Task 3a: Hydrological and Geochemical Processes Controlling the Transport and Sequestration of Organic C through the EBIS Soil Profiles

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Objectives

- **Quantify the impact of coupled hydrological and geochemical processes on the fate and transport of dissolved organic C through the EBIS soil profiles.**

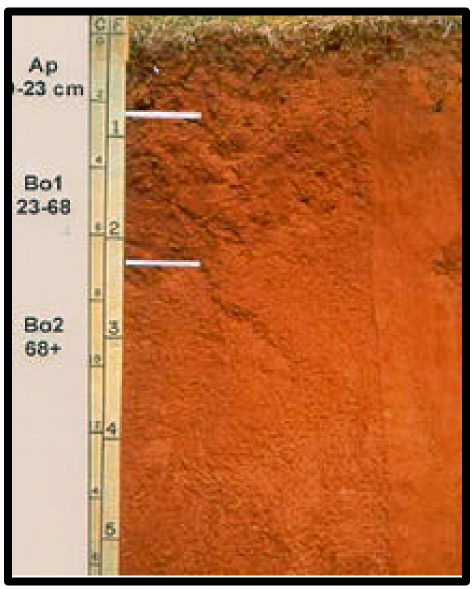
- **Quantify the mechanisms that control enhanced carbon accumulation within deep subsoils of forested Ultisols and Inceptisols.**

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.

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

Ultisol devoid of organic C



Ultisol enriched with organic C

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.

Importance of soil structure

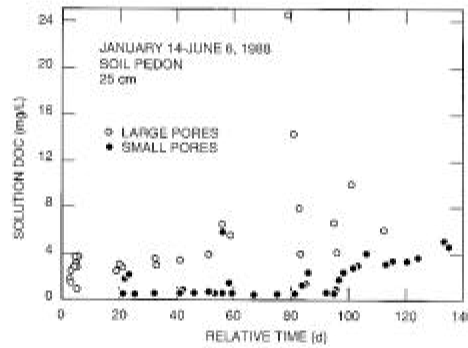
Well structured subsoils consist of a complex continuum of pore regimes ranging from macropores at the mm scale to micropores at the sub-ìm scale.

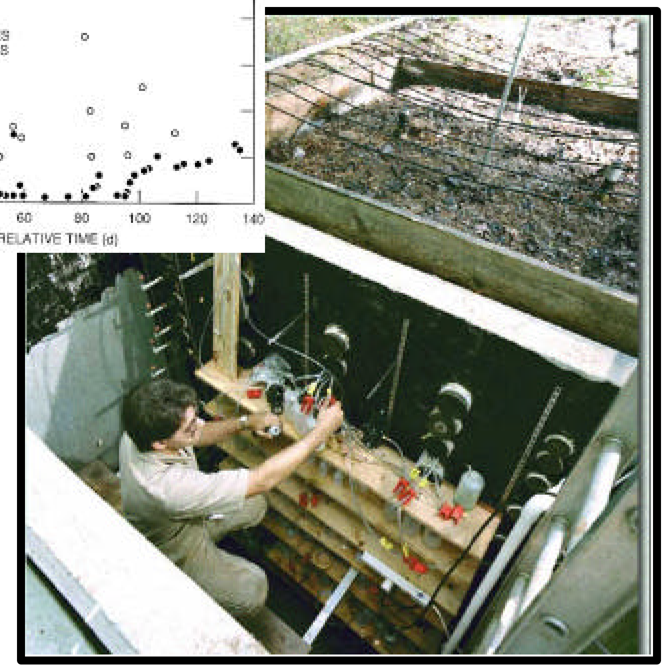
The pore structure of the media is hydrologically interconnected where water and solute mass can move from one pore class to another.

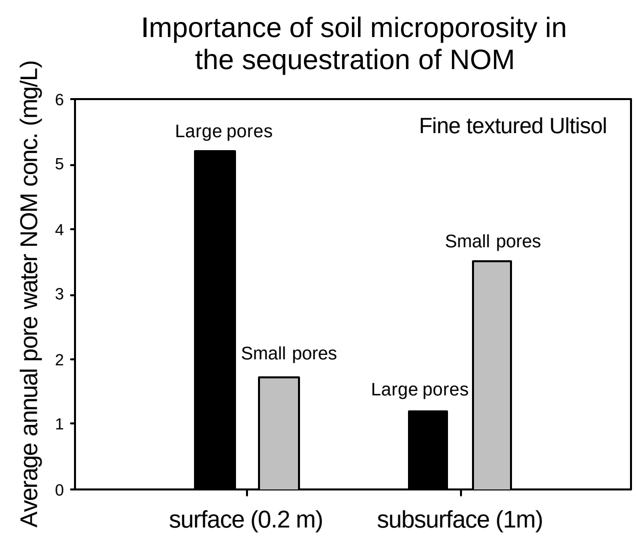
In structured soils, hydrologic and concentration gradients drive pore water NOM preferentially into micropores where it is physically protected from microbes.

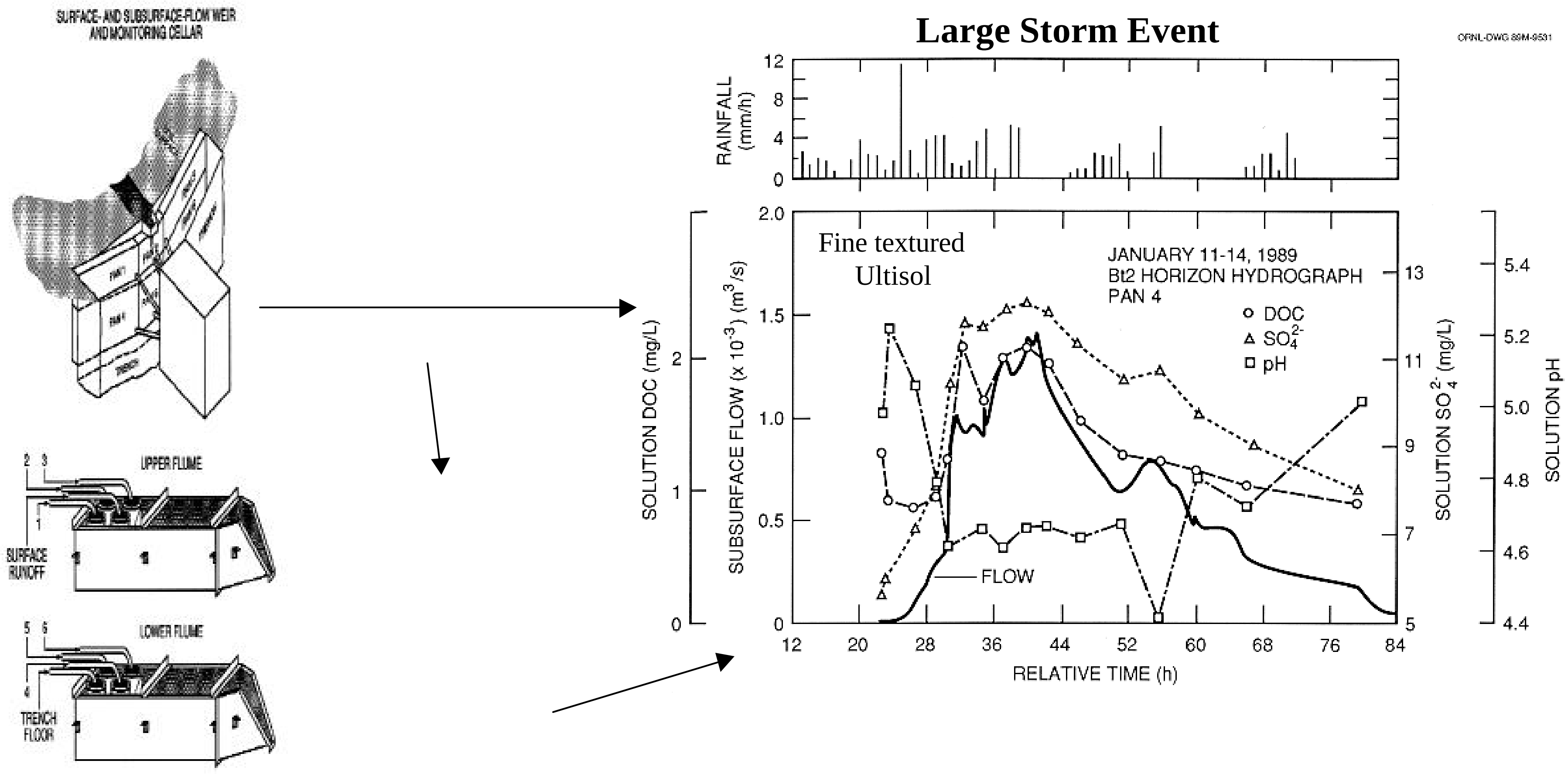
Large pores tend to carry NOM deeper into the soil profile, whereas small pores act as a source/sink and store NOM for potentially long time periods.

Small pores frequently constitute more than 90% of the total soil porosity.









Preferential <u>lateral flow</u> can diminish the potential for organic C sequestration in subsoils due to significant bypass of the soil matrix and decreased C resident times in the soil profile.

On the other hand, preferential <u>vertical flow</u> in deep mature soils can drive organic C farther into the soil profile thereby enhancing sequestration.

Competitive solid phase sorption reactions minimize the flux of carbon during lateral drainage due to increased pore water residence time within the soil profile.

Approach

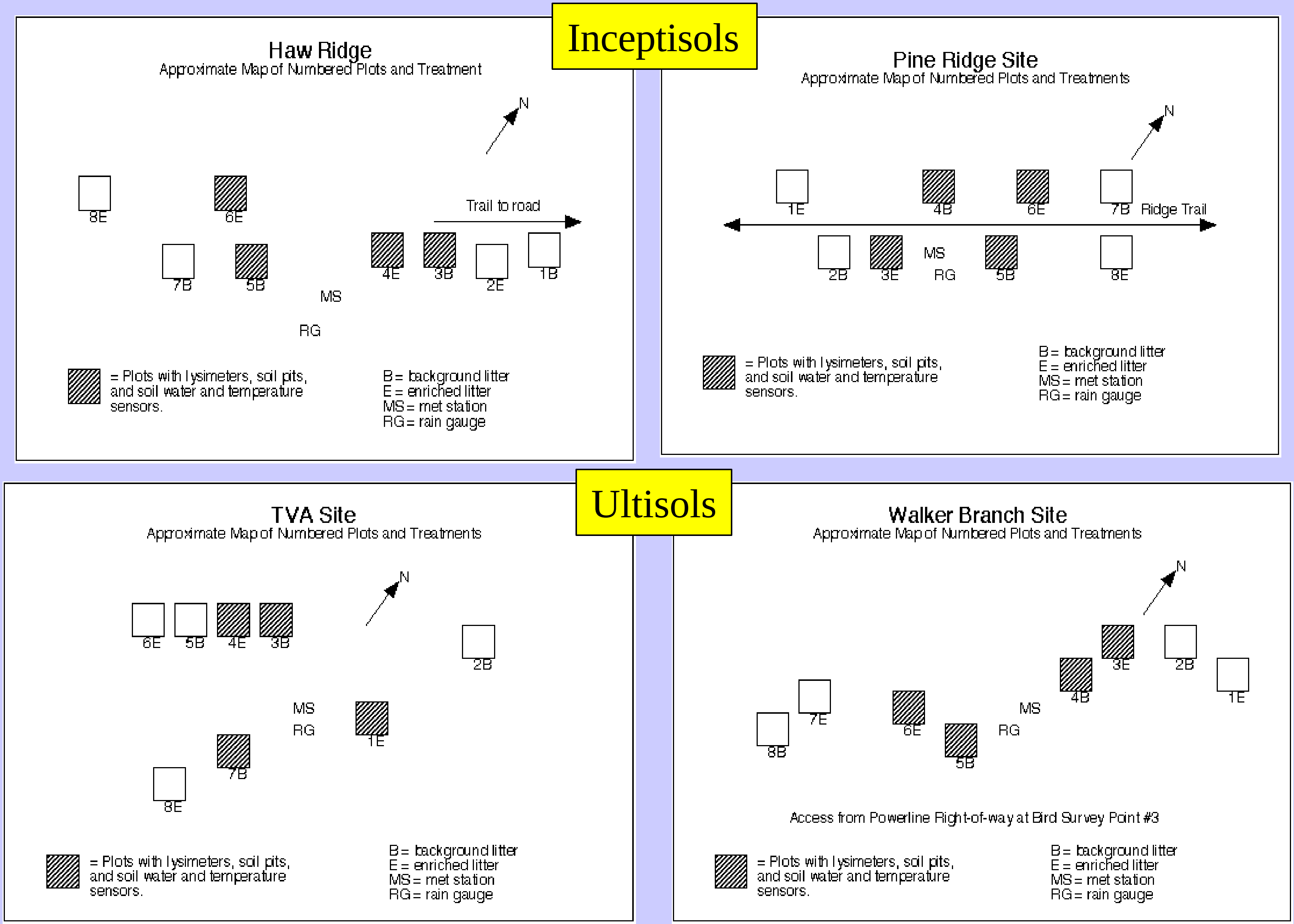
- Two background and two enriched plots from each of the four EBIS sites (16 plots) were instrumented with four tension lysimeters and four tension-free lysimeters. Two of each type were placed within the A- and B-horizons of the soil profiles.

- Fifty liters of a nonreactive Br tracer was evenly applied over each of the instrumented areas using a backpack sprayer.

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

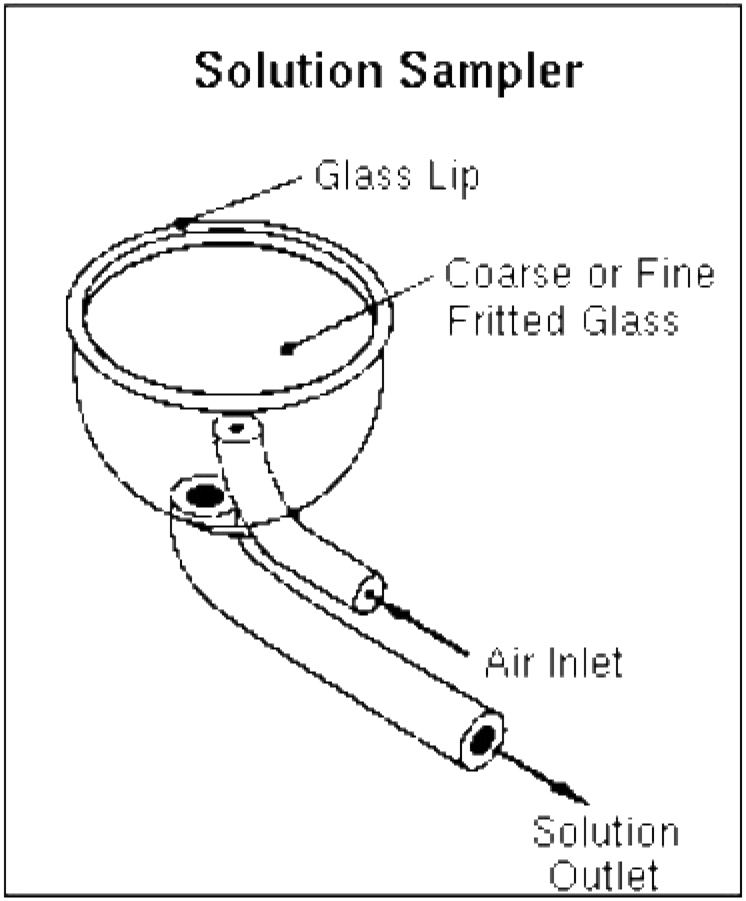
- Bulk soil samples from each plot were characterized for select physical and chemical properties and organic C sorption isotherms were quantified for each subsoil.

Monitoring scheme



Multi-porosity sampling capabilities

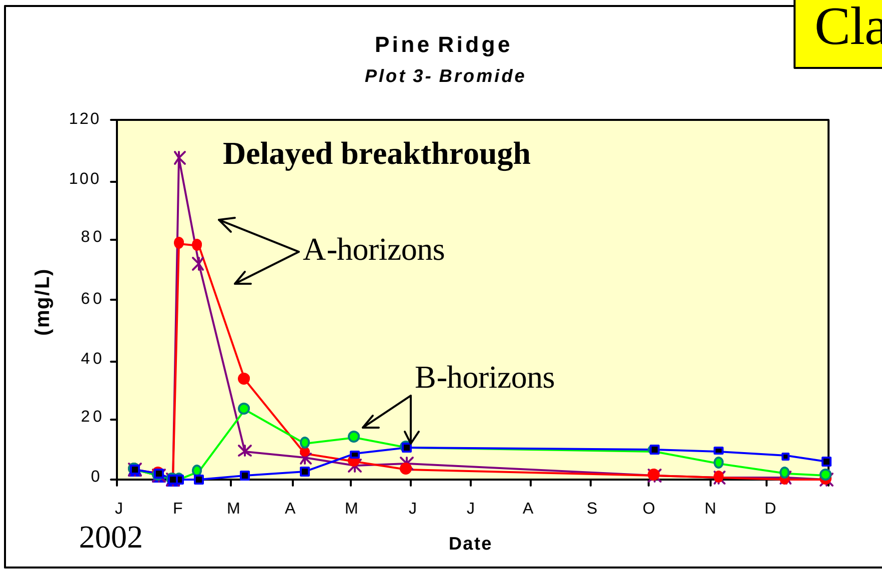
Zero/low tension solution sampler for monitoring macropore and mesopore domains

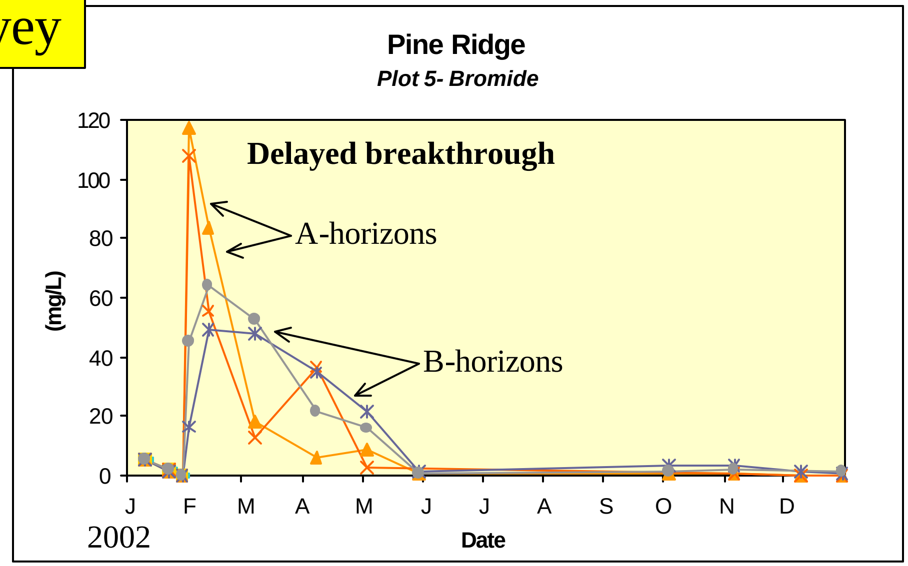


High tension solution sampler for monitoring micropore domains

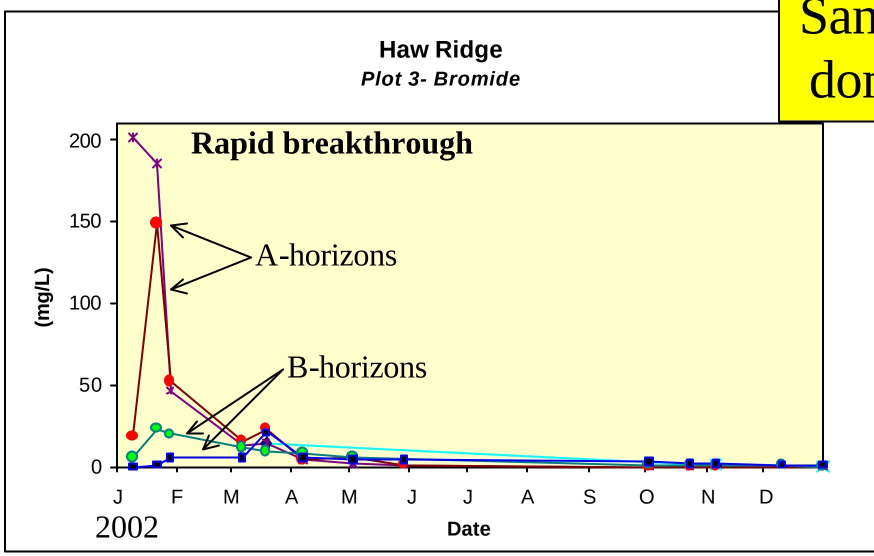
Example storm driven Br breakthrough in Inceptisol soil profiles

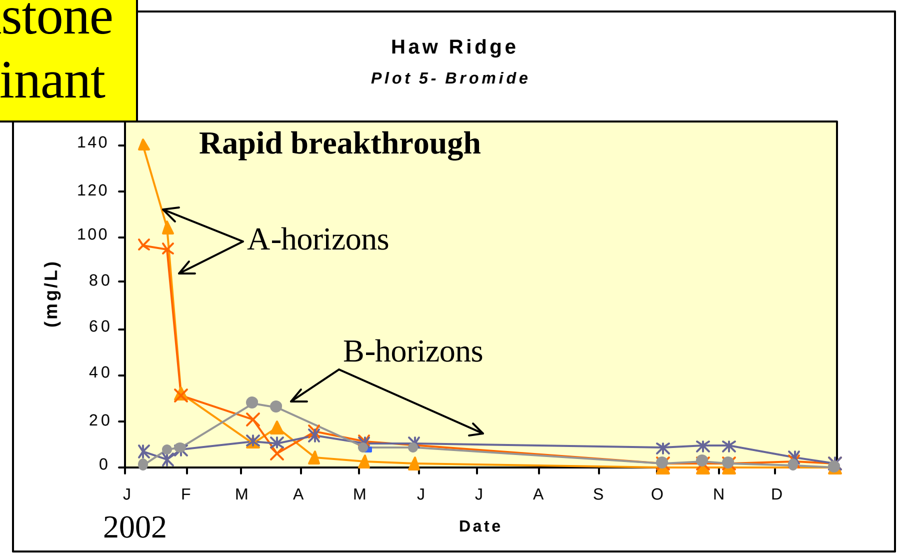
Clayey



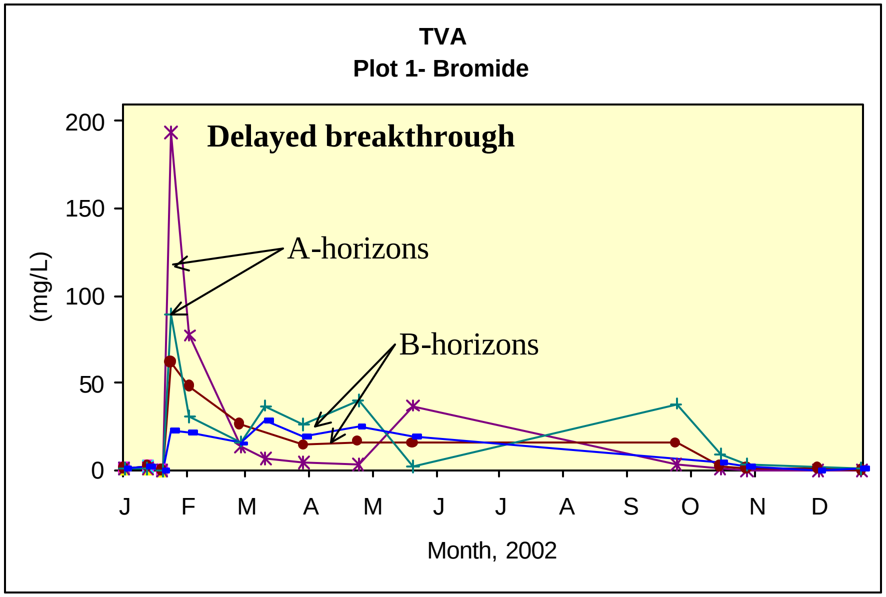


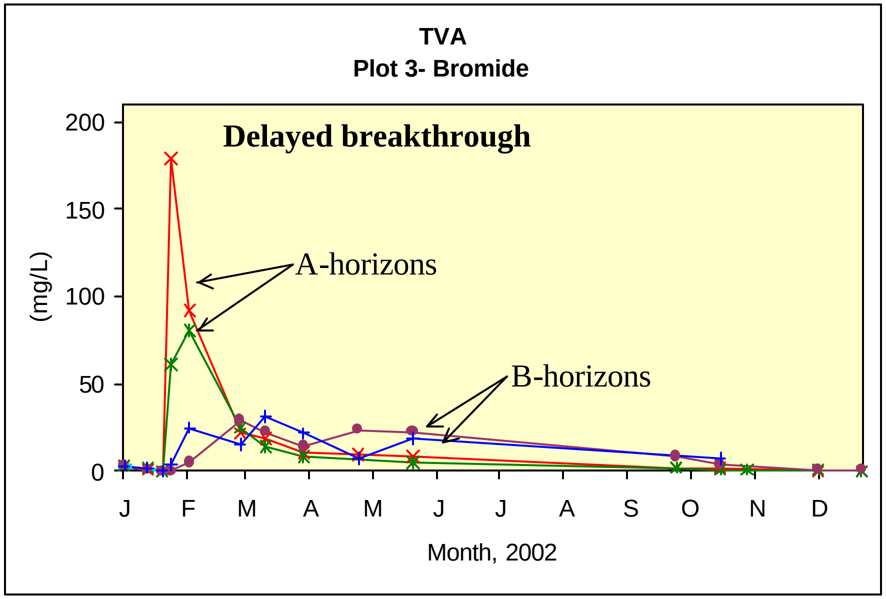
Sandstone dominant

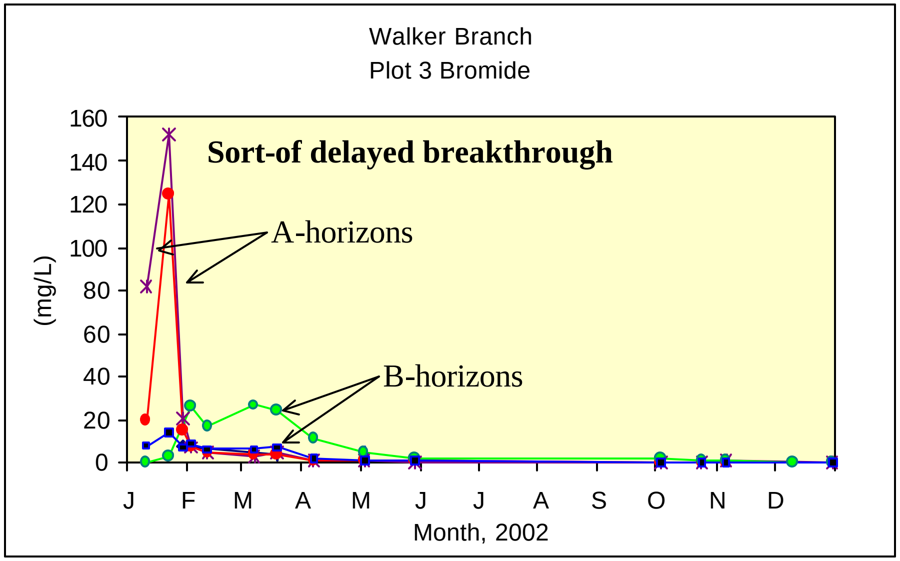


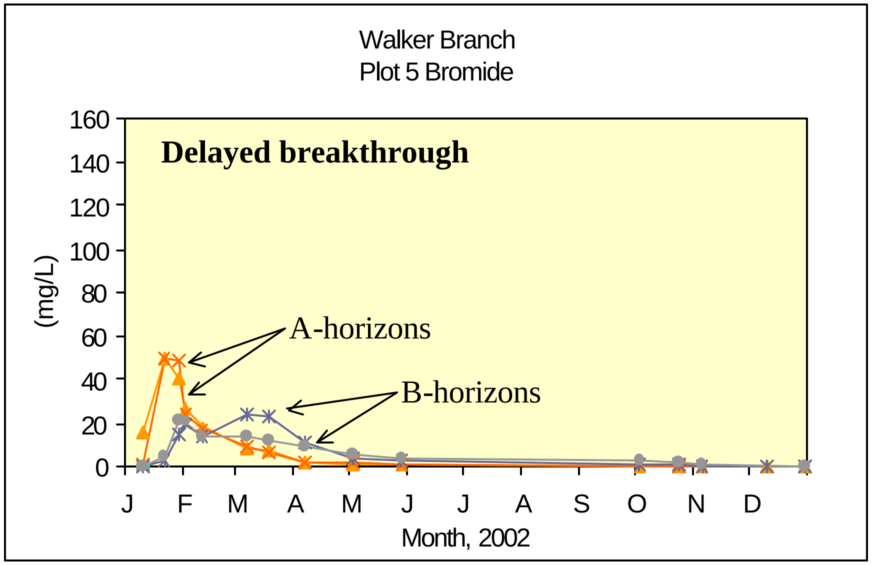


Example storm driven Br breakthrough in Ultisol soil profiles

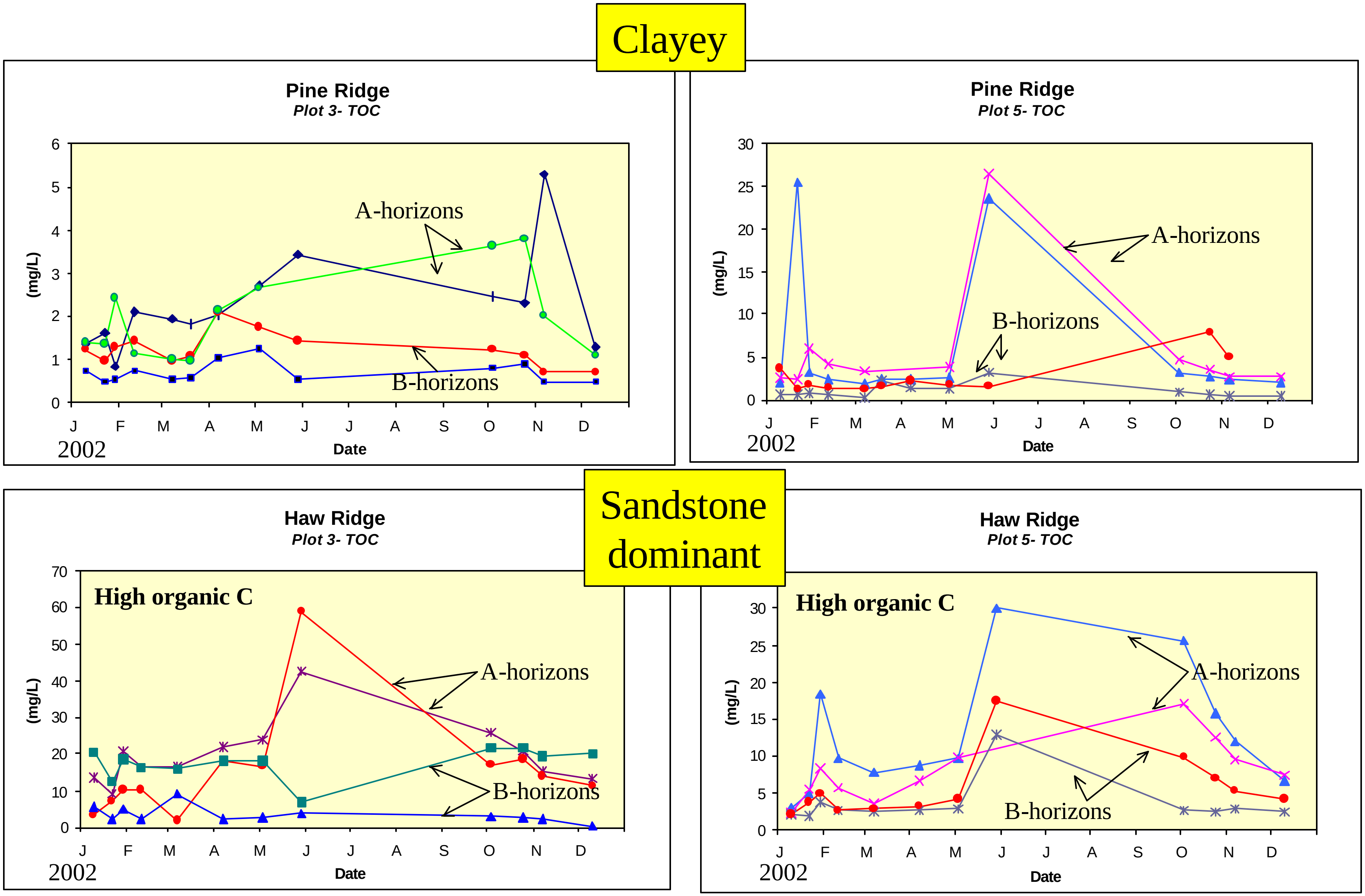




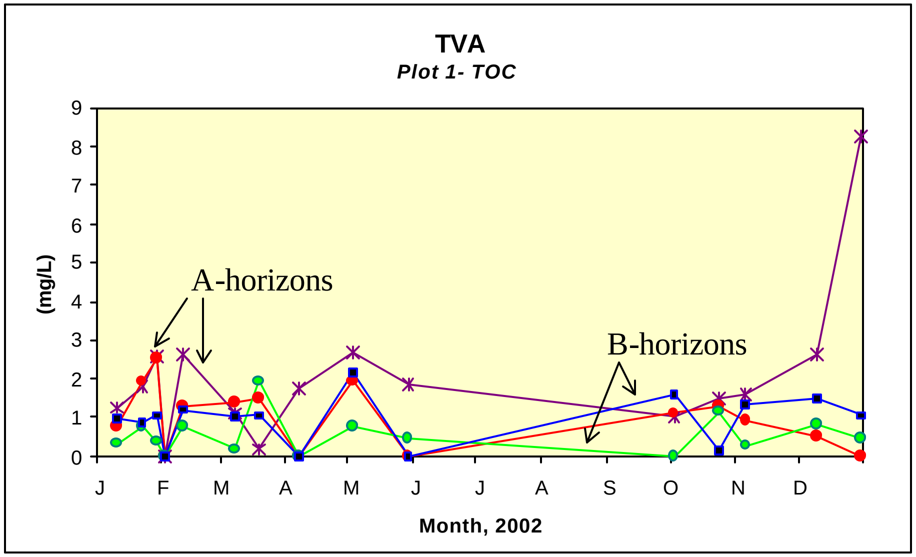


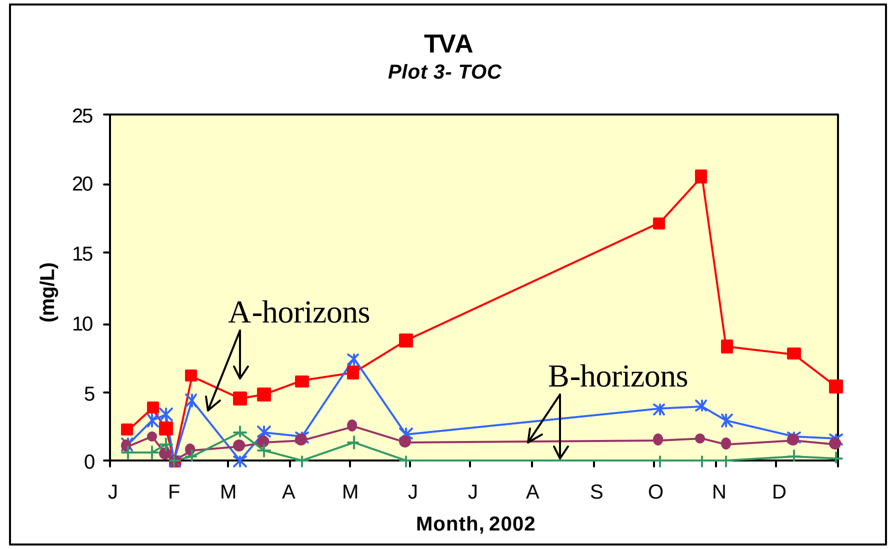


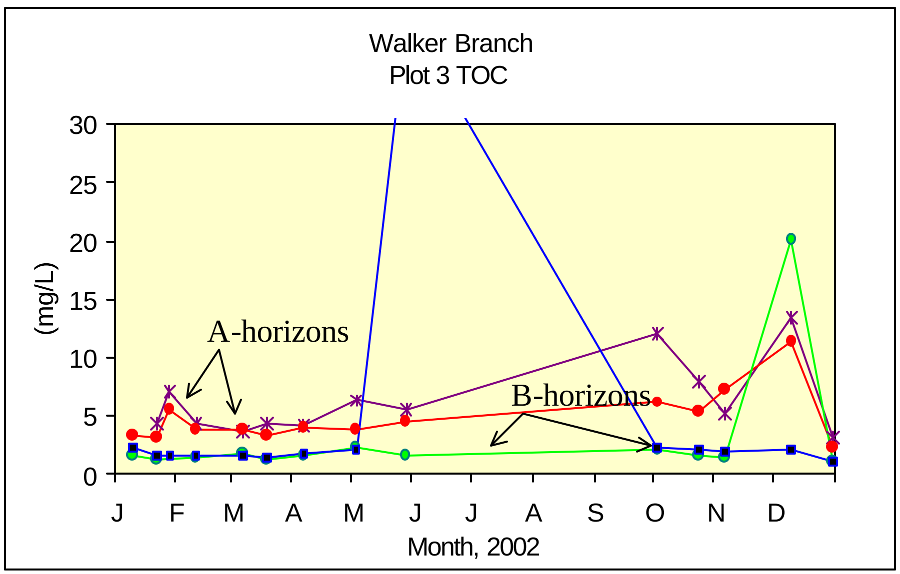
Example storm driven DOC concentrations in Inceptisol soil profiles

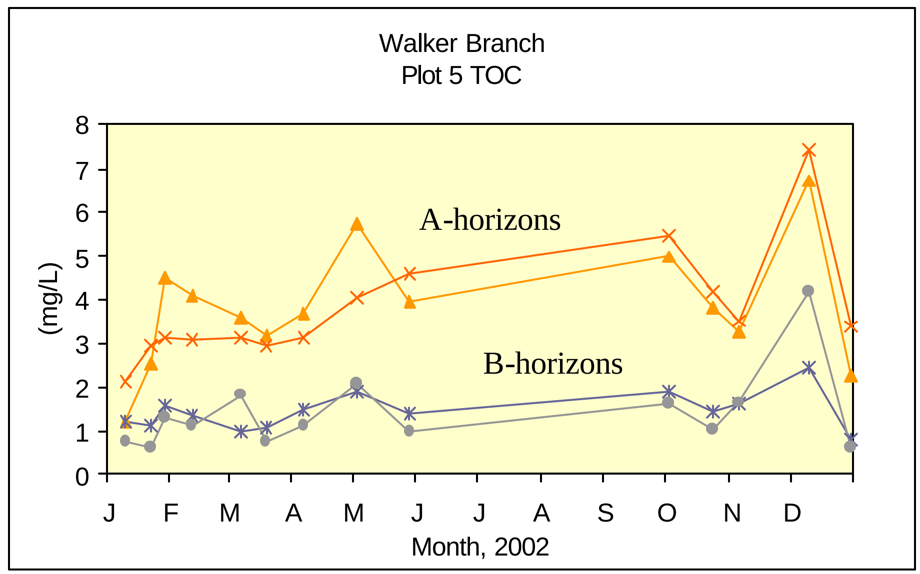


Example storm driven DOC concentrations in Ultisol soil profiles



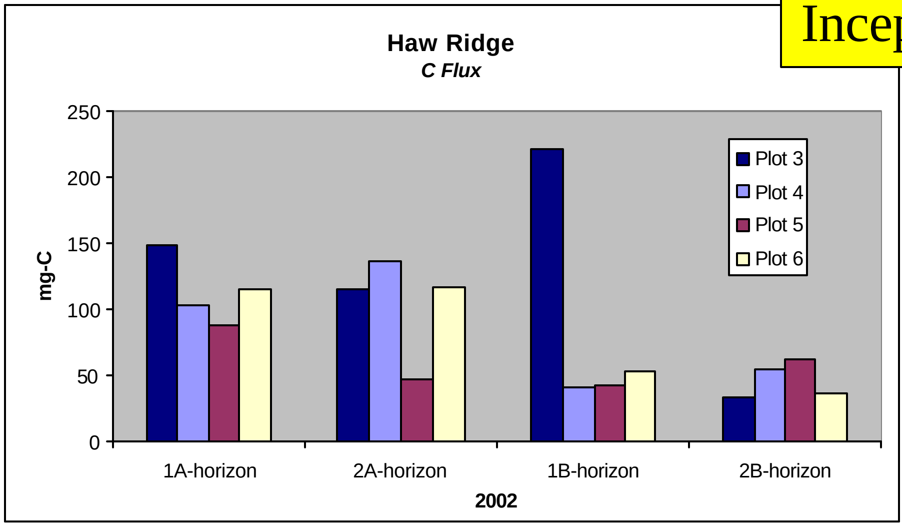


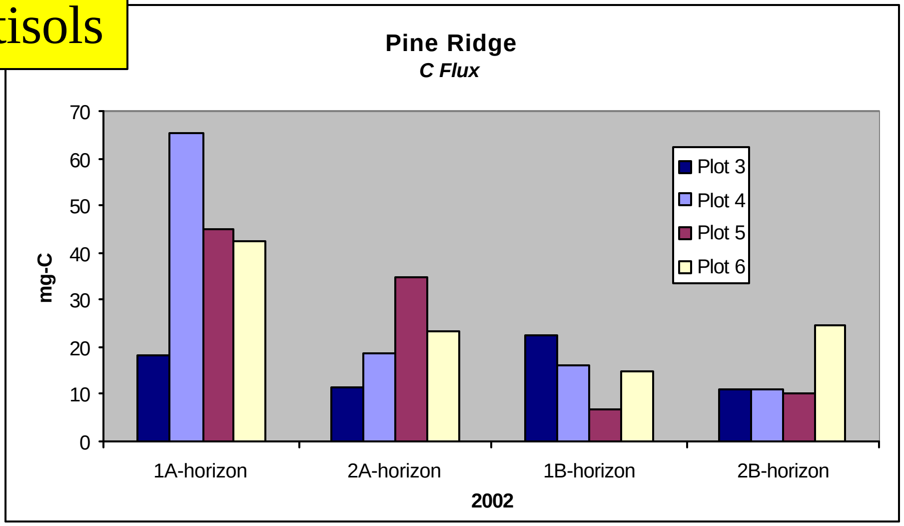




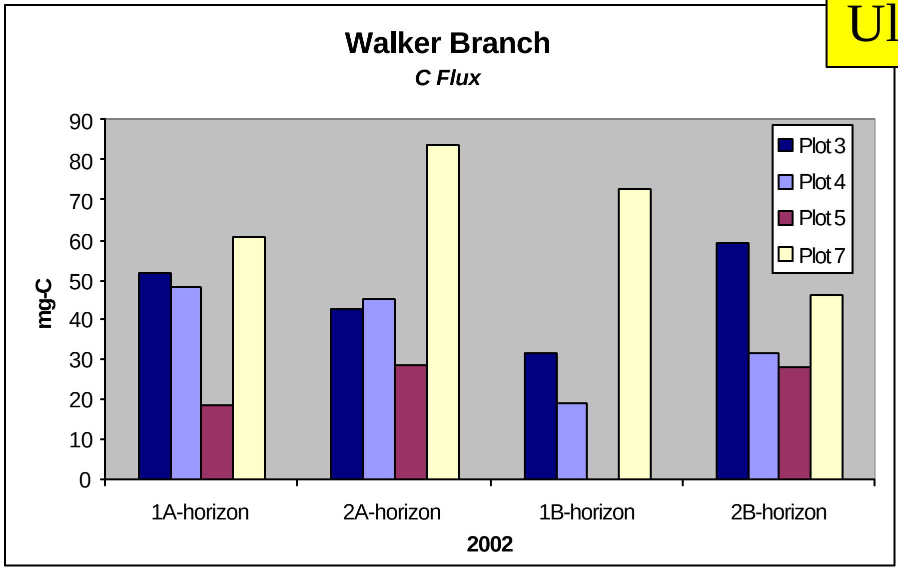
Storm driven DOC fluxes in Inceptisol and Ultisol soil profiles (lysimeter scale)

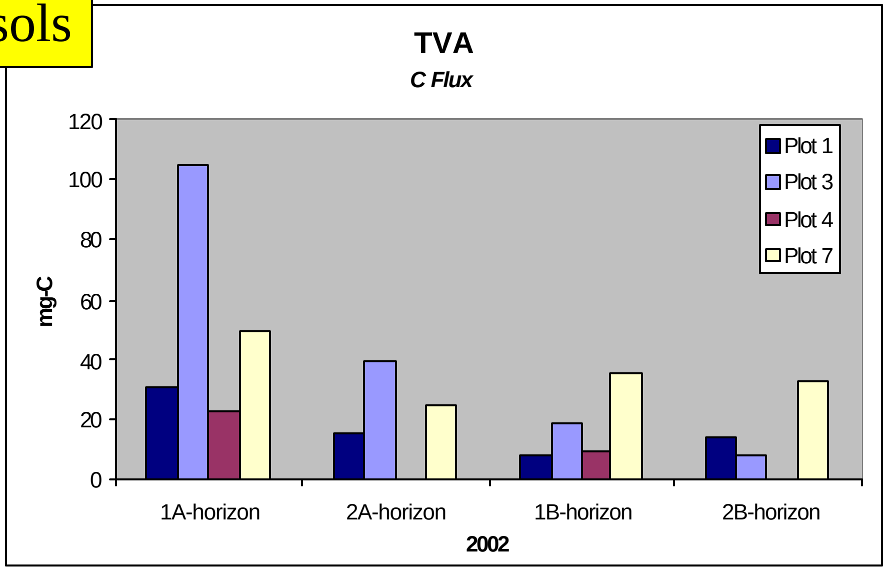
Inceptisols





Ultisols



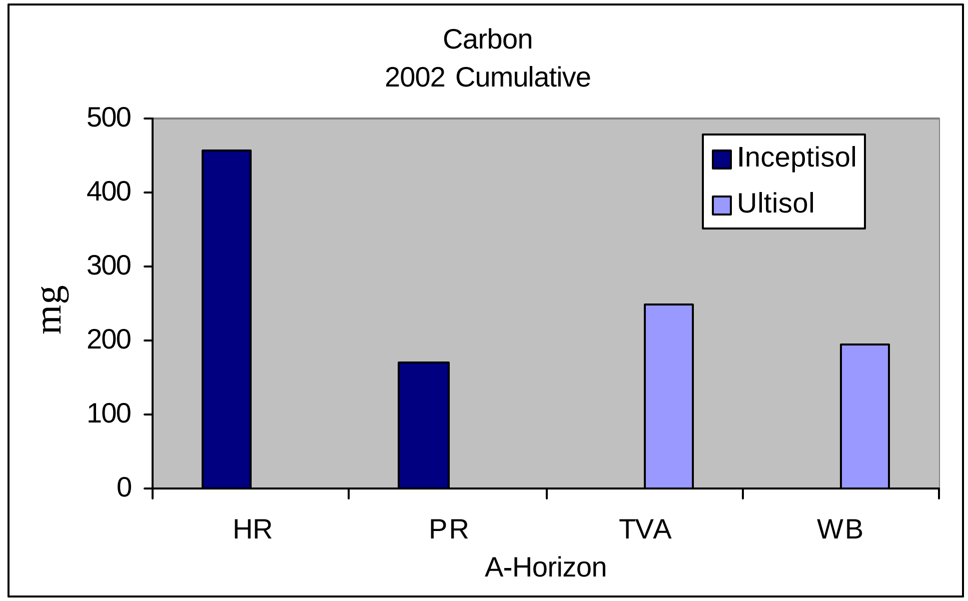


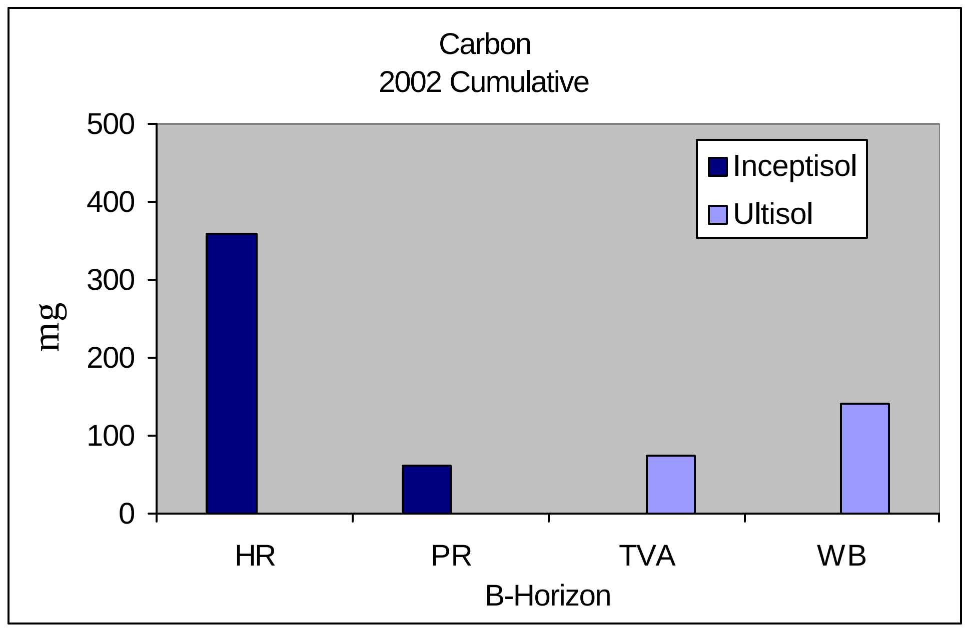
Summation of DOC fluxes in Inceptisol and Ultisol soil profiles (lysimeter scale)

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

•Haw Ridge (sandy inceptisol) has highest C flux which is consistent with its more rapid flow and transport characteristics and lower organic C retention capacity (slides to follow).

•Clayey soils (PR, TVA, WB) have lower organic C fluxes yet greater flux decreases during movement from A- to B-horizons. This may be related to their higher organic C retention capacity (slides to follow).



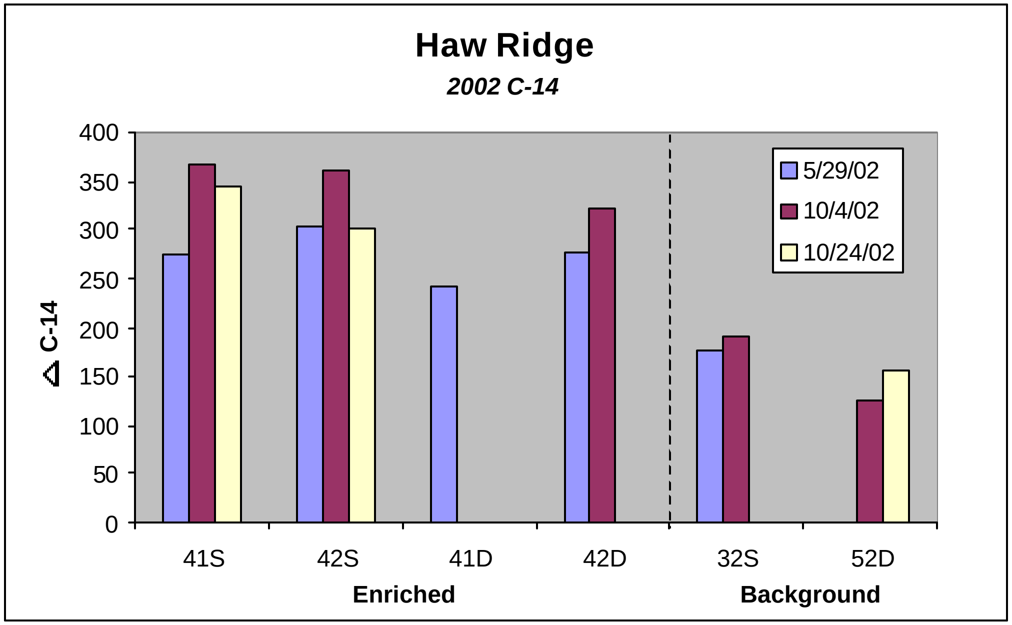


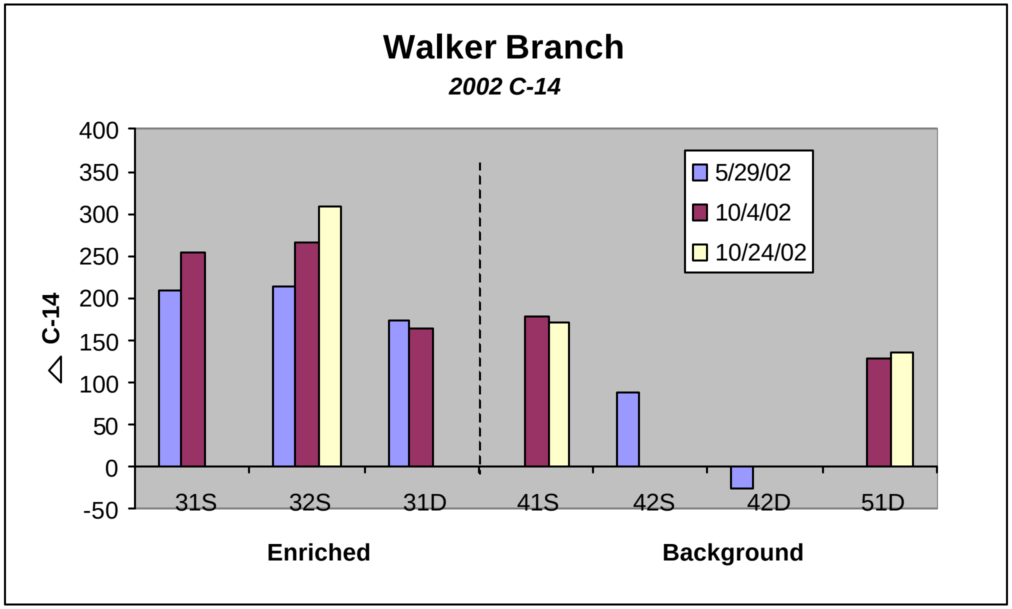
$\Delta^{14}C$ signatures in select pore water from Inceptisol and Ultisol soil profiles

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 (slides to follow).

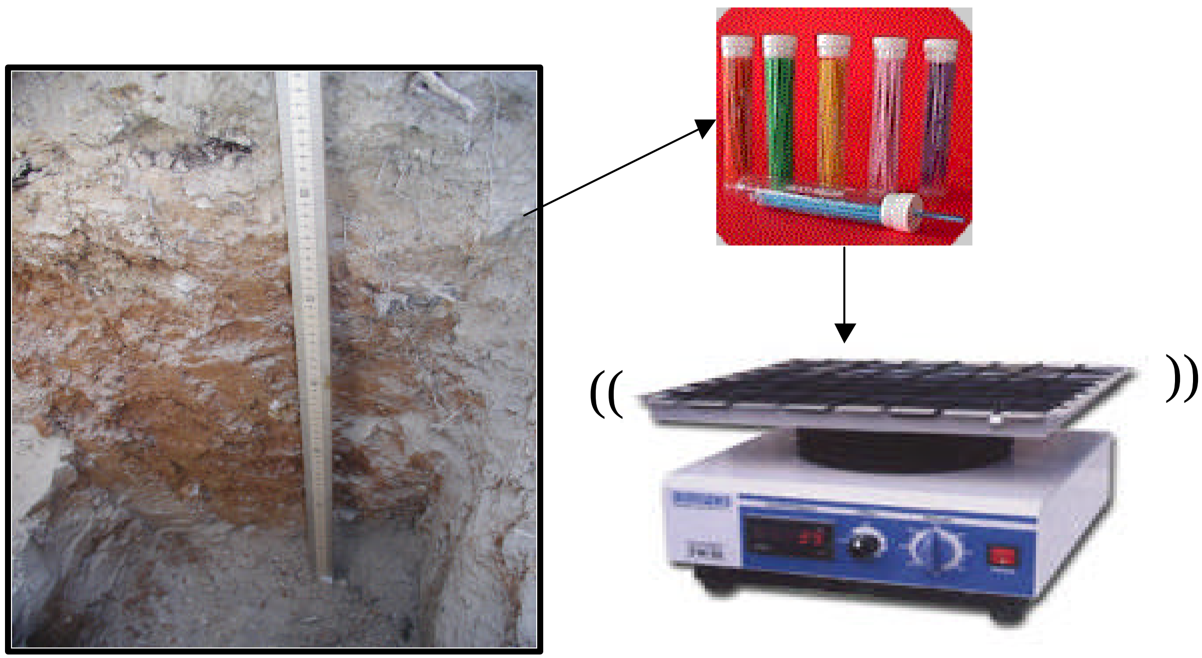
Pore water from WB has a lower $\Delta^{14}C$ signature relative to HR with B-horizon samples showing no evidence of enrichment. This may be related to the higher organic C retention capacity of WB (slides to follow).





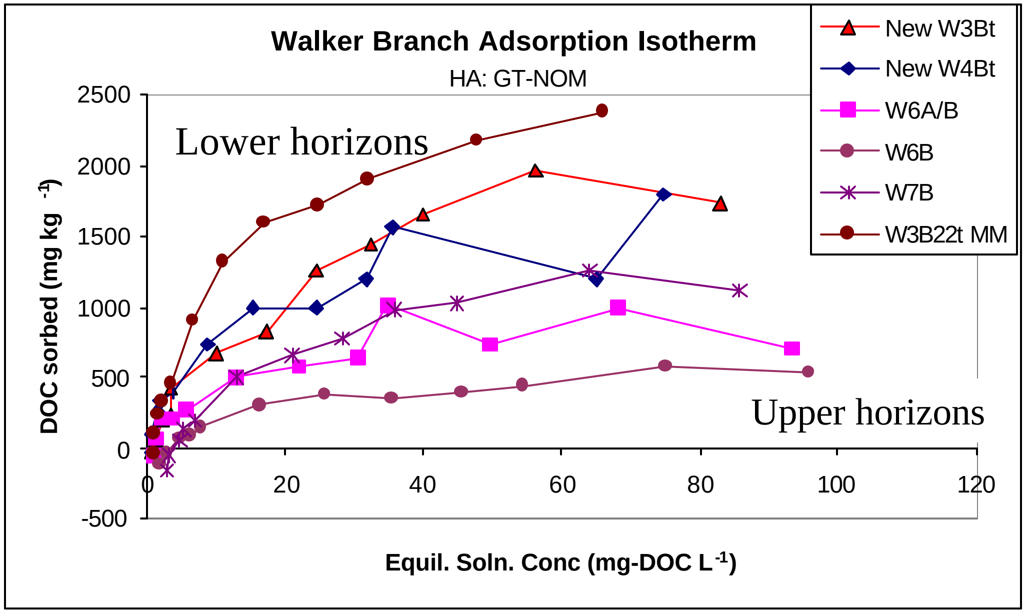
Organic C sorption isotherms

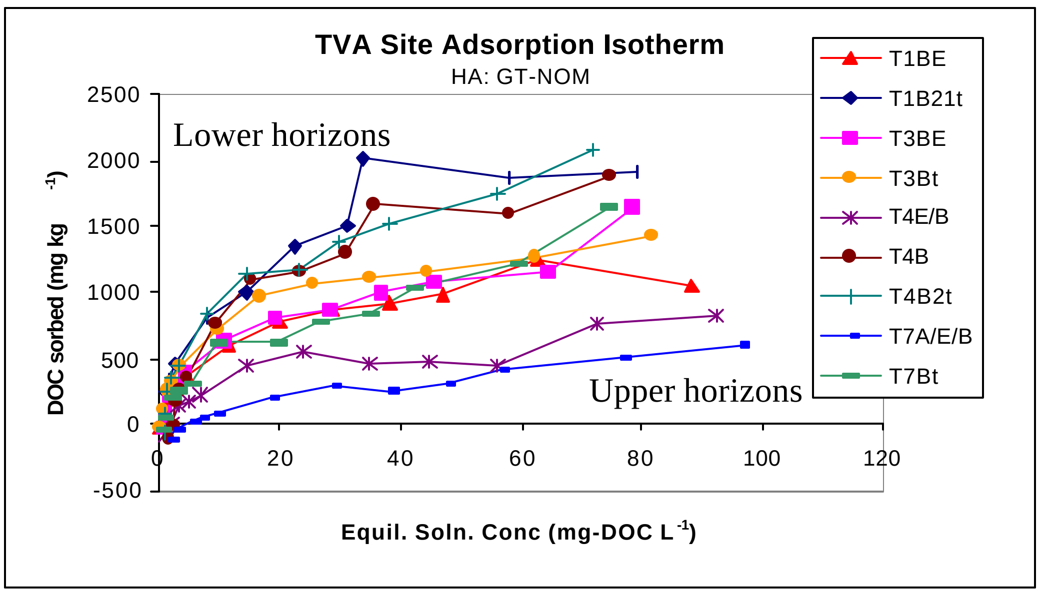
▪ A shake-batch method was utilized to construct dissolved organic carbon isotherms on the Ultisol and Inceptisol subsoils from the various EBIS plots.



▪ 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.

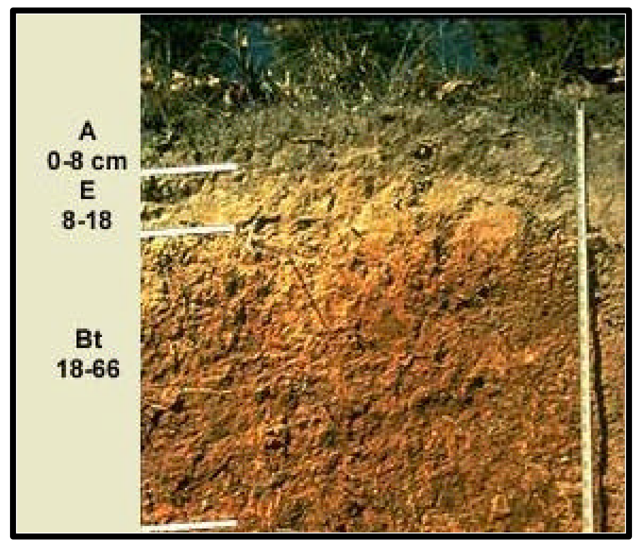
Carbon sorption isotherms on Ultisol soil profiles



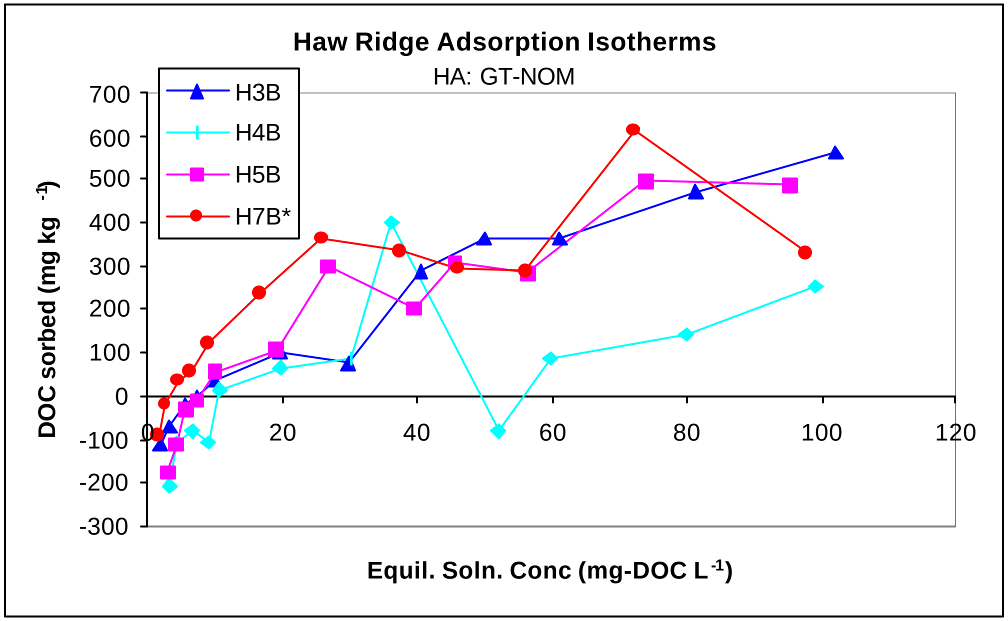


Soil samples from lower B-horizons have significantly larger carbon sorption capacities relative to upper A, E, A/E, and B/E horizons.

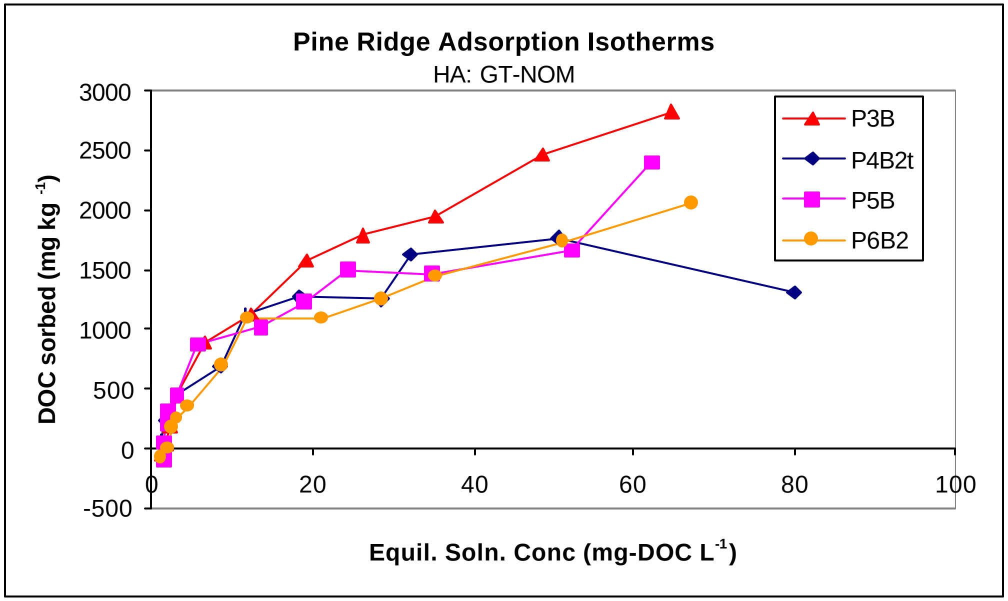
Typical soil profile



Carbon sorption isotherms on Inceptisol soil profiles

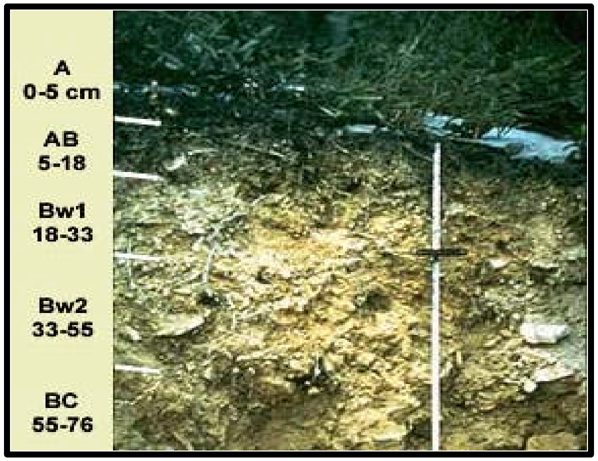


Low organic C sorption on sandy inceptisols with low Fe-oxide content.

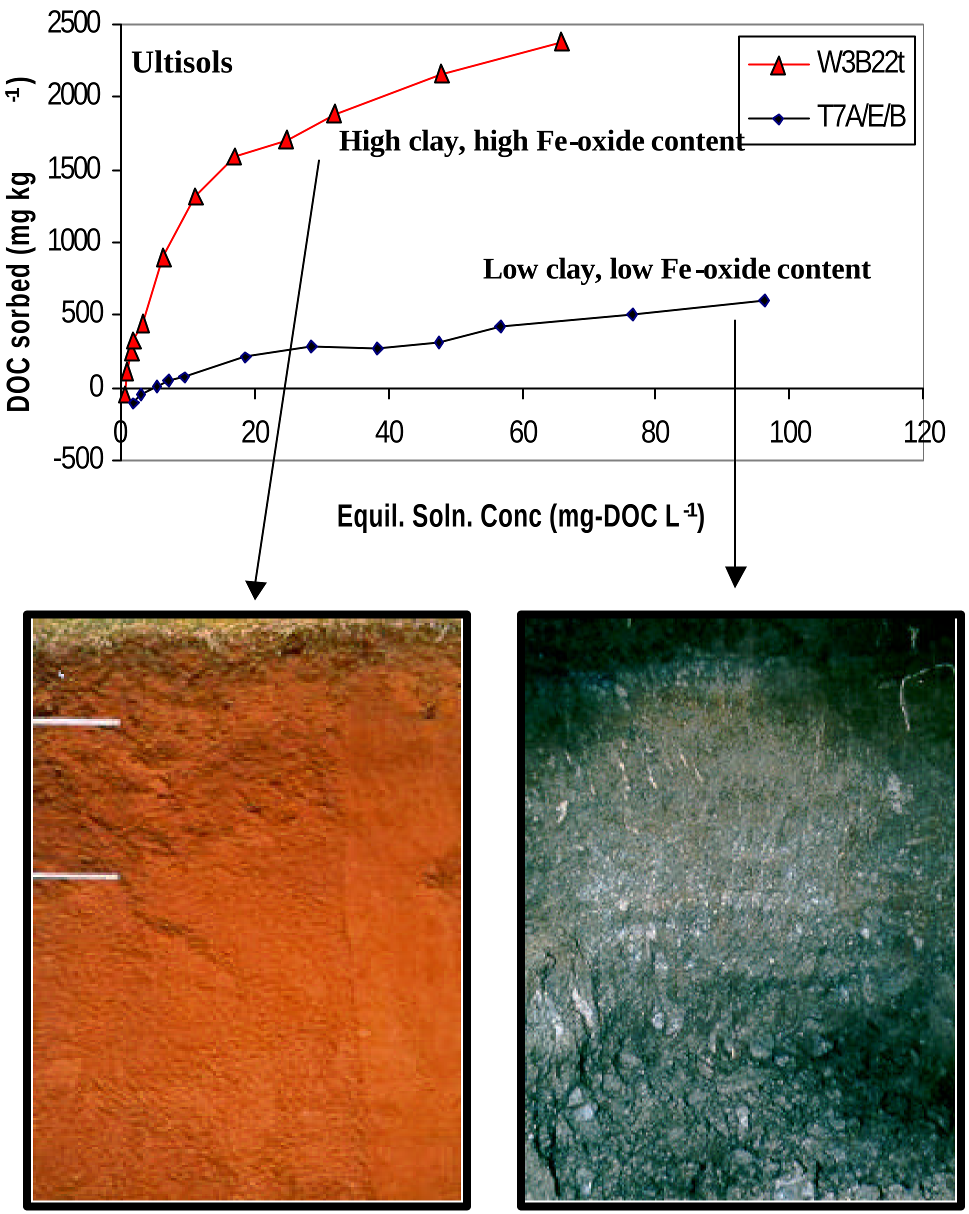


High organic C sorption on clayey inceptisols with high Fe-oxide content.

Typical soil profile



Importance of Fe-oxides and clay content



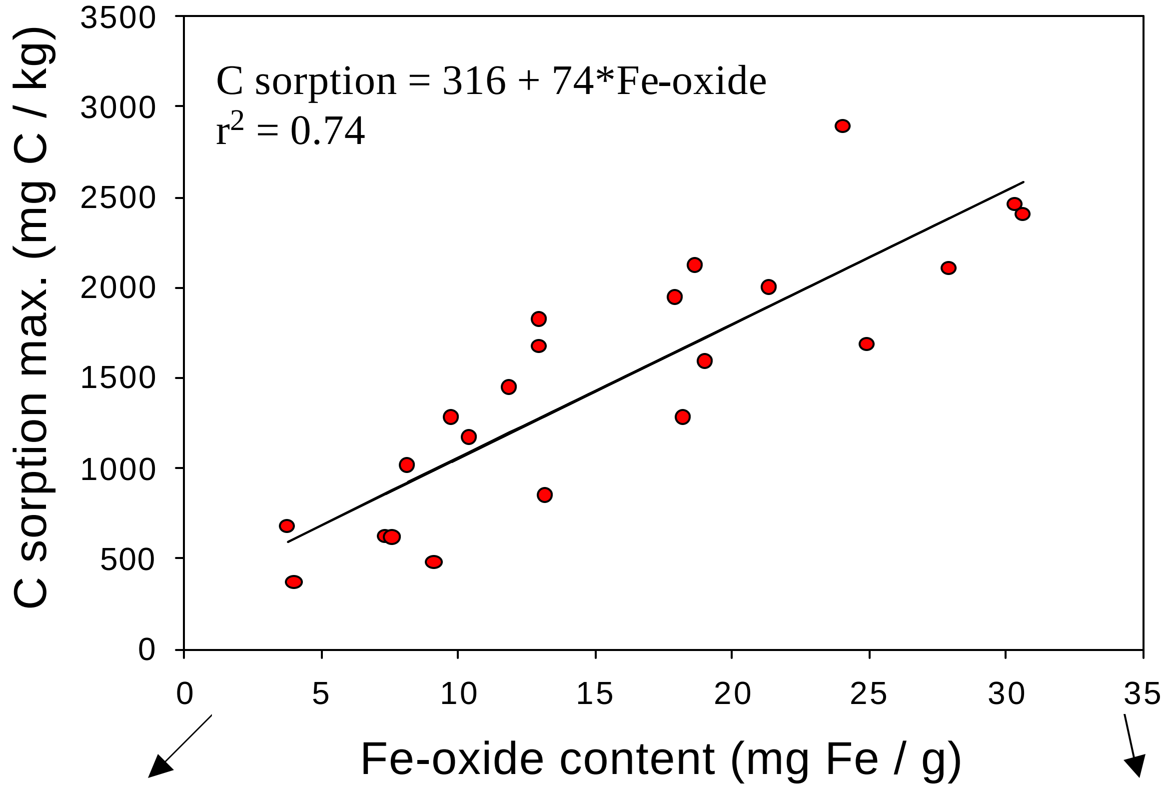
Highly weathered subsoils often contain appreciable clay that is heavily coated with amorphous and crystalline Fe-oxides.

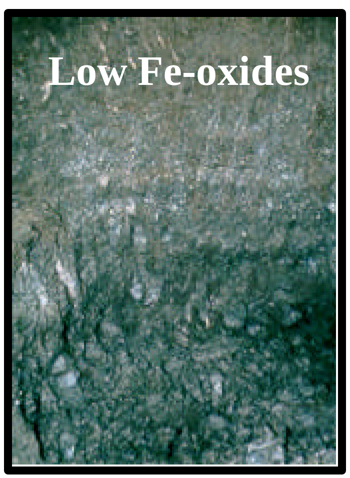
DOC sorption is drastically higher in soils From Fe-oxide rich sites on the ORR.

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

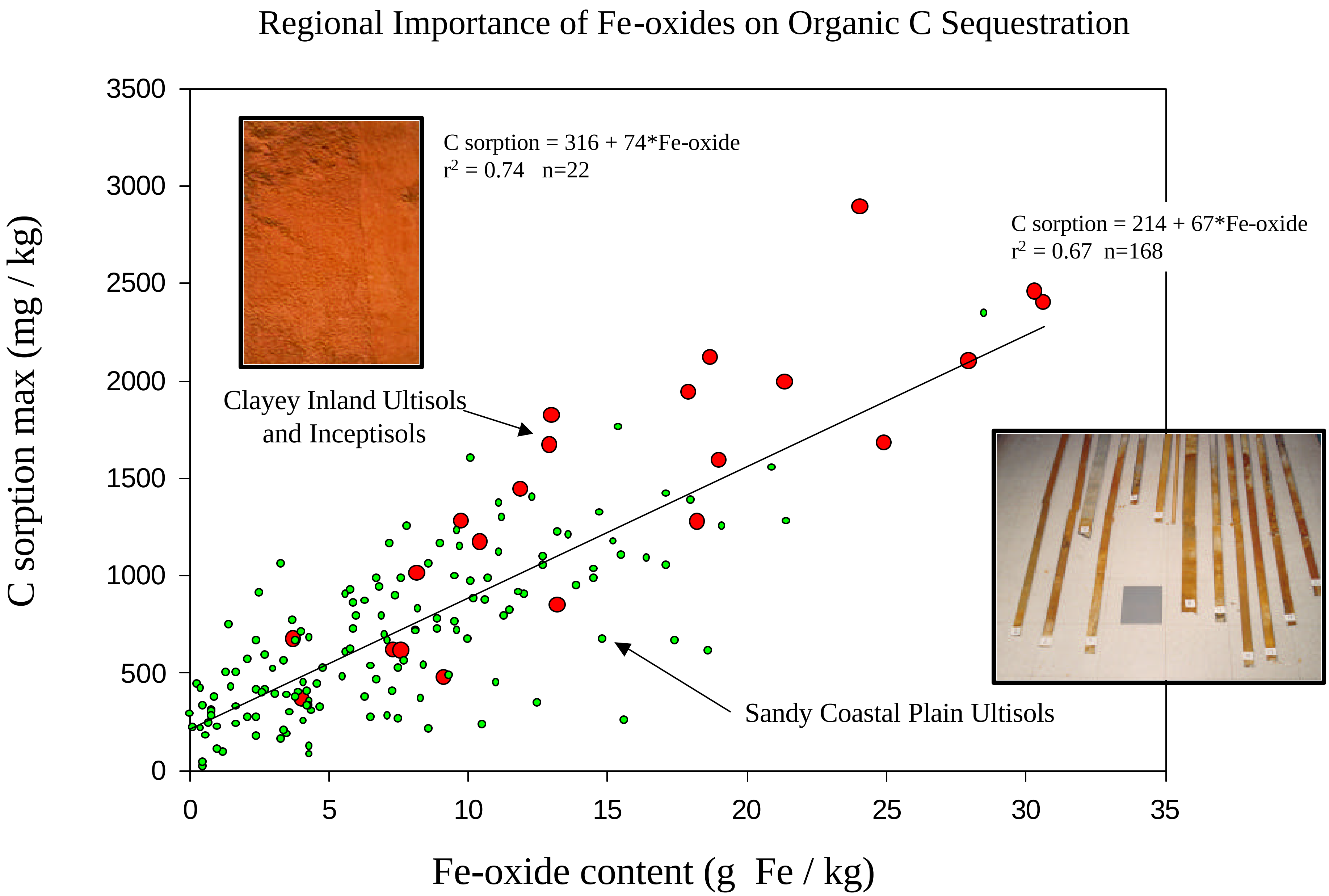
Numerous studies with synthetic Fe-oxides show similar results.

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.



Regional Importance of Fe-oxides on Organic C Sequestration
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
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

Summary

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

- Organic C fluxes at each site are consistent with the hydrodynamics and geochemical retention capacities of the soils.

- Organic C sorption is 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.