some other stuff on soil ^{13}C-abundance)

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Fine Root Production and Mortality

- Mass balance ^{15}N tracer method (Hendricks et al., 1997)
  - Labeling soil plots with enriched ^{15}N
  - Temporal measurements
    - mass of N in fine root structural pool (m_i and m_f)
    - ^{15}N in fine root structural pool ($^{15}N_i$ and $^{15}N_f$)
    - ^{15}N in available soil N pool ($^{15}N_p$)
- Mass of N added to fine roots via production

$$M_p = m_f\,(^{15}N_f - {}^{15}N_i)/(^{15}N_p - {}^{15}N_i)$$

- Mass of N removed from fine roots via mortality

$$M_m = [(m_i)(^{15}N_i) + (m_f)(^{15}N_p) - (m_i)(^{15}N_p) - (m_f)(^{15}N_f)] \,/\, (^{15}N_i - {}^{15}N_p)$$

Conditions and Assumptions

- Does not account for fine roots that complete their entire life cycle between initial and final root sampling dates
- ^{15}N concentration of available soil N ($^{15}N_p$) must be different from ^{15}N concentration of fine root structural pool ($^{15}N_i$)
- We assume that ^{15}N additions do not alter fine root dynamics
- Multiple small additions of ^{15}N tracer in 2004 added 0.54 g N m^{-2} to study plots (annual wet deposition is 0.63 g N m^{-2})
  - 4 applications: March 23, April 19, May 10, June 7
    - 0.38 g $^{15}NH_4NO_3$ m^{-2}; 5.7 atom% ^{15}N
  - Last application: July 6
    - 0.0375 g $^{15}NH_4Cl$ m^{-2}; 99 atom% ^{15}N

Field Methods

- Labeled eight 1-m^2 plots with ^{15}N at each study site
- Began initial root sampling mid-August 2004
- Combined four O-horizon samples and four soil cores (0-16 cm) from each plot
- Buried 2 anion exchange resin bags in each plot
  - Baker Analyzed IONAC® NA-38; OH^- form; capacity 236 mg g-1 IER^-
- Buried 2 cation exchange resin bags in each plot
  - Baker Analyzed Dowex® 50W-X8; H^+ form; capacity 36 mg g-1 IER
- Repeated sampling late-November 2004
- Scheduled resampling April 2005

Laboratory Methods

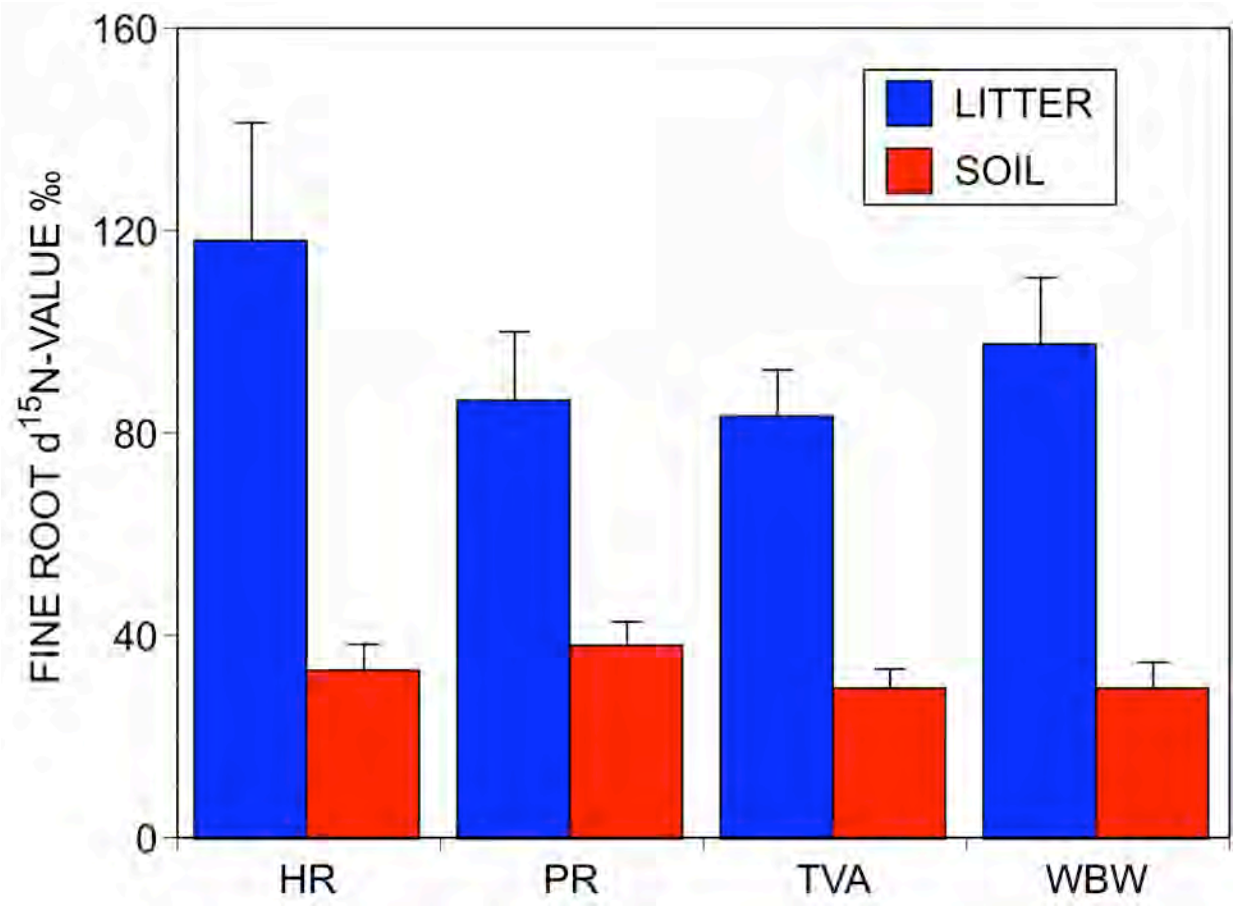
- Washed IERs with deionized water, dried (70 °C), IRMS analysis to determine ^{15}N concentration of available soil N ($^{15}N_p$)
  - Anion exchange resin is 3.29% N ($\delta^{15}N$-value = 0.75 ‰)
  - Cation exchange resin is N-free
- Separated roots from O-horizon and mineral soil samples by hand (labor intensive)
  - Gently washed roots in Na hexametaphosphate (5 g L^{-1}) to remove adhered soil particles
  - Further separated fine roots (<2 mm) from coarse roots (>2 mm)
  - Oven dried roots and calculated dry mass (g m^{-2})
  - Analyzed dry roots for ^{15}N (preliminary measurement)
- Boiling water extraction (3 hours) will be used to isolate fine root structural pools (residue) for ^{15}N analysis

Initial Root Biomass and Root N Pool (Aug. 2004)

Study site	Horizon	Root biomass ($g\ m^{-2}$)	Fine root biomass ($g\ m^{-2}$)	Fine root nitrogen ($g\ N\ m^{-2}$)
HR	O-horizon	58 ±22	58 ±22	0.72 ±0.26
	Mineral soil	897 ±112	407 ±41	2.80 ±0.31
PR	O-horizon	62 ±14	62 ±14	1.07 ±0.26
	Mineral soil	1082 ±126	565 ±41	3.99 ±0.24
TVA	O-horizon	63 ±18	63 ±18	0.83 ±0.26
	Mineral soil	984 ±97	584 ±66	4.18 ±0.53
WBW	O-horizon	29 ±8.6	29 ±8.6	0.46 ±0.14
	Mineral soil	1320 ±228	517 ±61	3.45 ±0.40

Initial Root ^{15}N (Aug. 2004)

- Successfully labeled fine roots in both O-horizon and mineral soil
- Elevated ^{15}N ≈10 to 100 times over natural abundance levels



Available Soil ^{15}N (Nov. 2004)

IER	Variable	HR	PR	TVA	WBW
Cation (NH_4-N)	$\delta^{15}N$ ‰	45.7 ±10.5	94.7 ±15.8	34.9 ±3.6	26.1 ±9.3
	mg N g^{-1}	0.45 ±0.06	0.87 ±0.09	0.42 ±0.02	39 ±0.03
Anion (NO_3-N)	$\delta^{15}N$ ‰	3.5 ±0.3	3.1 ±0.3	6.1 ±2.3	3.3 ±0.7
	mg N g^{-1}	16 ±1	18 ±0.3	16 ±0.5	16 ±0.5

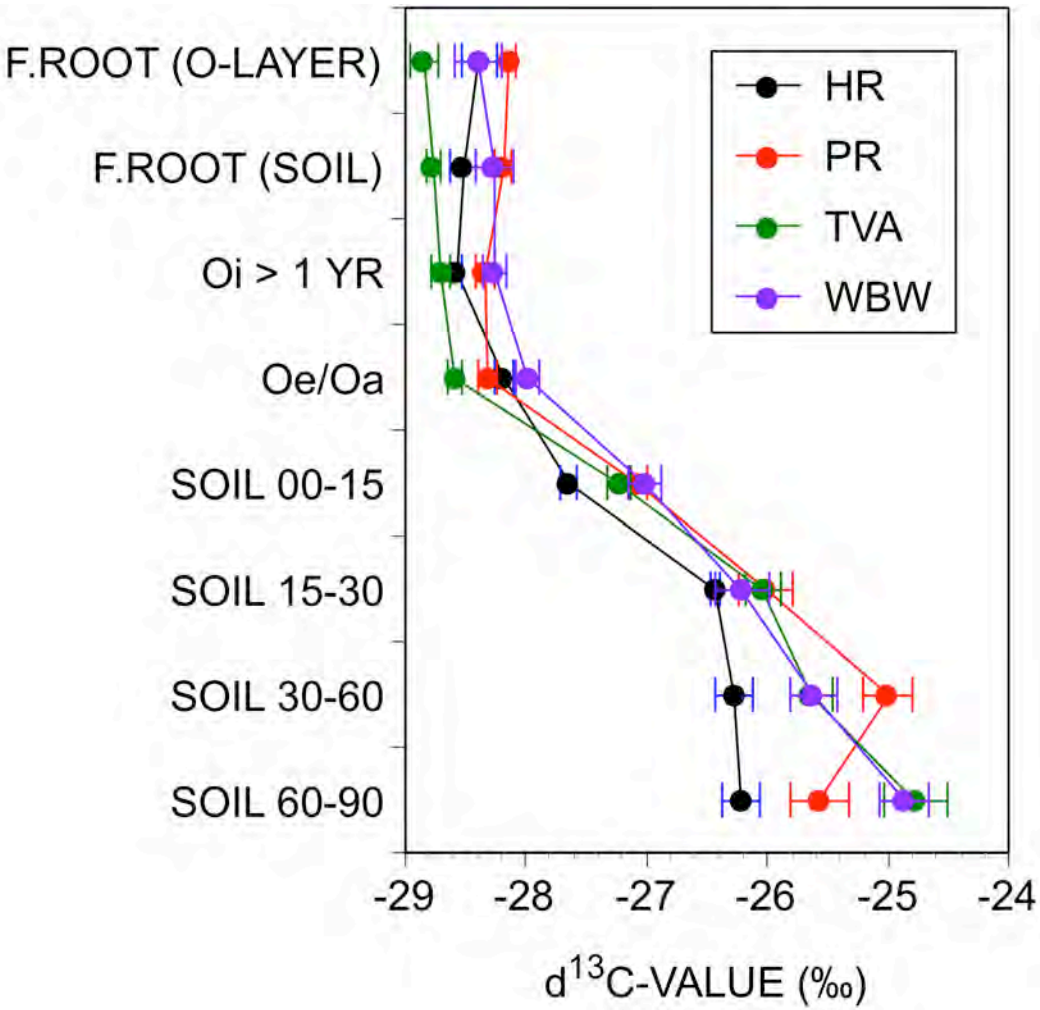
- N amounts on ion exchange resins in November were <8% of capacity
- Cation resins contain more ^{15}N than anion exchange resins (consistent with low soil nitrification rate) … no indication of anion ^{15}N enrichment
- Natural abundance of ^{15}N in extractable soil ammonium is ≈4 to 5 ‰

Remaining Tasks

- Repeat sampling of remaining plots (4 per site) in Apr. 2005
- Hand separate roots from O-layers and mineral soil samples collected in Nov. 2004 and Apr. 2005
- Analyze ion exchange resins from Apr 2005 collections (n = 32)
- Isolate fine root structural pools
  - August samples (n = 32)
  - November samples (n = 16)
  - April samples (n = 16)
- Analyze fine root structural pools for [N] and d^{15}N (August, November, and April samples, n = 64)
- Calculate fine root production and mortality (Aug. - Nov.; Nov. - Apr.)

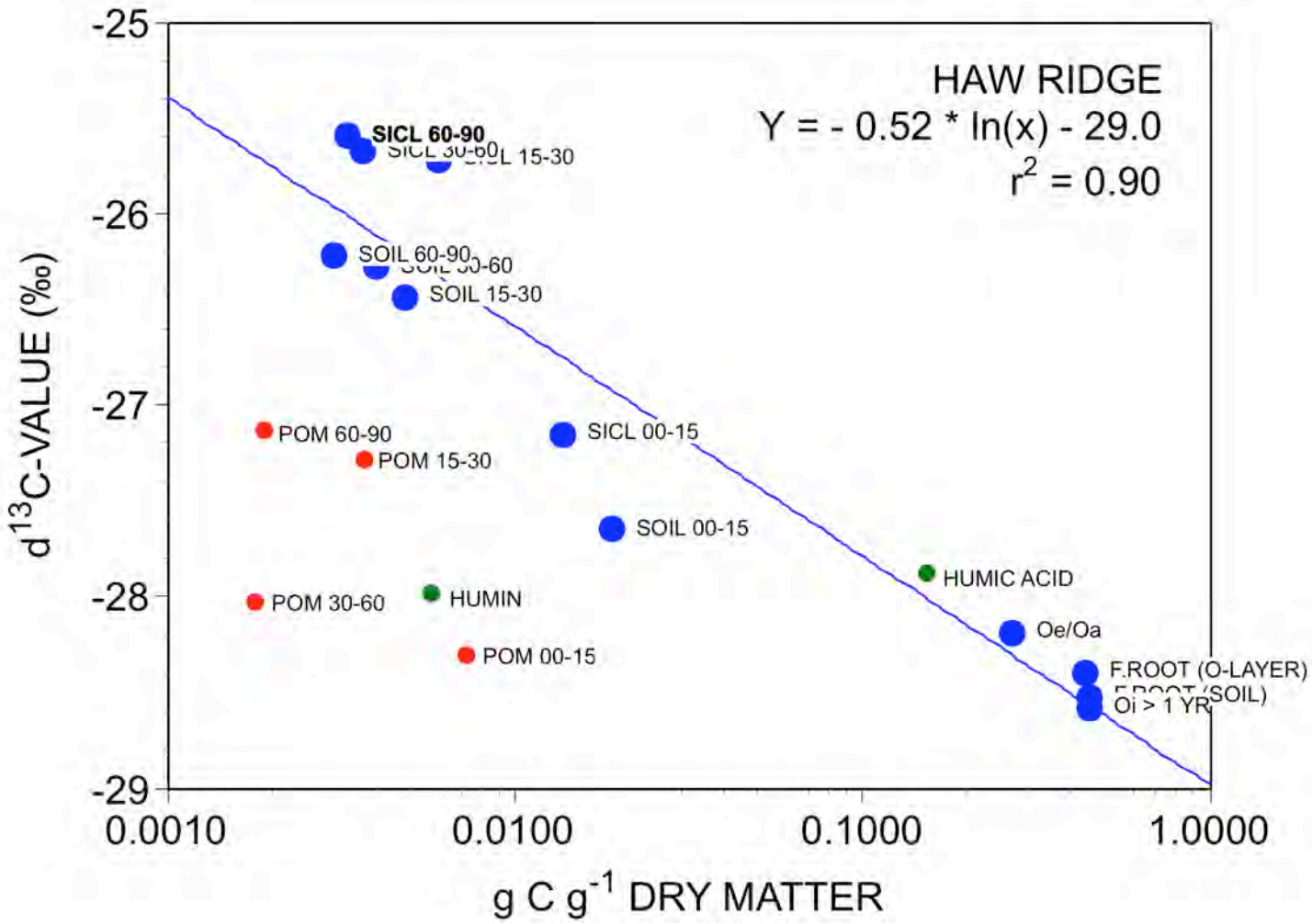
Additional samples available from each site to track fate of added ^{15}N
(1) O-horizon
(2) Surface mineral soil

Vertical Profile ^{13}C-abundance

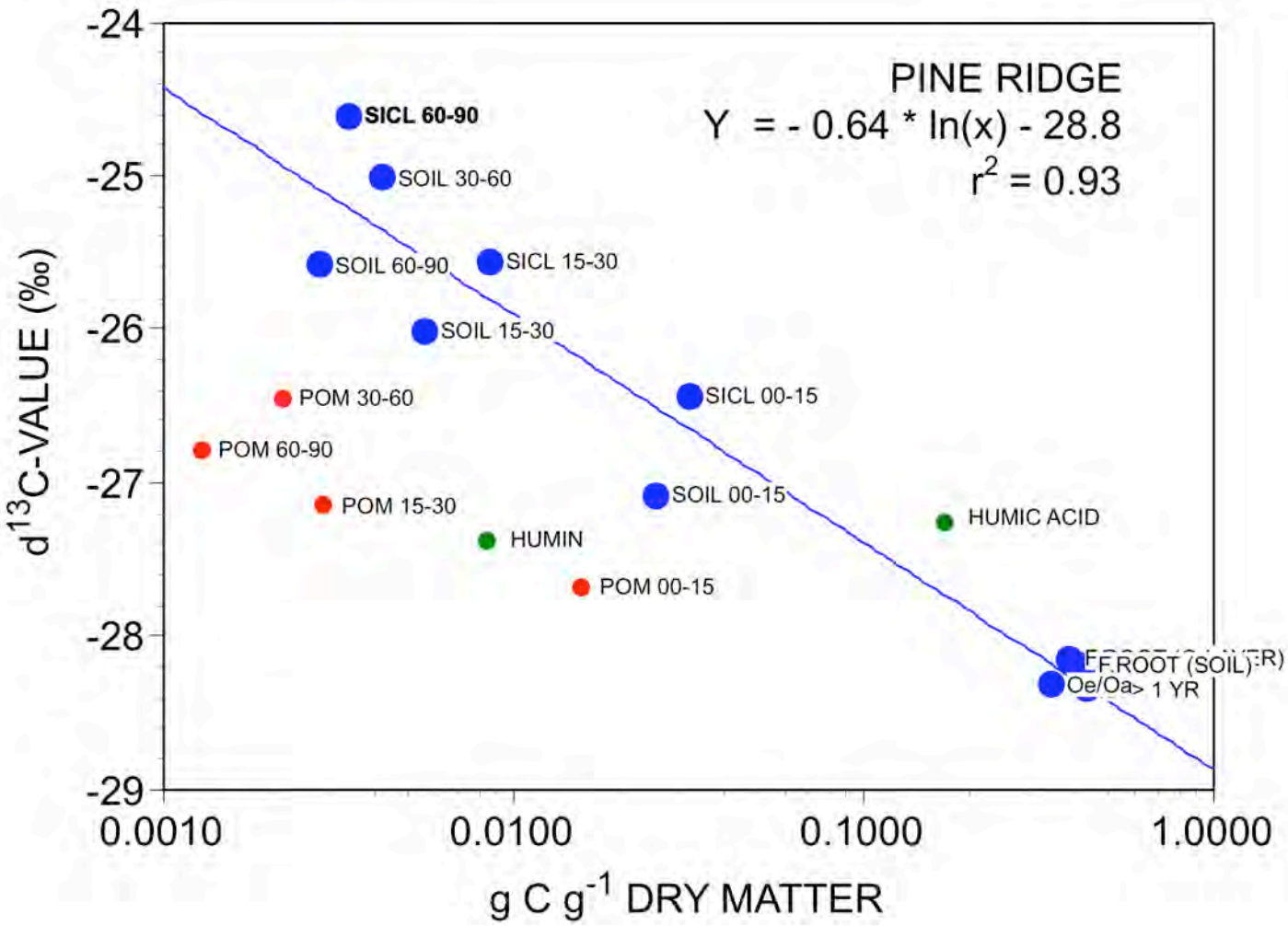


- ^{13}C-abundance increases with soil depth
- ^{13}C increases along a continuum from fresh C inputs to old, highly stable soil C
- Significant nonlinear regression between $\delta^{13}C$ and [C]
- Regression can be used to estimate end-members (“old” and “new” SOC)

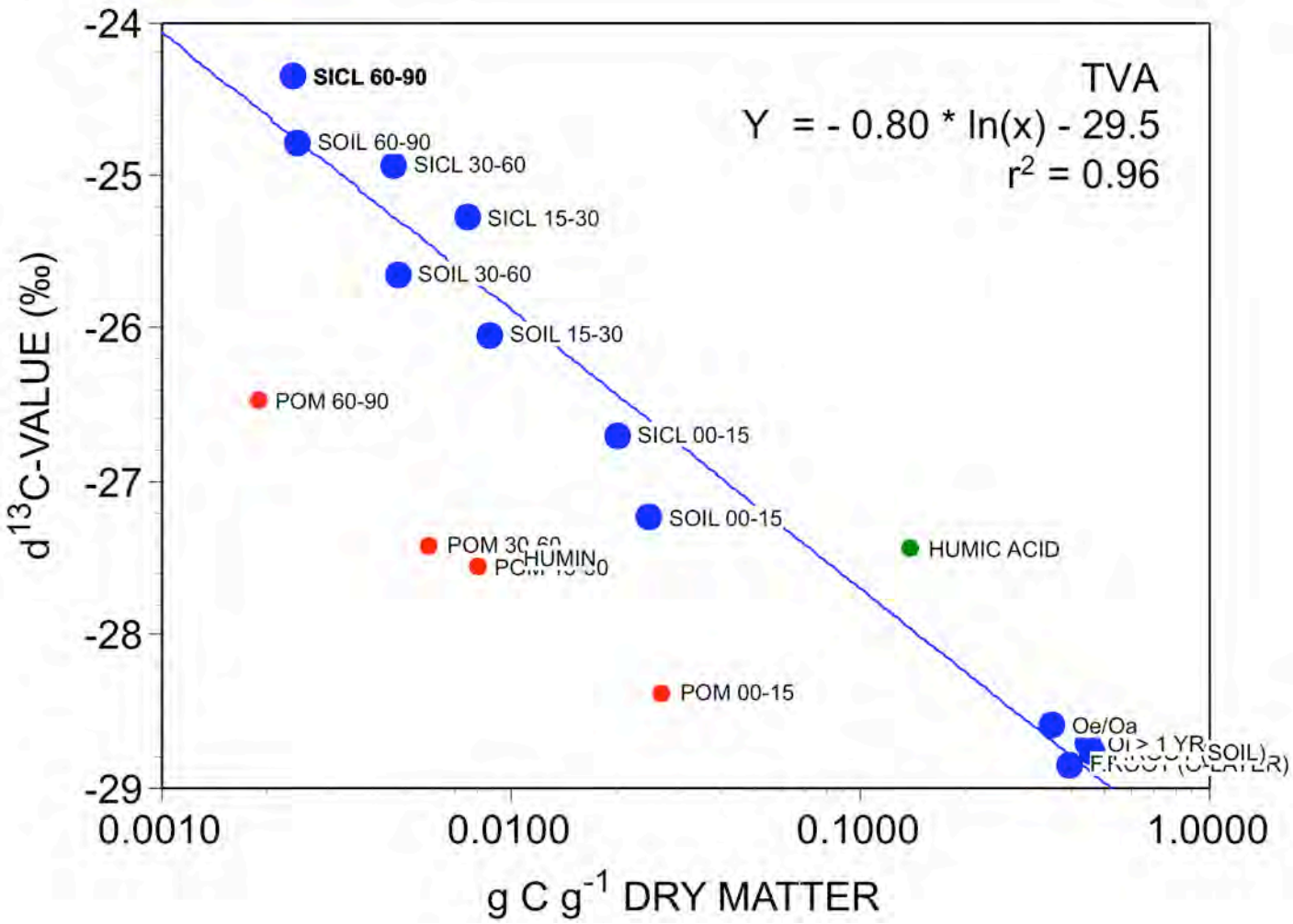
Regression at Haw Ridge



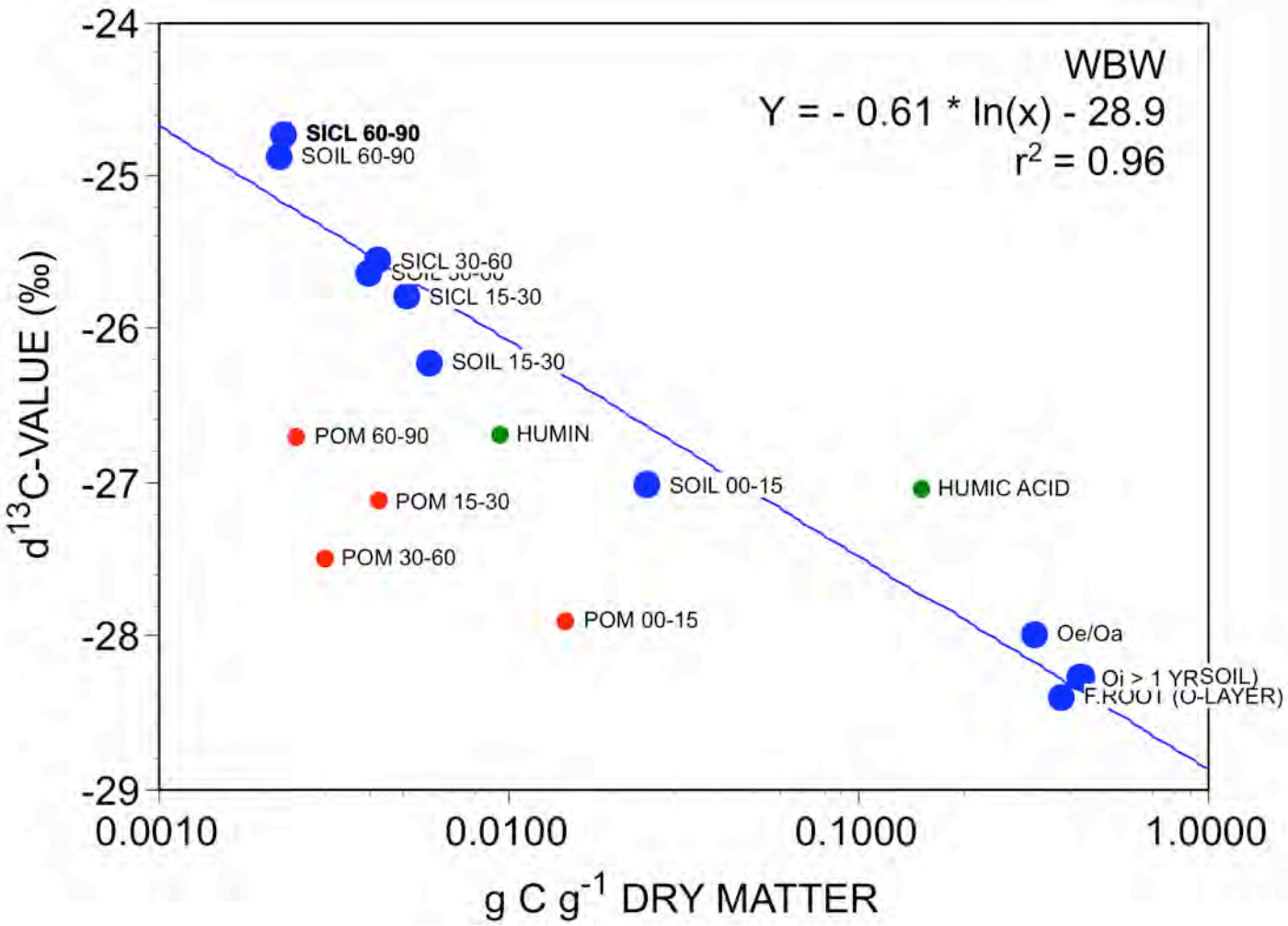
Regression at Pine Ridge



Regression at TVA

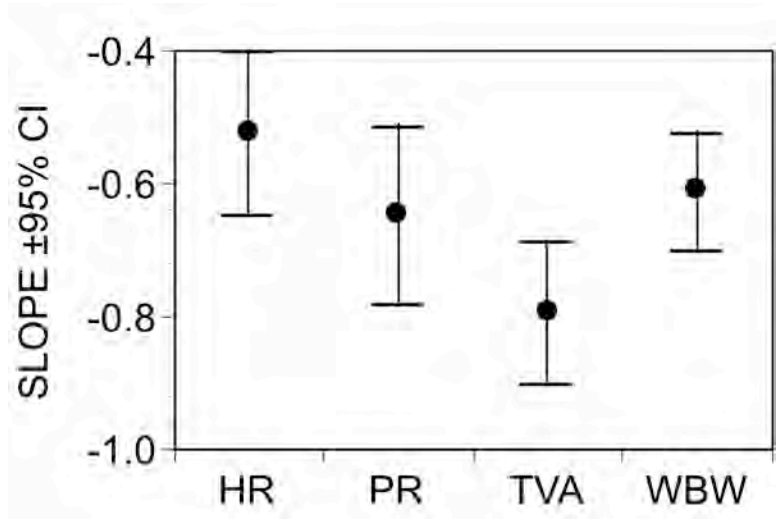


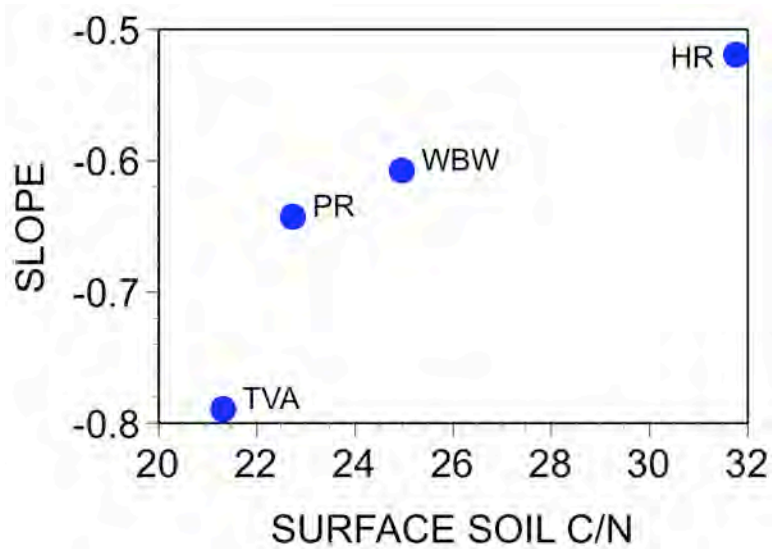
Regression at Walker Branch



Differences Between Sites

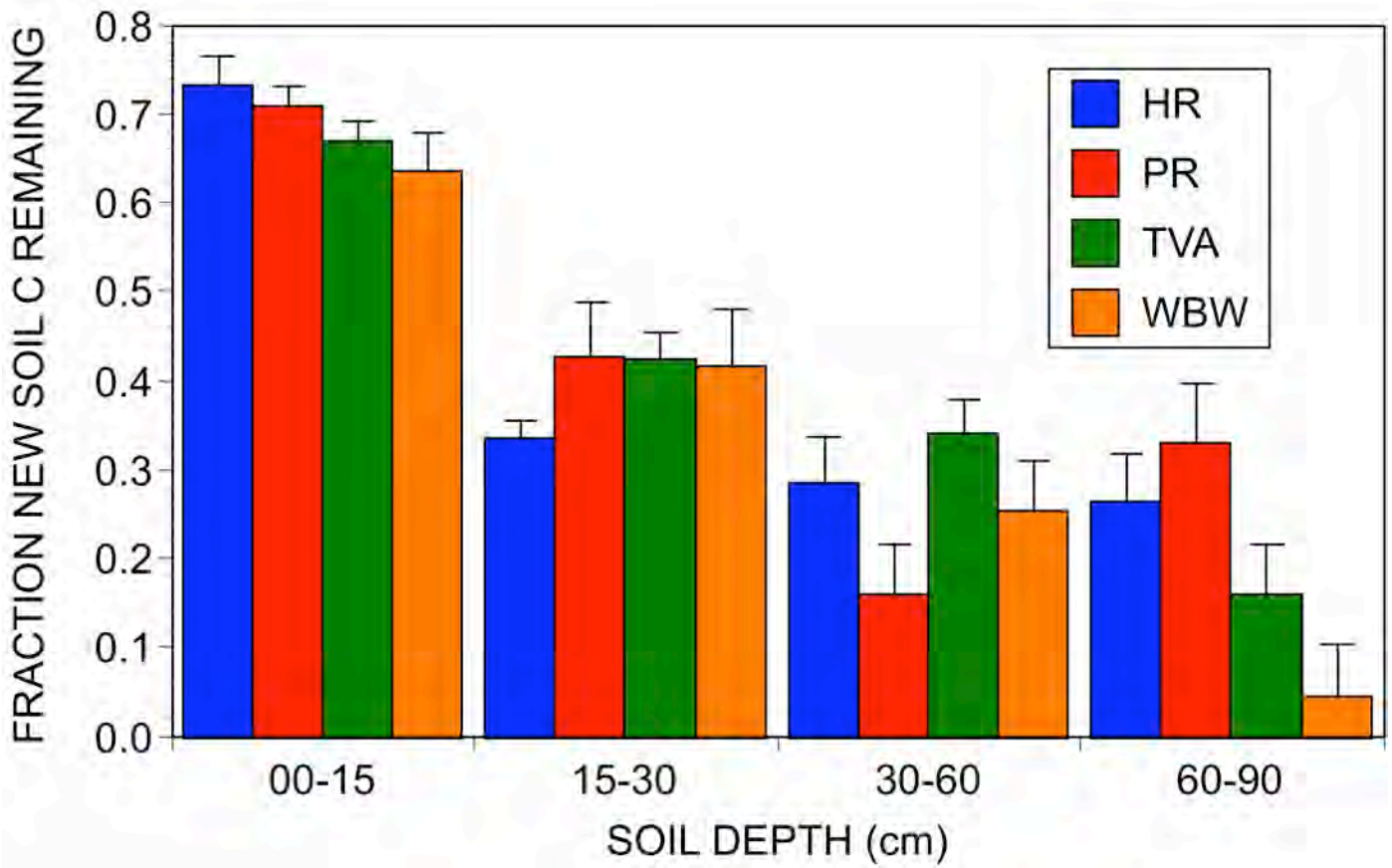
- Previous work indicates that the slope of the regression varies with climate and litter quality (C:N ratio)
- Lower litter C:N ratios are associated with more negative slopes (greater change in $\delta^{13}C$ per unit change in [C])
- More new C remaining at the terminus of decomposition at sites with higher C:N ratios (lower litter quality)
- Need additional data on C:N ratios, $\delta^{13}C$-values, and $\delta^{15}N$-values in leaf litterfall inputs at the 4 sites





Calculated Fraction New C Remaining vs. Soil Depth

- Mixing model with two end members: new C inputs and “old” soil C
- A larger fraction of soil C at depth (60-90 cm) at HR and PR is “new” C



Summary

- Successfully labeled roots in O-horizons and surface mineral soil for determination of fine root production and mortality
- Plan to have estimates at the four sites for two periods:
  - August - November (end of growing season)
  - November - April (beginning of growing season)
- Analysis of stable C isotopes may indicate:
  - relative differences in OM decomposition at the four sites
  - Relative amounts of “old” and “new” C at various soil depths
- Future analysis of stable N isotopes may indicate relative differences between sites in soil N availability (forest sites with greater N availability tend to have more positive δ^{15}N-values in leaf litterfall)