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Comparison of Soil Acidification and Intensity of Podzolization Beneath Decaying Wood *versus* Non-woody Forest Floors in Coastal BC

Introduction

Forest managers concerned with maintaining soil productivity must consider the impacts of forestry practices upon the features of a site. One critical feature is the amount and type of organic matter on a site, which may affect soil development. This study addresses the question of whether CWD accumulations increase the intensity of podzolization, thus reducing the long-term productivity of a site.

Podzolization is defined as the chemical downward translocation of aluminum, iron and organic matter, resulting in the concentration of silica in the eluviated mineral soil layer (Ae horizon), and accumulation of the these products in the mineral soil layer below. From a soil productivity perspective, podzolization is often thought to affect nutrition, resulting in forest productivity decline. These nutritional properties include:

(1) upper horizons leached of cations and consisting of nearly pure Si;
(2) increased acidity;
(3) decreased nutrient availability as N and P are immobilized in organic horizons, due to the high capacity of Podzols to fix phosphate;
(4) build-up of a thick, slow-decomposing, acid mor humus form;
(5) precipitated organic matter that resists decomposition; and
(6) development of impermeable layers, resulting in a water table within the rooting zone.

Podzolization itself does not diminish productivity; rather, it is the ancillary soil properties. The intensity of these processes is seen as a measure of the rate of soil development towards the six aforementioned characteristics. Since increased intensity of podzolization lowers site productivity, podzolization measures can be used as indicators or indices of the potential for reduced productivity.

In moist cool climates, podzolization is inevitable with or without forest management. However, forest managers still need to know if their practices regarding CWD will alter the natural rate of change. Since the chemical nature of decaying wood is so different from other humus forms, and it can take many years for logs to fully decay in coastal BC, large accumulations of decaying wood persist long enough to affect the soil directly beneath. CWD accumulations may result in a lower forest floor pH, which may be associated with more intense podzolization. Thus CWD accumulations may negatively affect site productivity, especially in the west coast of BC where CWD accumulations can be large.

In this study, we investigated the long-term productivity implications of CWD accumulations by addressing the questions: is there (i) a thicker Ae layer, (ii) greater acidification, and (iii) greater degree of podzolization in forest floors with CWD *versus* those without?

Study sites and methods

Three study sites were located in the watersheds north of Vancouver in the Submontane Very Wet Maritime Coastal Western Hemlock (CWHvm1) variant. Old-growth stands dominated by Douglas-fir, western hemlock, Pacific silver fir and western redcedar, characterized by canopy trees 60 m in height, 300-750 years old, and 100-200 cm dbh were selected. Candidate stands were zonal, intermediate in both SNR and SMR. Within each stand, a 1-ha site was established, and twelve 1 m^2 pedons were systematically located. One side of each pedon consisted of a forest floor layer with a decay class IV or V log >2 m, with a diameter >30 cm, and incorporated by at least 30% (by volume) into the forest floor; the opposite side was a non-woody humus form. If the log was on a slope >10%, then only logs perpendicular to the slope within 20° were chosen. We randomly selected the side of the log to sample for the non-woody substrate. A 1 m long trench was dug lengthwise through the centre of the log, and extended perpendicularly for 1 m to the non-woody forest floor, forming a $1 m^2$ soil pit.

From each side of the pedon (*i.e.*, the two different substrates), the depth of the Ae horizon was recorded, and approximately 2000 cm^3 was collected from (i) the decaying log; (ii) the LFH layer; (iii) the Ae horizon if present or, if absent, the top 2 cm of the B horizon (separately from both substrate types); and (iv) the upper B horizon to a depth of 10 cm. Forest floor and upper B horizon samples were analyzed for pH, total C, total N, and mineralizable N; upper B horizon samples were also analyzed for extractable Fe and Al. We used indicators of the intensity of podzolization based on definitions of an "f" horizon: organically complexed Fe and Al; ratio of organic C to organically complexed Fe; ratio of the organically-complexed Fe and Al to the total free Fe and Al; and the iron activity ratio (the ratio of organically complexed plus non-crystalline Fe to total free Fe).

Forest floor samples were separated yielding: fraction A (lipids), humic acid (HA), and fulvic acid (FA). Each fraction was analyzed for carbon content ('C' in HA and 'C' in FA). The C indicates the amount of fulvic acid constituents thought to be responsible for the chelation of Al and other metals, especially Fe, and their percolation through the soil. The HA:FA ratio is an indicator of humification, with higher ratios reflecting more intense humification from greater biological activity. Lipids accumulate in acidic or anaerobic soil conditions where biological activity is low.

Results

Significant differences (α = 0.05) were detected between the mean pH of the non-woody *versus* woody substrates (Table 1). Total C and N, the C:N ratio, C in HA and C in FA were also significantly different. The HA concentration was greater in the woody substrates, the FA concentration greater in the non-woody substrates, and the HA:FA ratio greater in the woody substrates.

Table 1. Differences in mean chemical properties between the non-woody humus form and the CWD (woody), and between the mineral soil beneath the substrates in the CWHvm subzone. Standard error of the mean is in parentheses (n=3) and below are the α (treatment) p-values followed by the p-value for β, where applicable. For site × treatment interaction p-values, an asterisk indicates a significant unidirectional interaction effect. Cells in **bold** have significant α (< 0.05); cells in i*talics* have significant β (< 0.20). Min-N = mineralizable N; HA = humic acid; FA = fulvic acid.

chemical property	Forest Floor		Mineral soil horizon			
			Ae		Upper B	
	non-woody	woody	non-woody	woody	non-woody	woody
	mean (sterror) α	mean (sterror) β	mean (sterror) α	mean (sterror) β	mean (sterror) α	mean (sterror) β
Depth (cm)			3.5 (0.7)	3.8 (0.8)		
			0.506	0.216		
pH	**3.72 (0.04)**	**3.41 (0.02)**	*4.00 (0.08)*	*3.95 (0.11)*	*4.42 (0.05)*	*4.36 (0.07)*
	0.022		*0.447*	*0.026*	*0.168*	*0.003*
total C (%)	**48.87 (0.45)**	**58.84 (0.42)**	*2.95 (0.75)*	*3.55 (0.35)*	*5.43 (0.55)*	*5.17 (0.19)*
	0.001		*0.369*	*0.029*	*0.713*	*0.036*
total N (%)	**1.58 (0.06)**	**0.62 (0.05)**	*0.16 (0.05)*	*0.15 (0.04)*	0.23 (0.01)	0.19 (0.02)
	<0.001		*0.396*	*0.157*	0.247	0.860
C:N	**31.1 (1.4)**	**104.4 (9.8)**	22.5 (3.4)	27.4 (4.3)	**25.3 (2.8)**	**27.9 (2.9)**
	0.013		0.139	0.891	**0.001**	
min-N (ppm)			17.0 (5.0)	13.5 (1.7)	24.6 (1.9)	21.2 (2.6)
			0.403	0.267	0.386	0.212
C in HA (%)	**12.73 (0.28)**	**15.11 (1.71)**				
	<0.001					
C in FA (%)	**10.23 (0.43)**	**6.57 (0.53)**				
	0.007					
HA:FA	**1.28 (0.06)**	**2.52 (0.14)**				
	0.013					
Lipids (%)	**3.59 (0.15)**	**1.68 (0.20)**				
	0.031*					

There were variable results for both the A horizon (or top 2 cm of the soil) and the upper 10 cm of the B horizon directly under each forest floor substrate (Table 2). C:N ratio was significantly different in the lower 10 cm of the soil profile; however, the mean difference was not biologically meaningful. Significant differences in any chemical measure (α = 0.05) were not detected for the upper 10 cm of the B horizon. The power of the test for lack of significant difference between the woody and non-woody substrates was adequate (1-β > 0.80) for most of the measures.

Table 2. Differences in mean chemical properties between the mineral soil beneath the non-woody humus form and the CWD (woody) in the CWHvm subzone. Standard error of the mean is in parentheses (n=3) and below are the a (treatment) p-values followed by the p-value for b, where applicable. For site × treatment interaction p-values, an asterisk indicates a significant unidirectional interaction effect. Cells in **bold** have significant α (< 0.05); cells in i*talics* have significant β (< 0.20) values. Pyrophosphate = sodium pyrophosphate extractable; dithionite = dithionite-citrate extractable.

Chemical property	Mineral soil horizon			
	Ae		upper B	
	non-woody	woody	non-woody	woody
	mean (sterror) α	mean (sterror) β	mean (sterror) α	mean (sterror) β
Pyrophosphate Fe (%)	0.30 (0.09) 0.555	0.24 (0.04) 0.817	0.75 (0.14) 0.468	0.67 (0.05) 0.900
Pyrophosphate (Fe + Al)(%)	0.56 (0.11) 0.353	0.45 (0.07) 0.228	*1.57 (0.18)* *0.150*	*1.43 (0.13)* *0.040*
Organic C / Pyrophosphate Fe	61.7 (31.4) 0.521	43.3 (10.8) 0.974	*9.2 (2.0)* *0.909*	*9.1 (0.9)* *0.003*
Pyrophosphate (Fe + Al) / Dithionate (Fe + Al)	*0.43 (0.05)* *0.980*	*0.43 (0.06)* *<0.001*	*0.63 (0.07)* *0.212*	*0.60 (0.07)* *<0.001*
Oxalate - Fe / Dithionite - Fe	*0.47 (0.05)* *0.652*	*0.49 (0.03)* *0.057*	*0.62 (0.06)* *0.245*	*0.64 (0.07)* *0.003*

Discussion

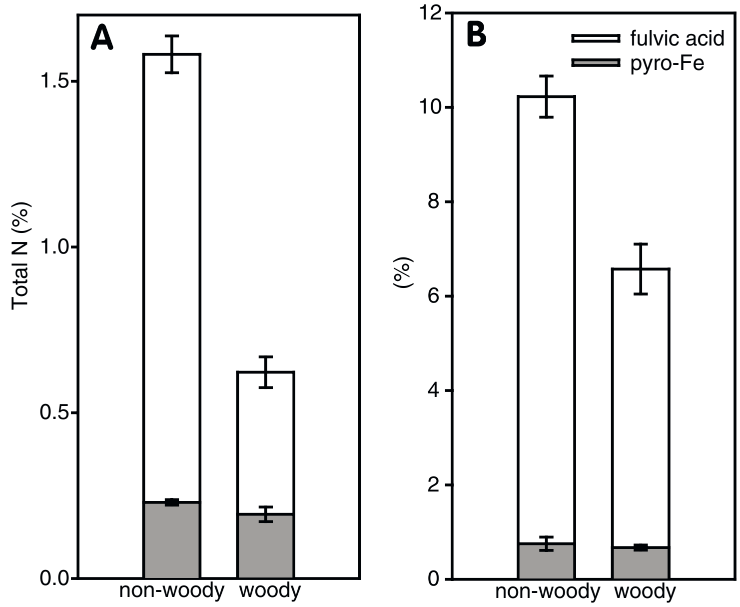
Despite differences in nutrient properties and humus fractions between the non-woody and woody substrates, there were few differences in the corresponding nutrition and podzolization measures (depth of Ae horizon, Fe and Al extractions) of the soil directly beneath (Figure 1). In particular, the greater concentration of FA associated with the non-woody substrate did not translate into equivalent differences in the factors of the degree of podzolization. FA is the main constituent of organic material responsible for chelation of Fe and Al, and the downward movement of this complex. Thus, a deeper Ae horizon is not associated with accumulations of CWD for soils on zonal sites. In fact, the potential productivity of CWD is either equal to non-woody forest floor re: intensity of podzolization or, CWD has a lower productivity based on its lower fulvic acid. Either way, long term site productivity appears to be unaffected by CWD.

This study was part of a larger study where sampling occurred along an elevation and latitudinal gradation in nine climatically different areas in BC. The study areas were located in: (1) southwestern BC in each of the Very Dry Maritime Coastal Western Hemlock (CWHxm) subzone, the Very Wet Maritime Coastal Western Hemlock (CWHvm) subzone, and the Moist Maritime Mountain Hemlock (MHmm) subzone; (2) southern central BC in each of the Very Dry Warm Interior Douglas-fir (IDFxw) subzone, the Moist Warm Interior Cedar Hemlock (ICHmw) subzone, and the Moist Cool Engelmann Spruce - Subalpine Fir (ESSF mk) subzone; and (3) central BC in each of the Wet Cool Interior Cedar Hemlock (ICHwk) subzone, the Moist Cool Sub-Boreal Spruce (SBSmk) subzone, and the Moist Warm Boreal White and Black Spruce (BWBSmw) subzone. These locations covered a precipitation, temperature, and continentality gradient in three respects: longitude, latitude, and altitude. All areas had similar results to those reported here.

Conclusions

Based on the similarity of the depth of Ae horizon, pH, and the chemical variables in the Bf horizon, current evidence suggests that decaying wood does not increase acidification and eluviation of mineral soils on zonal sites in coastal BC.

Figure 1. Difference in (A) total N between the non-woody and woody substrates (open boxes) and the upper 10 cm of the mineral soil (shaded boxes) and (B) between the C in fulvic acid between the non-woody and woody substrates and pyrophosphate Fe in the upper 10 cm of the mineral soil. Error bars represent one standard error of the mean.



The theory that CWD causes increased acidification and eluviation compared to non-woody forest floors appears to be false in this case. Based on the evidence to date, forest managers deciding to leave a legacy of CWD for habitat and biodiversity need not be concerned about impacts on the long-term productivity of zonal sites.

Reference

Kayahara, G.J. 2000. The effects of coarse woody debris on site productivity of some forest sites in southwestern British Columbia. Ph.D. Dissertation. University of British Columbia, Vancouver, BC.123 pp.

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Editor: Karel Klinka (klinka@interchange.ubc.ca)
Research: Gordon Kayahara (gordon.kayahara@mnr.gov.on.ca)
Production and design: Christine Chourmouzis (chourmou@interchange.ubc.ca)
Financial support: Forest Renewal British Columbia and Fletcher Challenge Canada
For more information contact: Gordon Kayahara

Copies available from:
www.forestry.ubc.ca/klinka or
K. Klinka, Forest Sciences Department, UBC,
3036-2424 Main Mall, Vancouver, BC V6T 1Z4