Task 3a: Transport and sequestration of dissolved organic C in contrasting soils amended with C-14 enriched leaf litter

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Objectives

- **Use ^{14}C enriched litter as a well defined source to quantify dissolved organic C flux through soil profiles as a function of storm events.**

- **Quantify the impact of coupled hydrological and geochemical processes on the fate and transport of dissolved organic C through contrasting soil profiles being used in the Enriched Background Isotope Study at ORNL.**

- **Quantify the mechanisms that control enhanced carbon accumulation within deep subsoils of forested Ultisols and Inceptisols.**

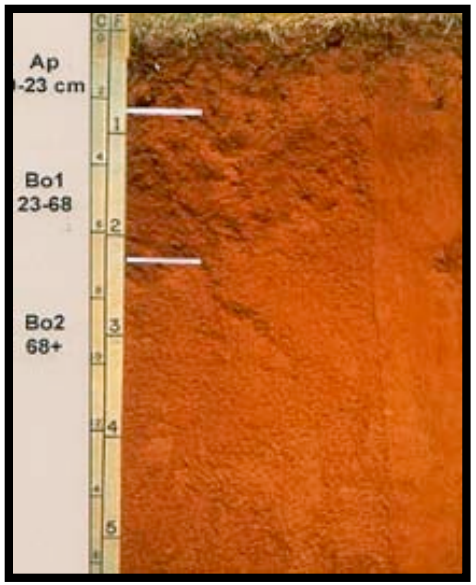
Background

Widespread, highly developed mature soils such as Ultisols and some Inceptisols have deep soil profiles that have a tremendous capacity to sequester organic C that has been made soluble from surface horizons.

Mineral stabilized organic C within the subsoil decreases the rate of carbon turnover by orders of magnitude relative to upper A/B and E/B horizons.

Competing geochemical and hydrologic processes (e.g. sorption and micropore protection vs. preferential flow and biodegradation) control organic C accumulation or loss through soil profiles.

Ultisol devoid of organic C due to agricultural abuse



Ultisol enriched with organic C through improved management technologies

Example of deep profile organic C sequestration

Anthropogenically enriched soil of the Amazon

Adjacent unenriched soil

These soils are from the same physiographic position and have the same clay content and clay mineralogy. The soil on the left was enriched by ancient human occupation centuries ago; the right is unenriched. This illustrates that such soil enrichments can be maintained for several centuries.

Approach

- Two background and two enriched plots from each of the four EBIS sites (16 plots) were each instrumented with four tension lysimeters and four tension-free lysimeters. Two of each type were placed within the A- and B-horizons of the soil profiles (8 samplers per plot).

- Besides the addition of enriched and background litter, a nonreactive Br tracer was evenly applied over each of the instrumented areas using a backpack sprayer (i.e. distributed initially to the soil matrix porosity).

- Solution samplers were monitored during all storm events and analyzed for Br, TOC, inorganic anions, and pH. Numerous select samples were analyzed for ^{14}C.

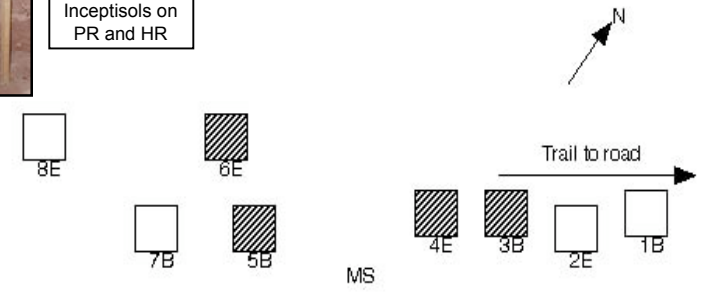
- Bulk soil samples from each plot were characterized for select physical and chemical properties and organic C sorption isotherms were quantified for each subsoil.

Monitoring scheme

Inceptisols on PR and HR

Inceptisols

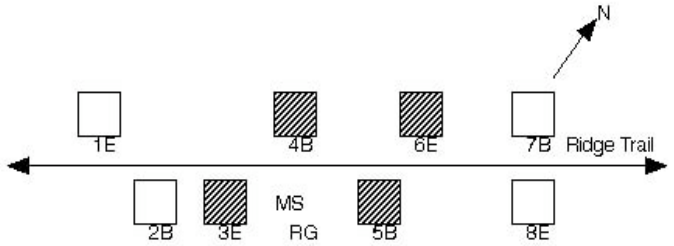
Haw Ridge
Approximate Map of Numbered Plots and Treatment



= Plots with lysimeters, soil pits, and soil water and temperature sensors.

B = background litter
E = enriched litter
MS = met station
RG = rain gauge

Pine Ridge Site
Approximate Map of Numbered Plots and Treatments



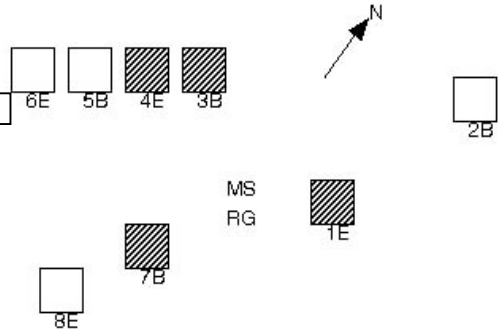
= Plots with lysimeters, soil pits, and soil water and temperature sensors.

B = background litter
E = enriched litter
MS = met station
RG = rain gauge

Ultisols on WB and TVA

Ultisols

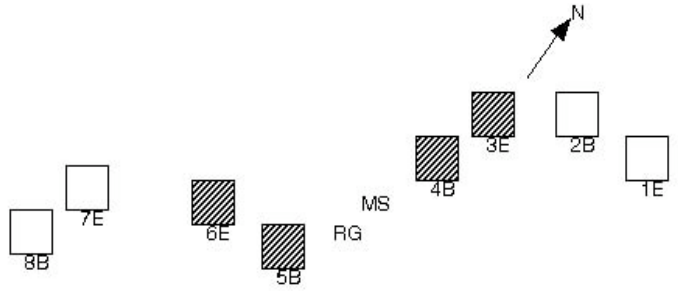
TVA Site
Approximate Map of Numbered Plots and Treatments



= Plots with lysimeters, soil pits, and soil water and temperature sensors.

B = background litter
E = enriched litter
MS = met station
RG = rain gauge

Walker Branch Site
Approximate Map of Numbered Plots and Treatments



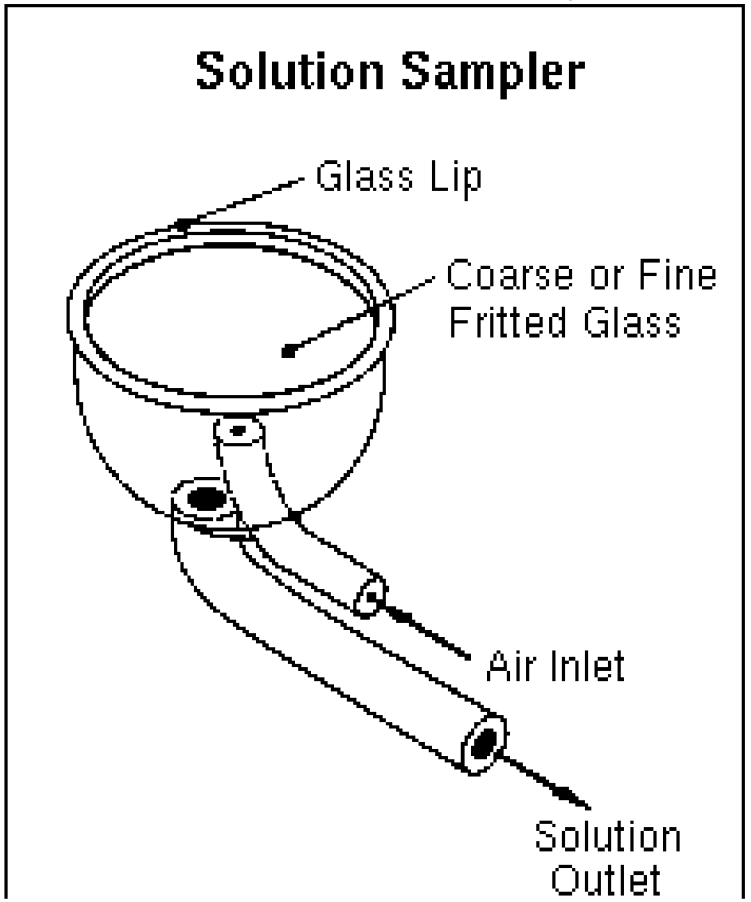
Access from Powerline Right-of-way at Bird Survey Point #3

= Plots with lysimeters, soil pits, and soil water and temperature sensors.

B = background litter
E = enriched litter
MS = met station
RG = rain gauge

Multi-porosity sampling capabilities

Zero/low tension solution sampler for monitoring macropore and mesopore domains

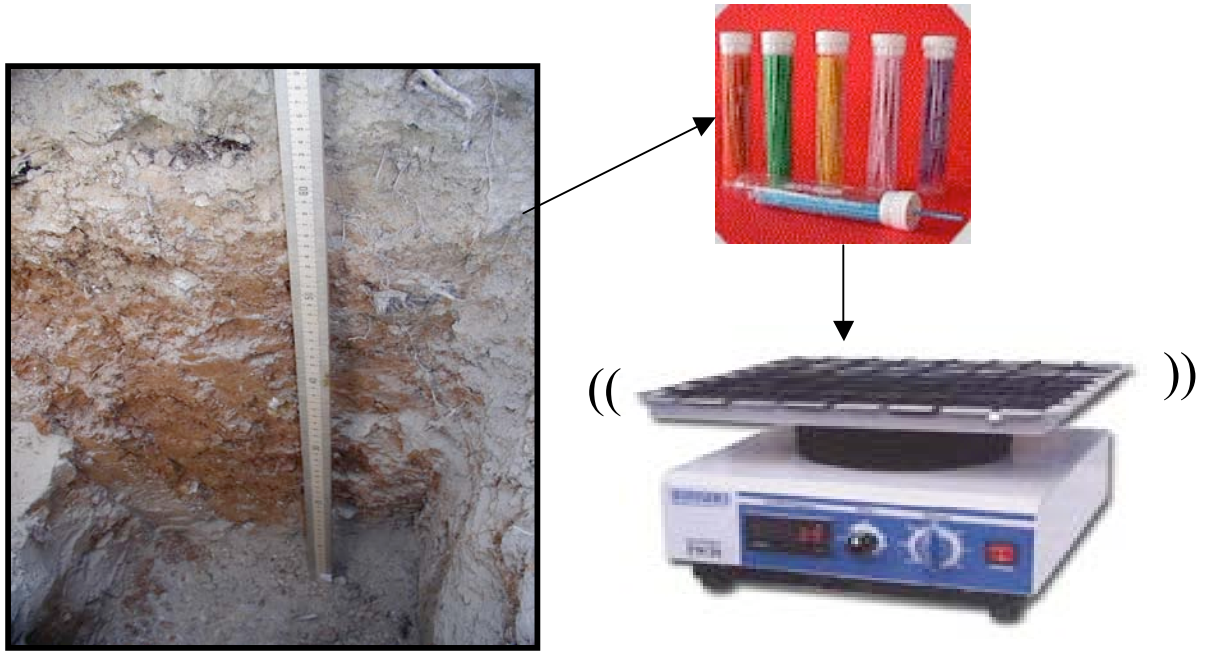


Funds lacking to do an adequate investigation of large pore organic C fluxes

High tension solution sampler for monitoring primarily micropore domains

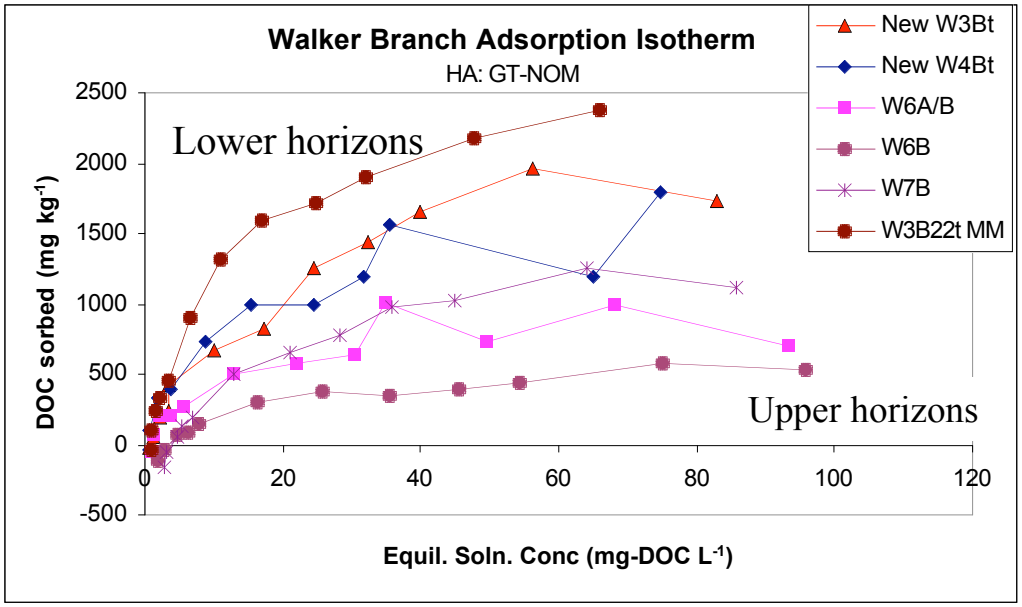
Results: Organic C sorption isotherms

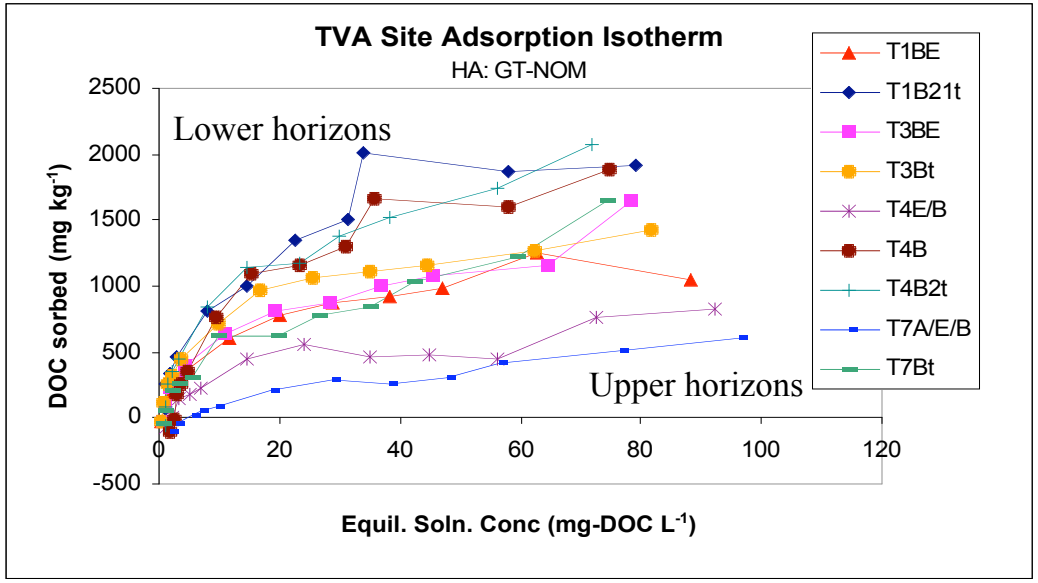
- A shake-batch method was utilized to construct dissolved organic carbon isotherms on the Ultisol and Inceptisol subsoils from the various EBIS plots.



- Select physical and chemical properties of the subsoil samples were determined in an effort to cross-correlate soil properties with differences in DOC solid-phase adsorption.

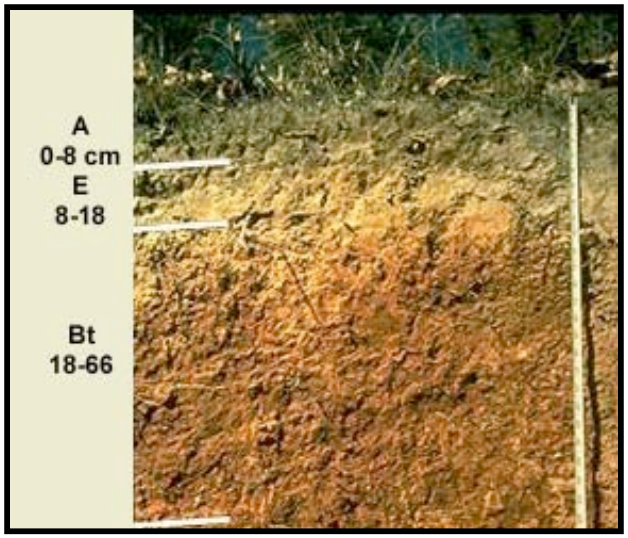
Carbon sorption isotherms on Ultisol soil profiles



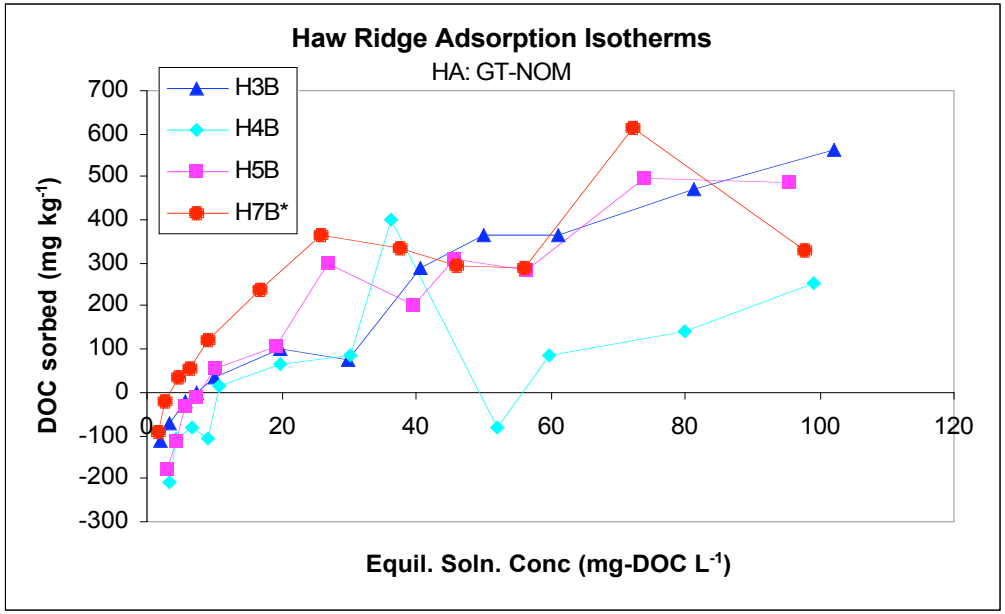


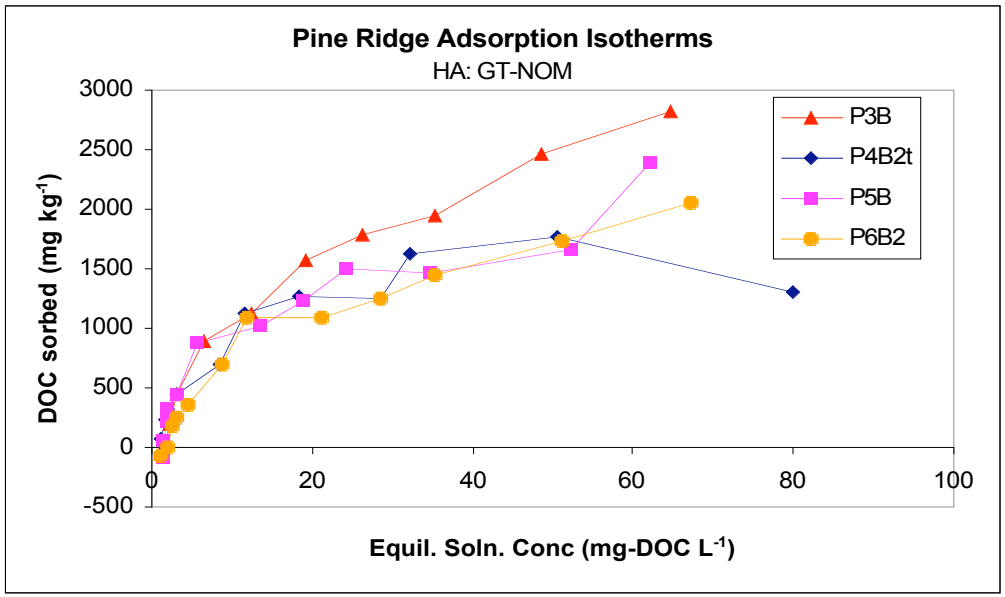
Soil samples from lower B-horizons have significantly larger carbon sorption capacities relative to upper A, E, A/E, and B/E horizons.

Typical soil profile



Carbon sorption isotherms on Inceptisol soil profiles

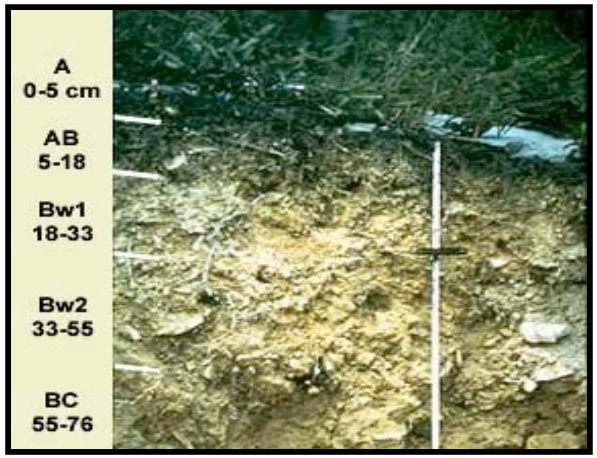




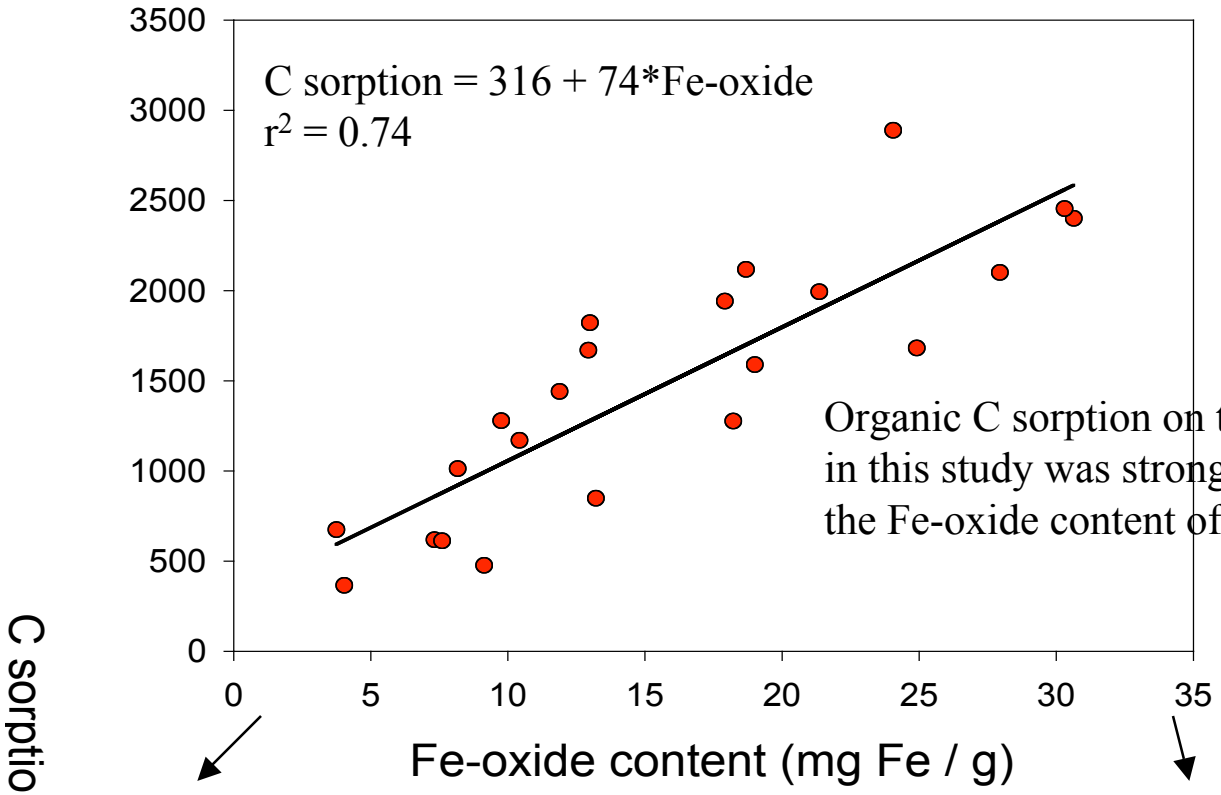
Low organic C sorption on sandy inceptisols with low Fe-oxide content and significant indigenous solid phase O.M. (i.e. Haw Ridge).

High organic C sorption on clayey inceptisols with high Fe-oxide content (i.e. Pine Ridge).

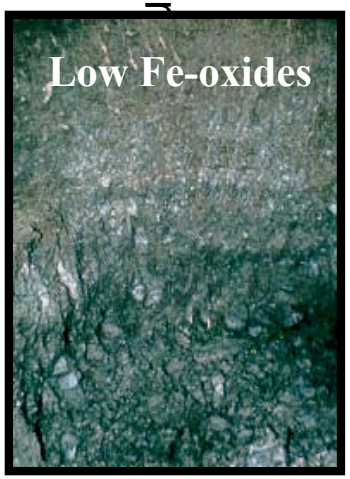
Typical soil profile



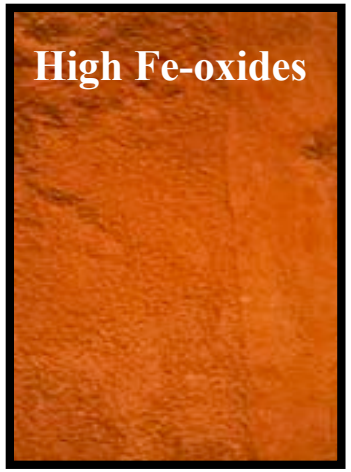
Influence of soil Fe-oxides on organic C sorption

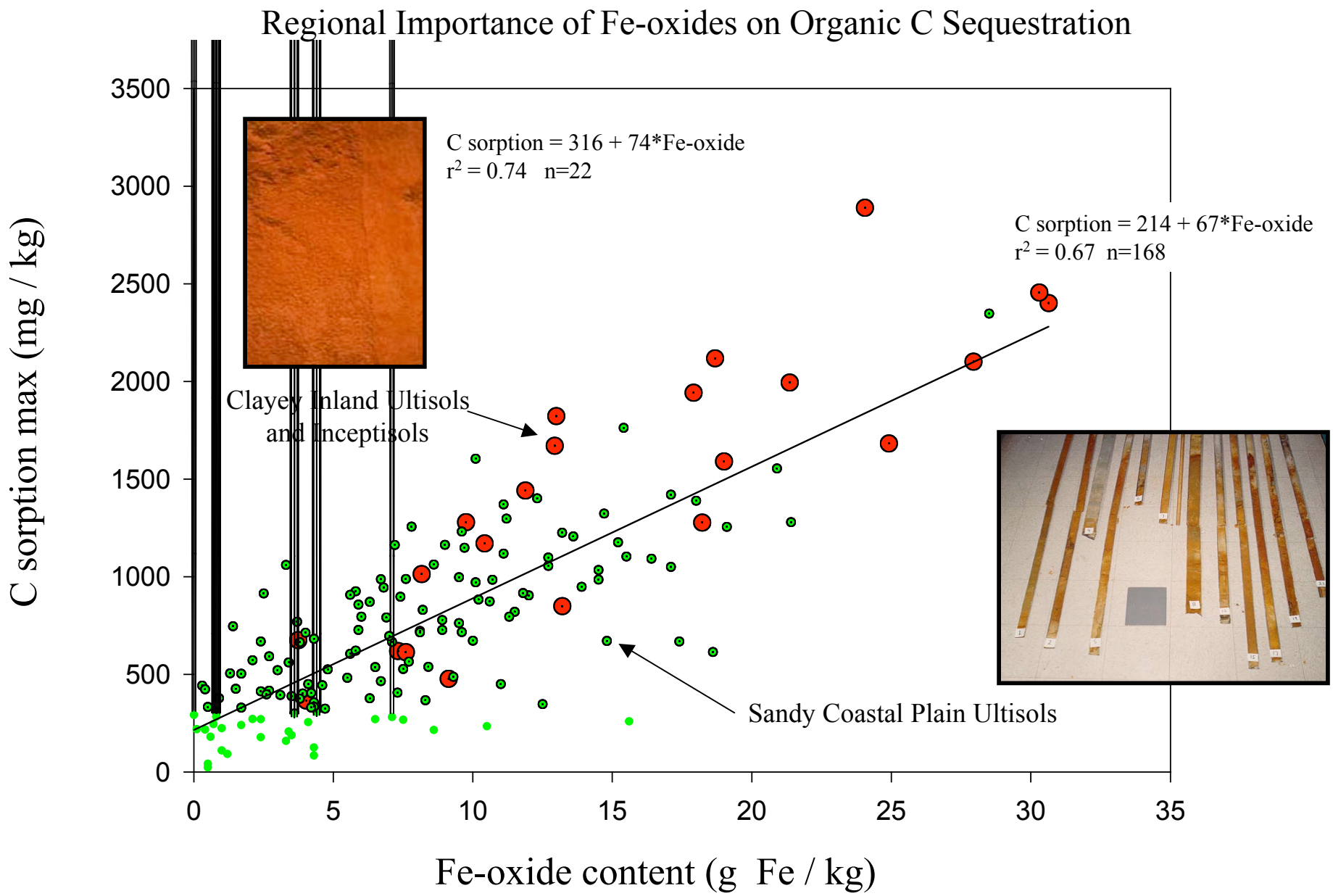


Organic C sorption on the 22 soils used in this study was strongly correlated with the Fe-oxide content of the media.



Fe-oxide coatings on mineral surfaces strongly sequester pore water organic C which can potentially limit bioavailability and transport to groundwater.




Regional Importance of Fe-oxides on Organic C Sequestration
C sorption max (mg / kg)
Fe-oxide content (g Fe / kg)
0
500
1000
1500
2000
2500
3000
3500
0
5
10
15
20
25
30
35
C sorption = 316 + 74*Fe-oxide
r2 = 0.74 n=22
C sorption = 214 + 67*Fe-oxide
r2 = 0.67 n=168
Clayey Inland Ultisols
and Inceptisols
Sandy Coastal Plain Ultisols

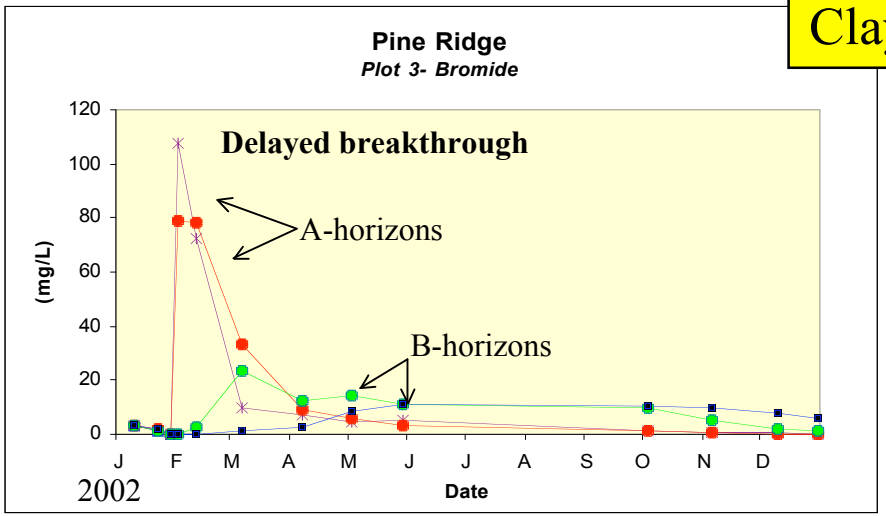
Storm driven transport of organic C

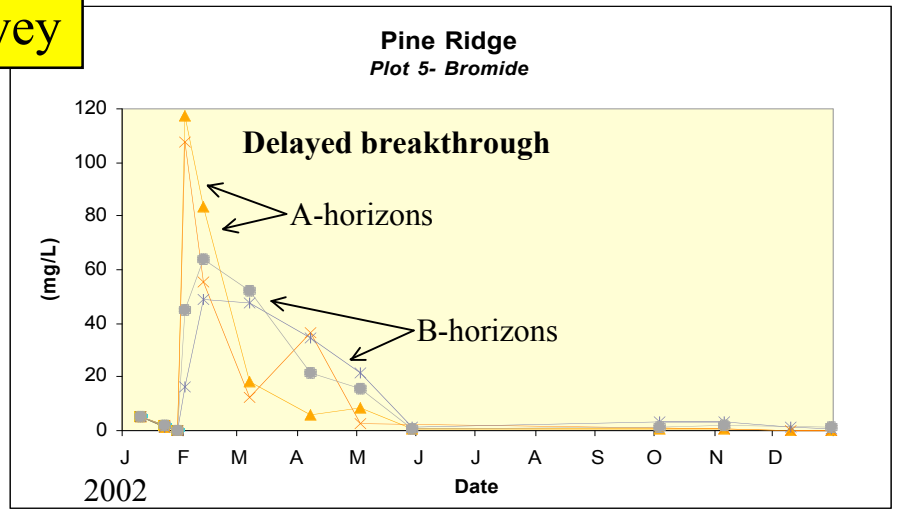
Example storm driven Br breakthrough in Inceptisol soil profiles

Non-reactive Br tracer provides useful data for quantifying flow and transport processes at the various sites.

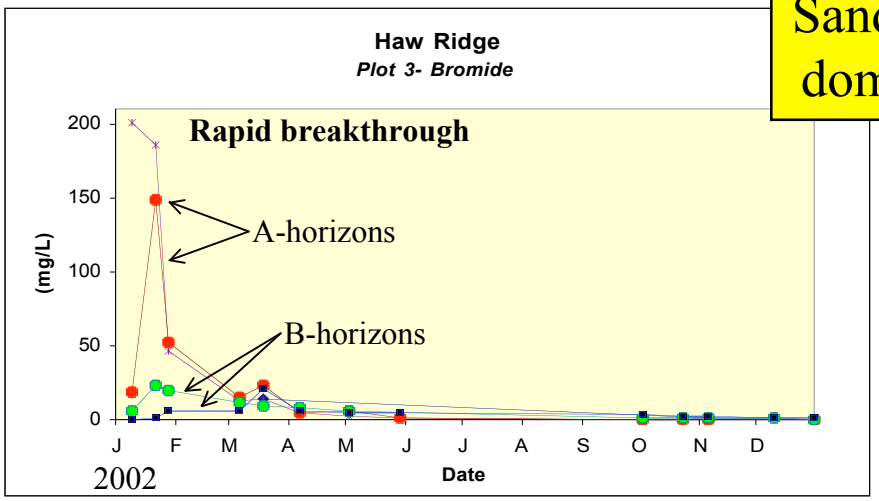
Haw Ridge exhibits the most rapid infiltration characteristics which is consistent with its more highly structured media and lower microporosity relative to the more clayey Pine Ridge and Ultisol soils.

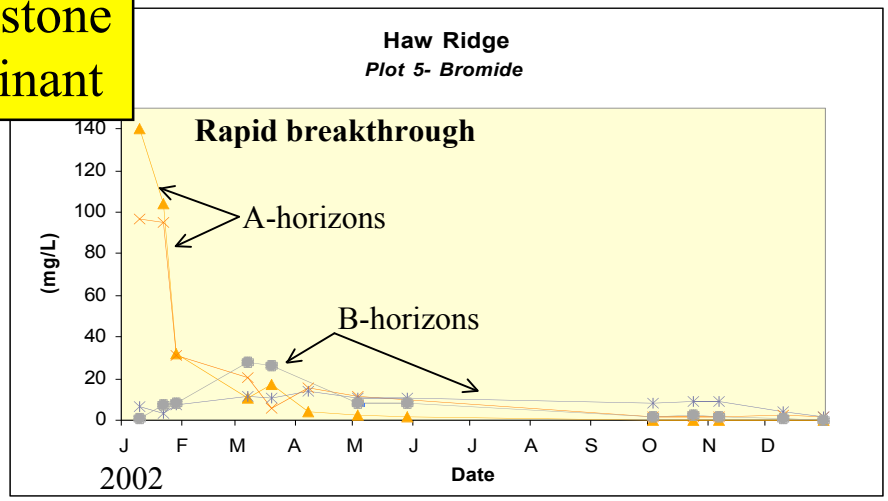
Clayey



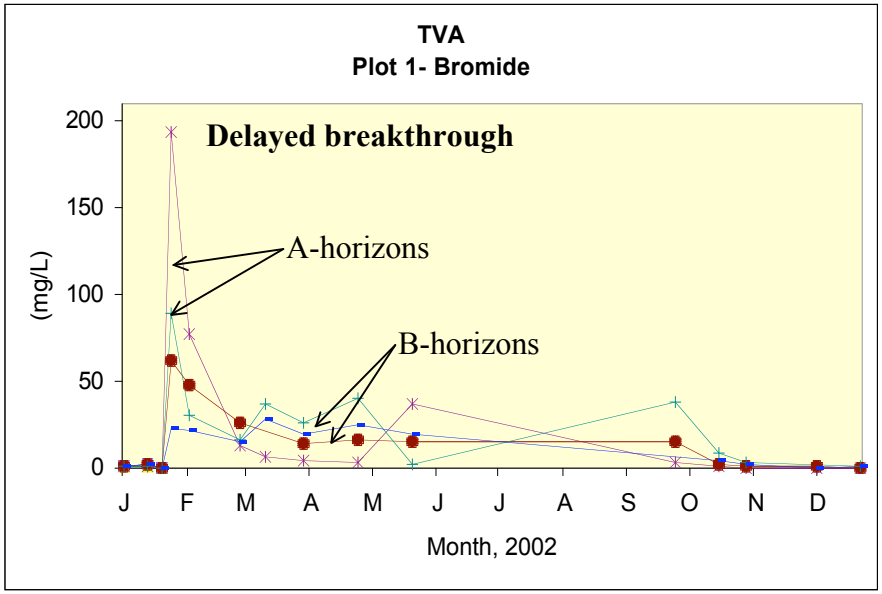


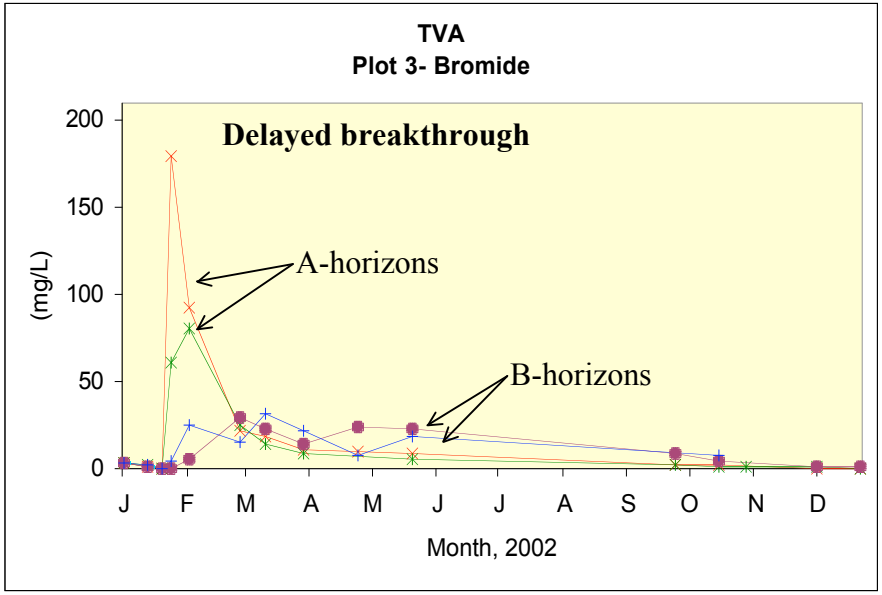
Sandstone dominant

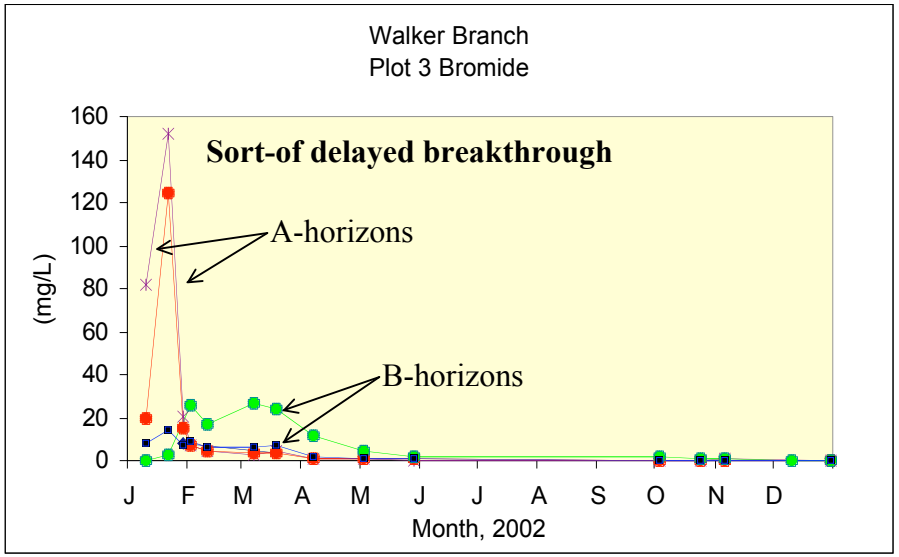


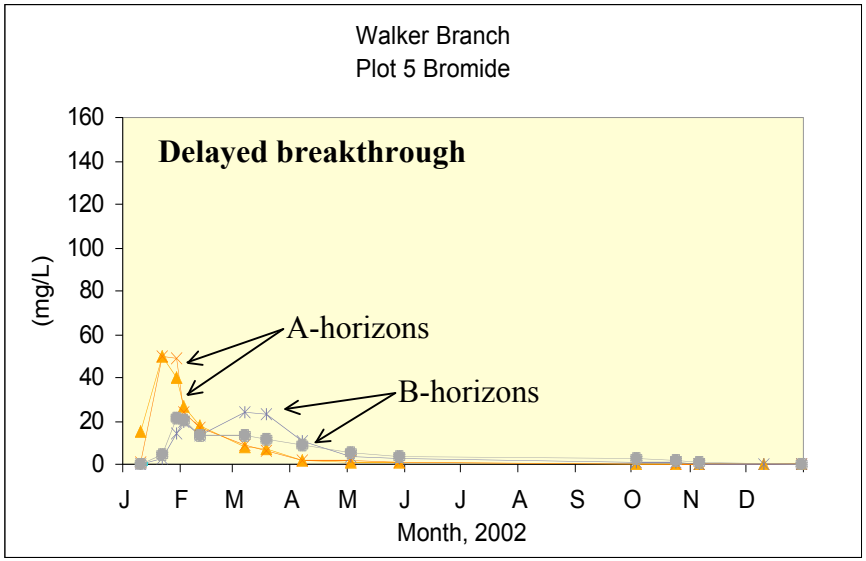


Example storm driven Br breakthrough in Ultisol soil profiles





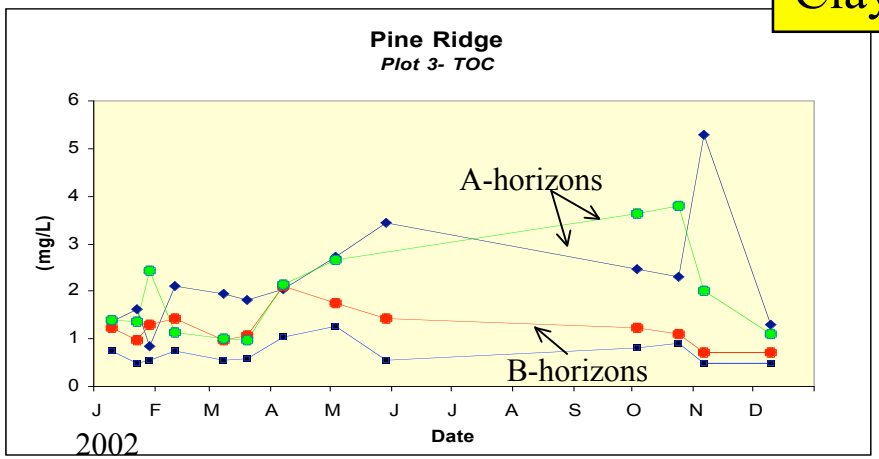


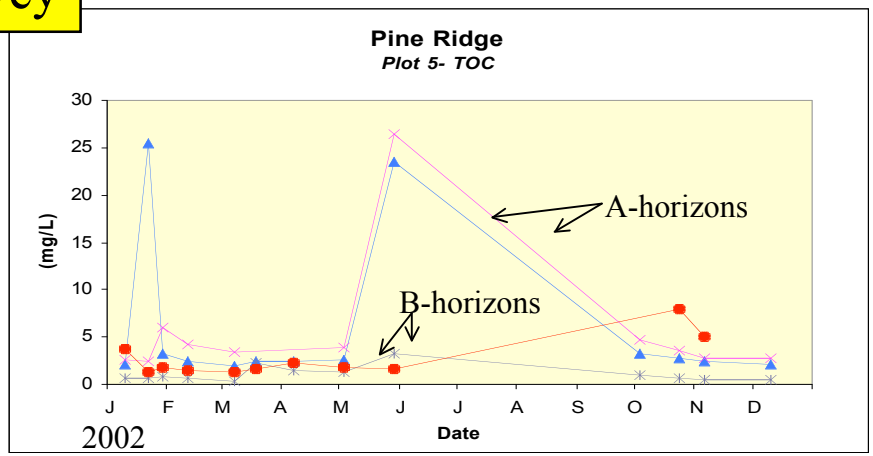


Example storm driven DOC concentrations in Inceptisol soil profiles

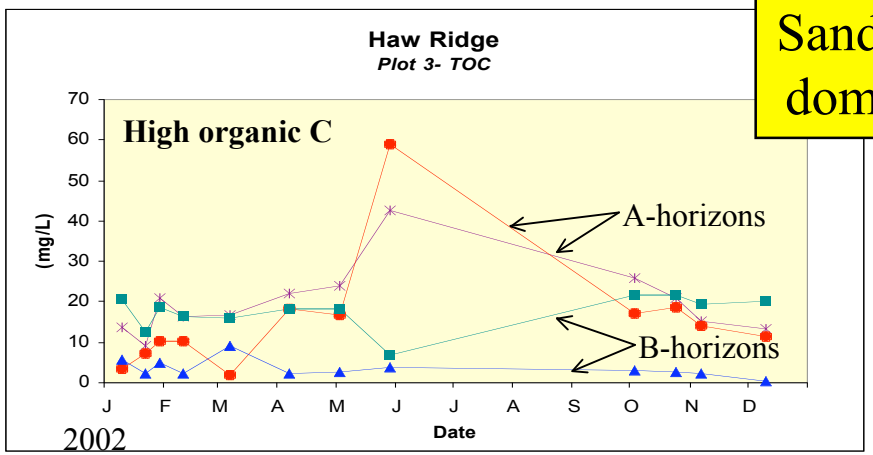
- **DOC concentrations higher for A-horizons relative to B-horizons.**
- **Haw Ridge (sandy inceptisol) consistently has highest pore water organic C concentrations that continue into the B-horizon. Since infiltration is more rapid in these soils coupled with their lower organic C retention capacity, greater losses of dissolved organic C may be expected in these systems.**

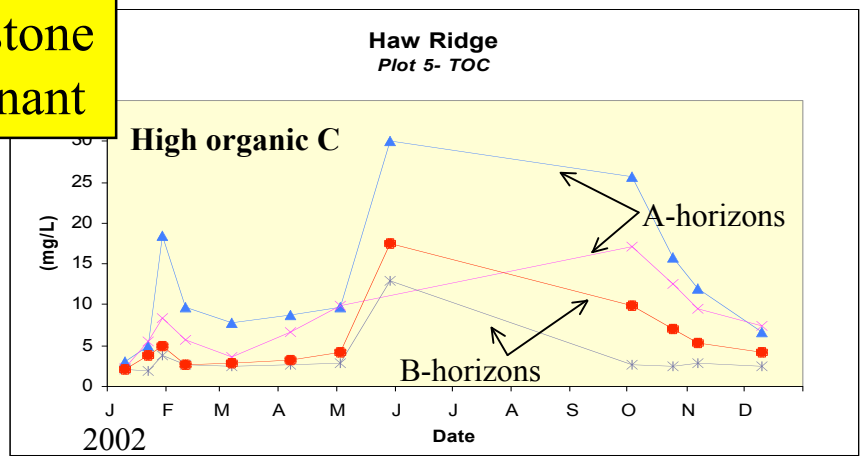
Clayey



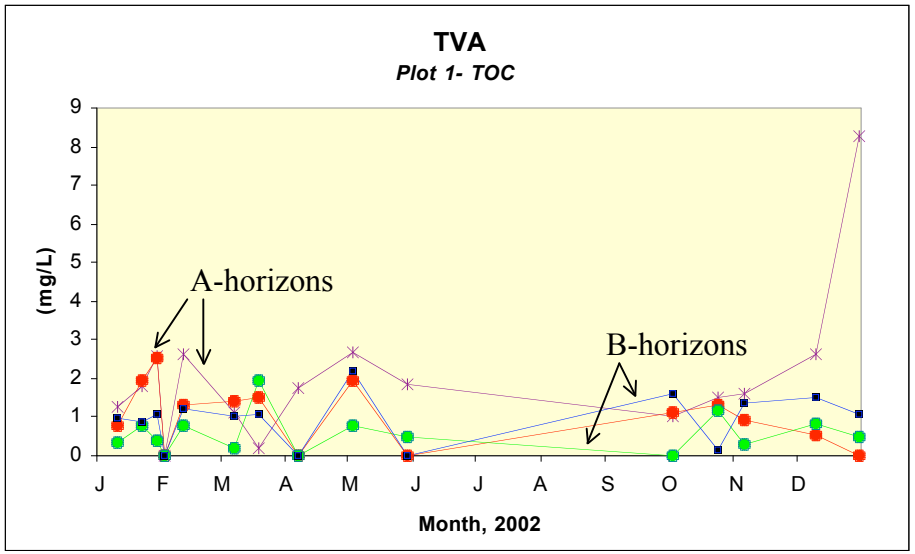


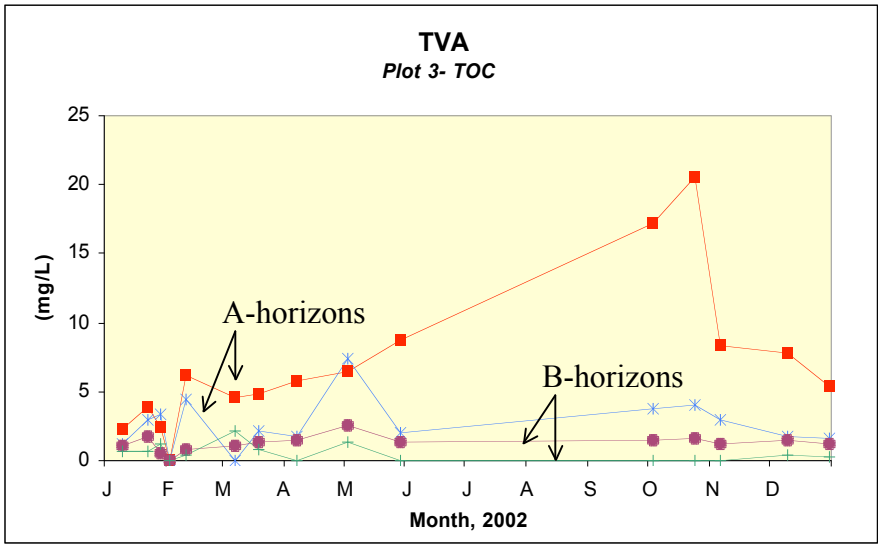
Sandstone dominant

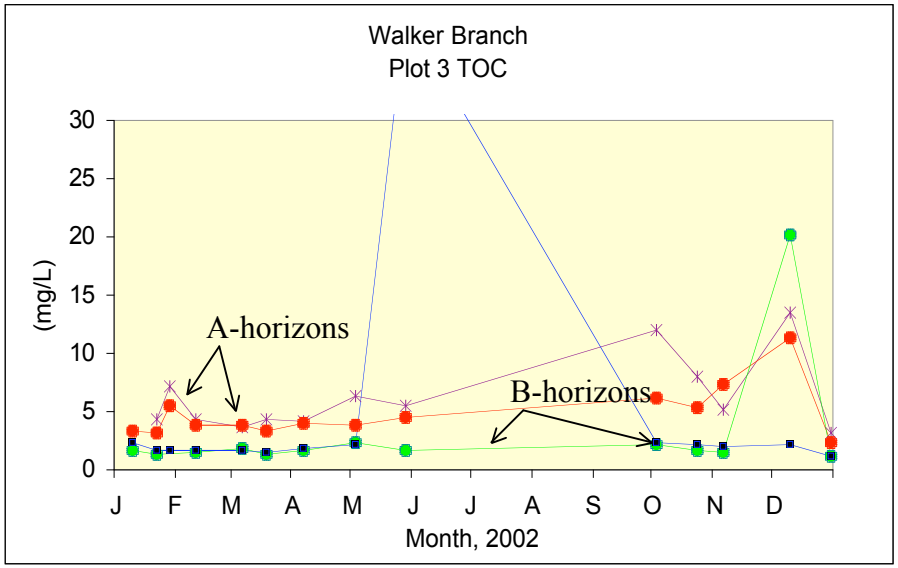


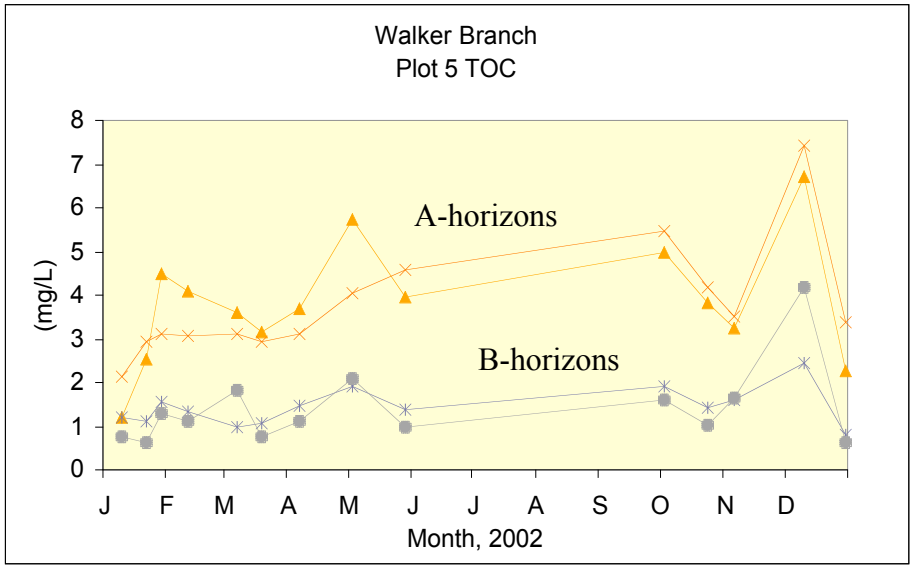


Example storm driven DOC concentrations in Ultisol soil profiles





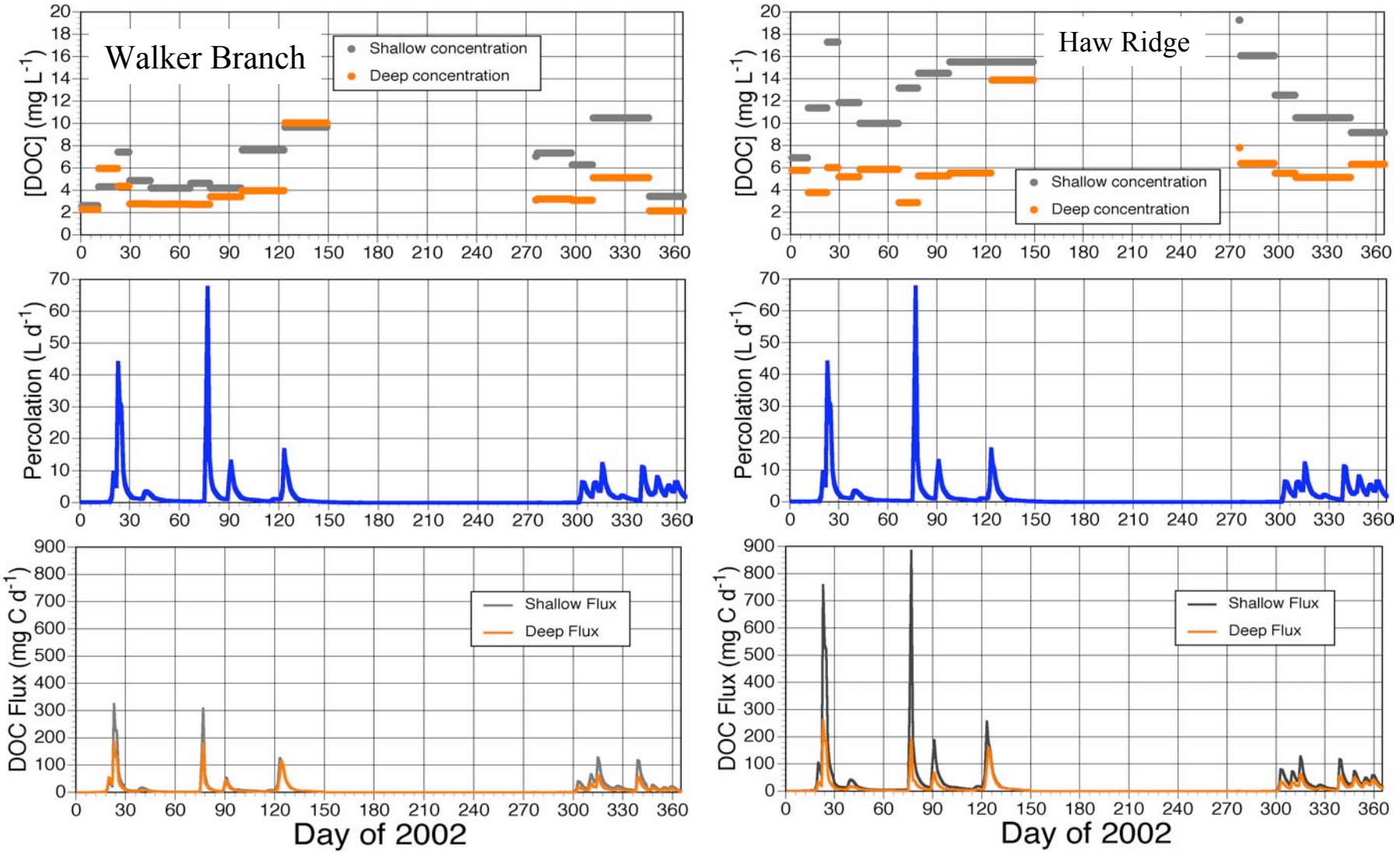




Organic C flux through soil profiles

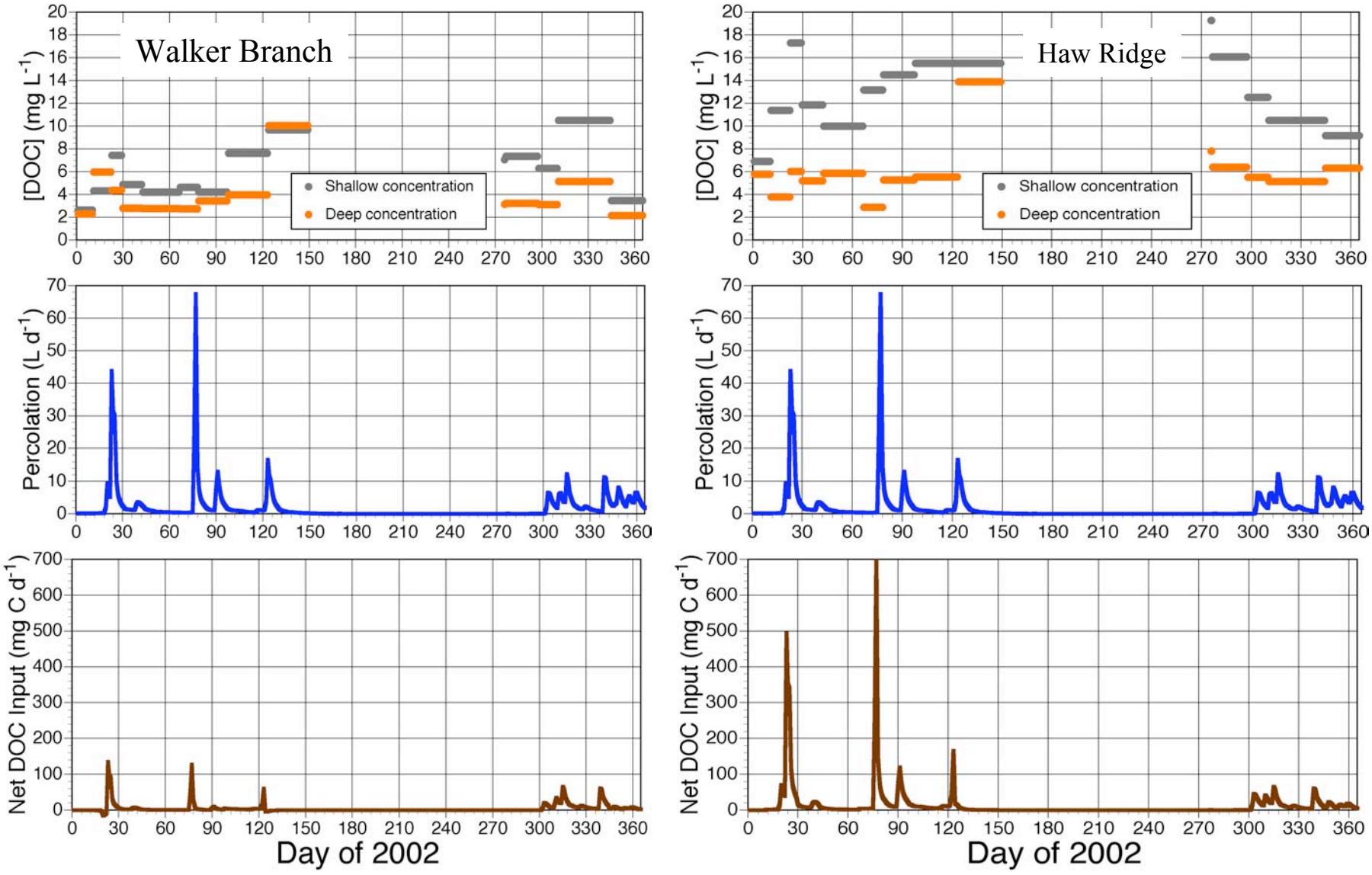
DOC flux higher for A-horizons relative to B-horizons.

Haw Ridge (sandy inceptisol) has highest C flux relative to Pine Ridge and Ultisol soils which is consistent with its more labile C source and rapid flow and transport characteristics.



Net organic C inputs into the B-horizons

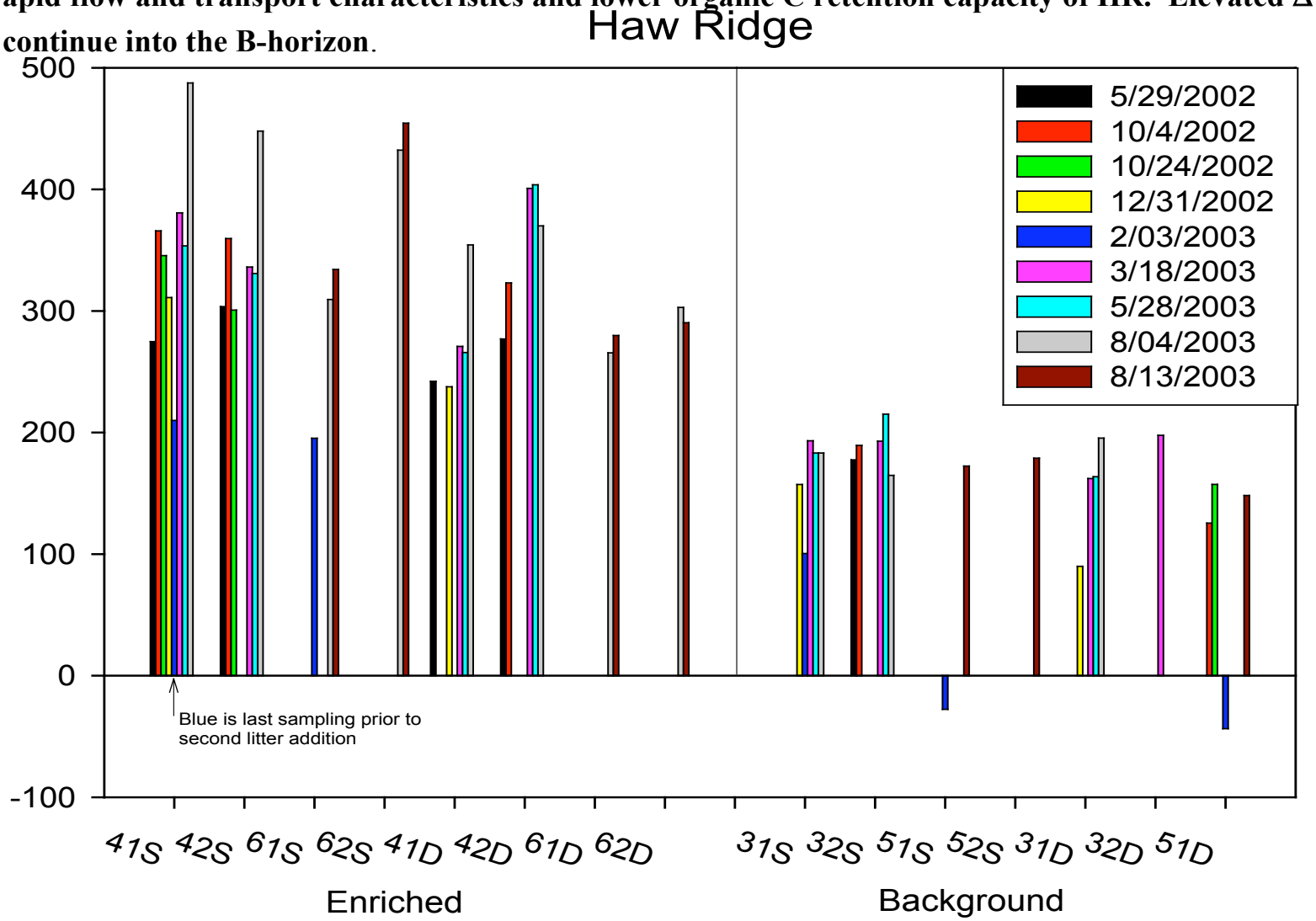
Estimated organic C inputs in the Walker Branch Ultisol and Haw Ridge Inceptisol B-horizons showing that these lower horizons typically receive more C than they lose.



$\Delta^{14}C$ signatures in select pore water from Haw Ridge Inceptisol soil profile

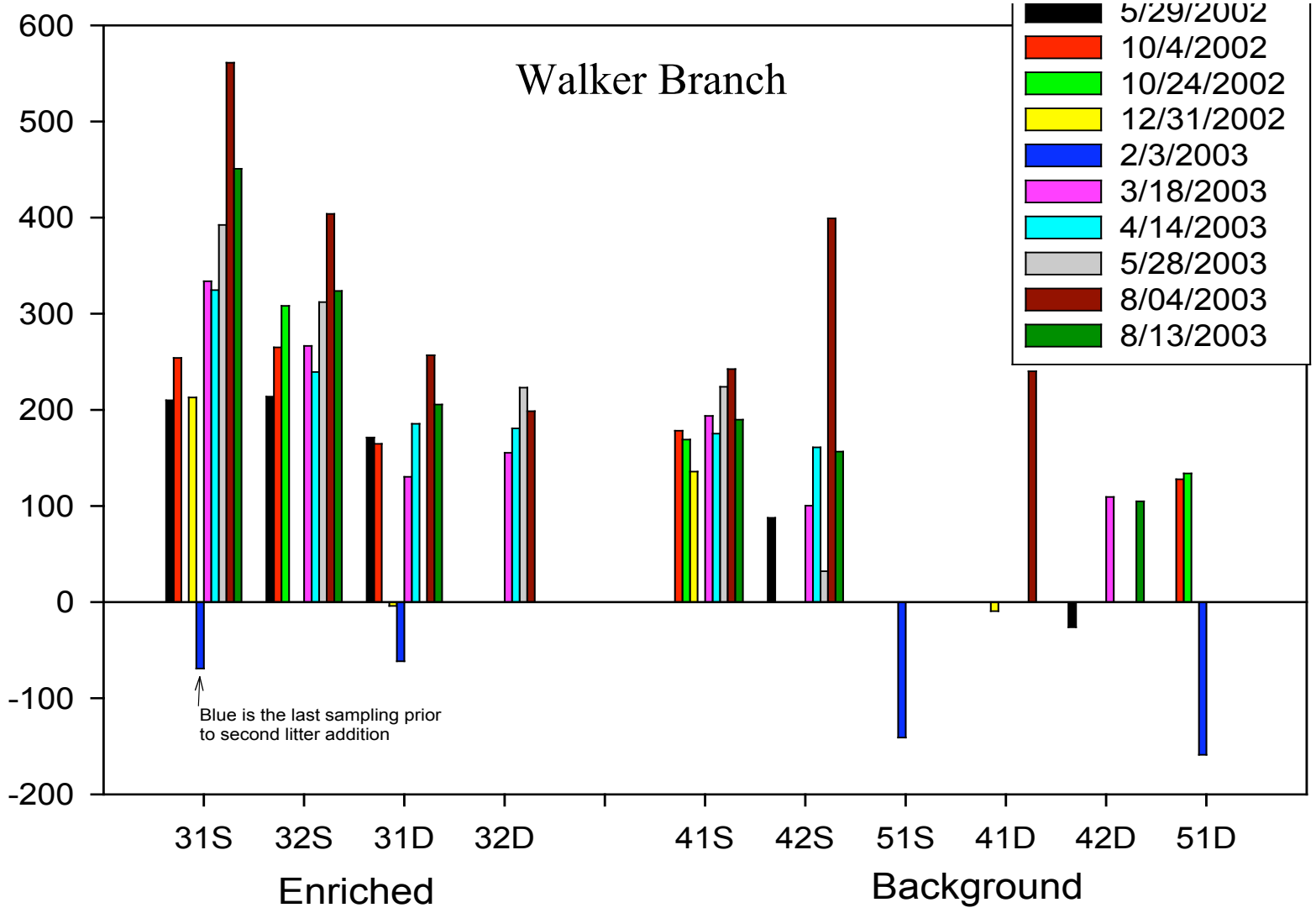
Enriched plots have higher $\Delta^{14}C$ signatures in pore water than background plots.

Pore water from Haw Ridge has a higher $\Delta^{14}C$ signatures relative to Walker Branch which is consistent with the more rapid flow and transport characteristics and lower organic C retention capacity of HR. Elevated $\Delta^{14}C$ values continue into the B-horizon.



$\Delta^{14}C$ signatures in select pore water from Walker Branch Ultisol soil profile

Pore water from WB has a lower $\Delta^{14}C$ signature relative to HR with B-horizon samples showing no evidence of enrichment. This may be related to the higher organic C retention capacity of WB. Trends for WB similar to the other clayey soils Pine Ridge and TVA.

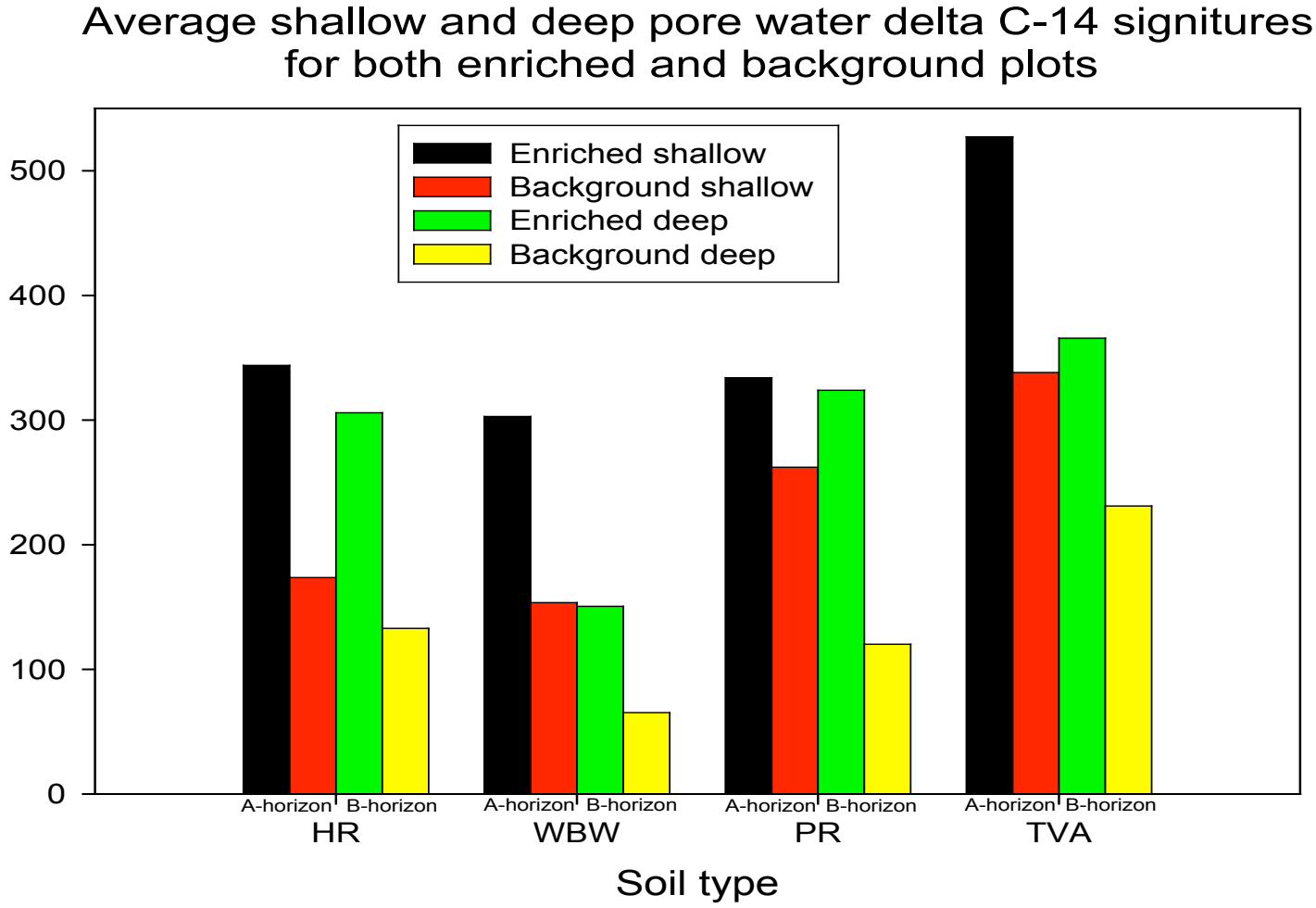


Average $\Delta^{14}C$ signatures of all pore water from each site

Possible pre-enrichment of Pine Ridge and TVA prior to EBIS experiment.

Enriched A- and B-horizons have consistently higher $\Delta^{14}C$ porewater than background A- and B-horizons for all sites.

Enriched porewater moves deeper in the Inceptisols relative to the Ultisols.



Summary

- Non-reactive Br tracer provides useful data for quantifying flow and transport processes at the various sites.

- Dissolved organic C fluxes at each site are consistent with the soil hydrodynamics and labile nature of the A-horizon organic matter.

- Net organic C accumulations observed in the B-horizon where organic C sorption was strongly correlated with the soil Fe-oxide content.

- Pore water $\Delta^{14}C$ signatures look promising. Enriched plots clearly show higher values than background plots, and the data is consistent with site hydrological and geochemical characteristics.