Soil Drainage and Forest Type Influences on Soil Organic Carbon Fractions in a New England Forested Watershed

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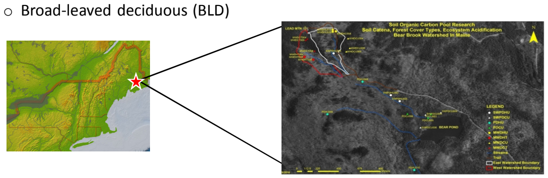
INTRODUCTION

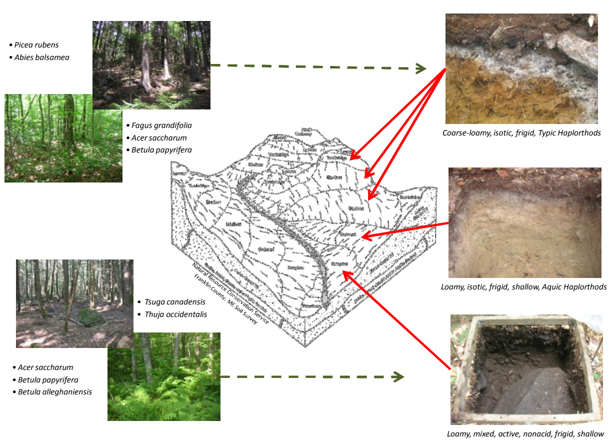
An estimated 70-80% of carbon residing in temperate forested ecosystems may exist in the soil, termed soil organic carbon (SOC)[1,2]. Our understanding of SOC dynamics in these systems originates from studies conducted in well drained, and to a lesser degree poorly and very poorly drained organic substrate, environments. Few studies have focused on understanding SOC dynamics in imperfectly drained systems. Imperfectly drained soils may provide linkages between terrestrial and aquatic systems, or occur in extensive isolated areas in the landscape as in the glaciated northeastern United States. Our primary research questions were:

- *Do differences exist in SOC dynamics among distinct soil drainage classes?*
  - Moderately well drained (MWD)
  - Somewhat poorly drained (SWPD)
  - Poorly drained (PD)
- *Do differences exist in SOC dynamics between different dominant forest types?*
  - Coniferous (CF)
  - Broad-leaved deciduous (BLD)



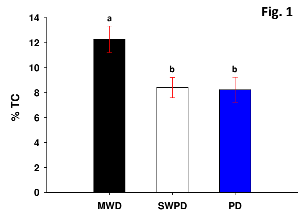
METHODS

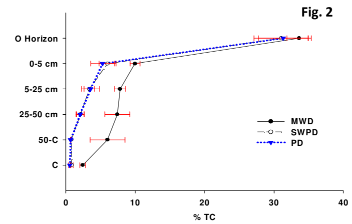
- Experimental design:
  - 6 compartments *(3 soil classes * 2 forest types)* * 3 plots = 18
- 18 quantitative pedons were excavated in 2010 for C and chemical analysis[3,4]
- Total C determined on LECO® CN-2000 Analyzer
- Sequential C extraction conducted on air dry samples using hot water (HWEC) and 6 M HCl (AHOC)[4,5,6]
- Monthly soil respiration (R_{SOIL}) measurements conducted with LI-COR® 6400
- Samples collected for seasonal measurements in conjunction with R_{SOIL} for gravimetric soil moisture (G_{SM}) and HWEC extraction on the O horizon and upper 5 cm of the mineral soil



RESULTS & DISCUSSION

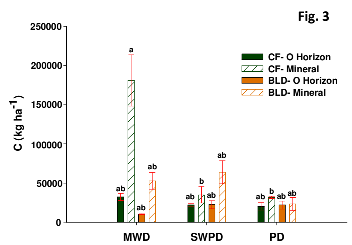
C Concentration

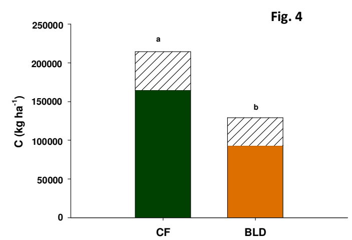




- Differences ($P<0.05$) existed for the whole pedon (Fig. 1) and the mineral soil in MWD compared to SWPD and PD.
- Differences are likely due to higher productivity leading to greater root biomass among soil drainage classes and increased C concentrations descending soil profile (Fig. 2).

C Content





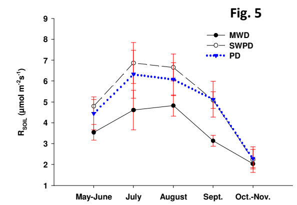
- MWD mineral soil (Fig. 3) and CF whole pedon (Fig. 4) had the highest soil C content.
- Differences in fine soil mass and potentially fine root biomass may explain higher C content in MWD and CF systems.

Selected Soil Chemical Properties

Depth Increment	Chemical Property	Soil Drainage Class			Forest Cover Type	
		MWD	SWPD	PD	CF	BLD
O Horizon	LOI	60	57	54	64[a]	50[b]
	C:N	23	26	25	27[a]	22[b]
	pH_{CaCl2}	3.20[a]	3.70[ab]	3.99[b]	3.35[a]	3.91[b]
0-5 cm	LOI	19[a]	12[ab]	10[b]	15	12
	C:N	20	21	18	22[a]	18[b]
	pH_{CaCl2}	3.57[a]	3.96[ab]	4.17[b]	3.75	4.04
5-25 cm	LOI	18[a]	8[b]	8[b]	12	10
	C:N	22	19	19	20	18
	pH_{CaCl2}	3.9[a]	4.23[b]	4.38[b]	4.09	4.29
25-C	LOI	17[a]	5[b]	5[b]	10	7
	C:N	24[a]	18[ab]	17[b]	21	18
	pH_{CaCl2}	4.07[a]	4.49[b]	4.54[b]	4.34	4.44
C Horizon	LOI	6[a]	3[b]	2[b]	3	4
	C:N	23[a]	16[b]	15[b]	19	17
	pH_{CaCl2}	4.27[a]	4.68[b]	4.75[b]	4.62	4.55

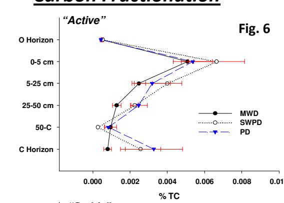
- Soil chemical properties that display significant differences ($P<0.05$) among soil drainage classes include LOI, C:N and pH_{CaCl2}, especially descending the profile. Differences between forest types were confined to the O and upper B horizon.

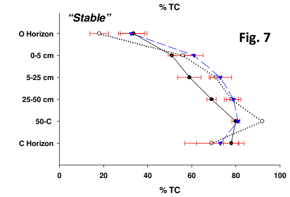
Soil Respiration

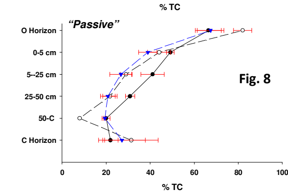


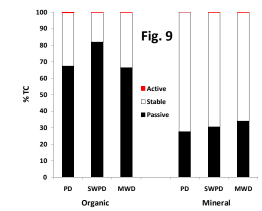
- SWPD and PD systems had higher R_{SOIL} values ($P<0.05$) than MWD, possibly reflecting a lower vulnerability to periods of moisture deficit during the growing season in the upper soil.

Carbon Fractionation









- Significant differences did not exist among drainages, forest types or their interactions in any C fraction, but did exist between the O horizon and mineral soil in the stable and passive fractions. Numerical trends existed with depth (Figs 6-8).
- Caution is warranted in data interpretation because the acid hydrolysis methodology for O horizons does not differentiate between "new" and "old" plant material.

CONCLUSIONS

Results from this study indicate SOC differs among drainage classes, and to a lesser degree forest types. It was initially hypothesized that a conventional sequence would exist of high to low SOC from PD to MWD, and from conifer to broad-leaved deciduous, due to reduced decomposition and increased accumulation. Yet evidence suggests the contrary for this drainage sequence, and only occasional differences were noted in forest types. One key contributing factor to these results could be the role of root biomass as a SOC source. A slightly different pattern emerged for R_{SOIL} during the 2010 growing season, a year with soil moisture deficits greater than normal. The R_{SOIL} results suggest that SWPD, and to a lesser extent PD soils are more resilient to moisture stress. This can be an important consideration in evaluating ecosystem resilience to intensified weather regimes associated with a changing climate. The results of this research indicate that understanding spatial patterns of soil drainage on the landscape is essential to defining ecosystem processes and SOC dynamics.

References

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Note: The Bear Brook Watershed in Maine (BBWM) is a National Science Foundation Long-Term Research in Environmental Biology site.