Persistence of Charcoal in Soils of the Cone Pond (New Hampshire) Watershed and Possible Effects on Soil Chemistry

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Introduction: **The effects of black carbon on forest soil chemical properties are not well understood. The presence of charcoal may stimulate nitrification if there is an adequate NH_4^+ supply (DeLuca et al. 2006) but lower rates where N is limiting (Gundale and DeLuca 2007). Recent evidence (Wardle et al. 2008) suggests that charcoal may accelerate humus loss. Other studies have shown benefits to agricultural soils.**

In our studies of forest soils in the northeast US, the Cone Pond watershed stands out as having a large charcoal component in and under the forest floor. The watershed soils also stand out in comparative studies as having the lowest N mineralization rates, the highest C/N ratios, the lowest exchangeable Ca^{2+}, and the highest exchangeable H^+ and Al^{3+}. This poster provides some background on the presence of black carbon in Cone soils and their unusual soil chemistry.

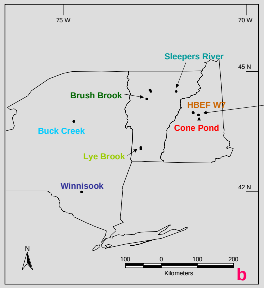


Figure 1. a) Aerial photo of the Cond Pond watershed; b) location in central NH; c) topo-map of watershed showing transect points; d) the pond; e) exposed bedrock near the top of the watershed

Charcoal at Cone Pond

Tree-throw showing charcoal below the forest floor.

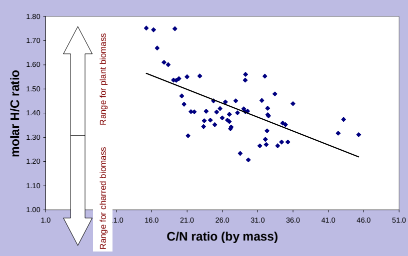
Charcoal visible on the underside of a excavated chunk of forest floor.

Oa horizon with visible charcoal.
C/N = 34.4; C = 300 g kg^{-1}; N = 8.7 g kg^{-1}

Historical records and dendrochronology suggest that the 1820 fire was intense due to large areas of blow-down from an 1815 hurricane. When sampling, fairly large pieces of charcoal were often noticed in and below the Oa horizon (see pictures above).

When further examining these samples, measurable amounts of charcoal were found in most (see right-hand picture above). The molar H:C ratio was lower in the high C/N samples (see graph), indicating the presence of pyrogenic C (biomass is usually in the range of 1.7 to 1.3 while pure charcoal is about 0.6). However, the weight of the obvious charcoal alone was not enough to account for the high C/N ratio. Other black carbon is probably present.

Cone Pond elemental ratios in Oa horizons



Discussion

It is speculative as to whether or not these extremes in soil chemical properties (panels A thru C) are related to fire history. These results were anomalous compared to other experimental sites with no documented history of fire. However, lasting effects of fire may be a more widespread phenomenon in the eastern USA than otherwise realized. Fires dating from 1820 are known from other parts of the White Mountains (Goodale 2003). Also, fires were common after early 20th century logging, especially in areas that were logged by railroad (Goodale and Aber 2001). More work is needed to ascertain the contribution of black carbon to forest soil properties in this region.

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Watershed characteristics:

The Cone Pond watershed consists of 33 ha of all-aged (maximum tree age, 270 years) forest within the White Mountain National Forest (Bullen and Bailey, 2005). The watershed has no known history of human habitation or forest harvest but did experience a large fire around 1820 (Buso et al., 1984).

Vegetation: The watershed cover is 80% mixed conifer forest, 15% northern hardwood forest, and 5% bedrock outcrop (Fig 1a). In 60 plots along the transects shown in Fig. c, the average dominance of individual species was:

Species	Percent of basal area
Red Spruce	41%
Eastern Hemlock	23%
Red Maple	10%
American Beech	9%
Paper Birch	8%
Yellow Birch	5%
Sugar Maple	3%

Soils are Aquic, Lithic, and Typic Haplorthods, and have developed in a thin (<2 m), firm, slowly permeable, dense basal till which limits deep percolation of drainage waters.

Bedrock: The watershed is underlain by sillimanite-grade metapelites of the Silurian Perry Mountain Formation. Bedrock is exposed along ridges, while the remainder of the watershed is mantled by glacial till (<2 m thick) derived primarily from local granitic and metapelitic rocks (Bailey and Hornbeck 1992).

A. High forest floor C/N ratios (low N per unit C)

The average C/N ratio in Oa horizons at Cone Pond was much higher than nine other NE US watersheds (Fig. A-1, Ross et al. in press). The cause appears to be the contribution of black carbon that has a low N content (Figs. A-2 and A-3). However, high conifer density has also been correlated with high C/N and this may be an additional factor at Cone Pond.

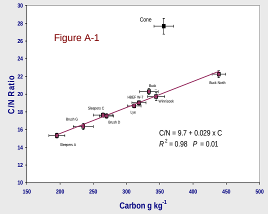


Figure A-2. 608 individual samples from 10 watersheds

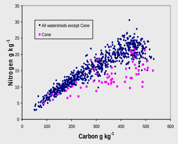
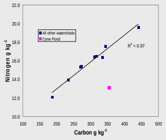


Figure A-3. Results from Fig. A-2 averaged by watershed.



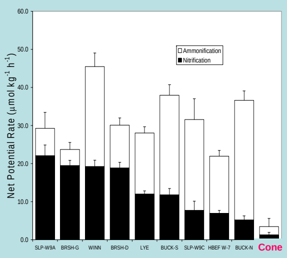
B. Low nitrogen mineralization

In two different cross-site studies, Cone Pond had the lowest net rates of both nitrification and ammonification in the surface horizons (Ross et al. 2004, Ross et al. in press). When compared to nine other watersheds (shown in Fig. 1b), Cone rates were remarkably low (Fig. B-1).

An Oa sample from the Cone Pond watershed also had the lowest gross rates of both ammonification and nitrification in a study of 12 NE USA forested watersheds (Ross et al. 2004).

Stream N export is also extremely low.

Figure B-1. Results from Fig. 1-2 averaged by watershed.



C. Low exch. Ca^{2+}, high exch. Al^{3+} and high exch. H^+

In a study of 12 red spruce sites in NE USA, Lawrence et al. (1997) found the highest exchangeable Al^{3+} in an Oa horizon from Cone (32.6 $cmol_c$ kg^{-1} **!!**) and the lowest average exchangeable Ca^{2+} (and Ca saturation) in the B horizon (0.11 cmolc kg^{-1} and 1.6% saturation of the CEC). See Fig. C-1for data from the Oa horizons in this study.

Ross et al. (1996) measured exchangeable H^+ by a variety of methods in some of the samples from the above study, along with samples from Brush Brook VT. An Oa sample from Cone had by far the highest exchangeable H^+ (Fig. C-2).

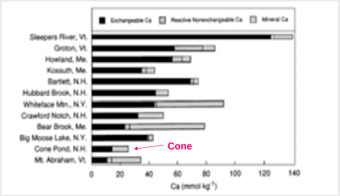


Figure C-1. Exchangeable and total Ca^{2+} in Oa horizons from 12 NE USA red spruce stands (from Lawrence et al. 1997)

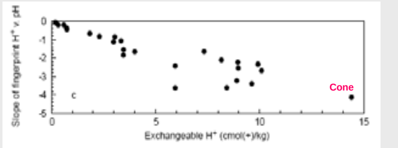


Figure C-2. Exchangeable H^+ in Oa horizons from 8 NE USA watershed (from Ross and Bartlett 1997)