



The imprint of coarse woody debris on soil chemistry in the western Oregon Cascades

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Abstract. Coarse woody debris (CWD) may create a spatially discrete soil imprint through the release of carbon rich, acidic dissolved organic matter (DOM). DOM has been implicated in many soil processes such as humus formation, nutrient immobilization, podzolization, and the dissolution of soil minerals. We investigated a potential CWD imprint on soil chemistry by sampling leachates and soil solutions under CWD at different stages of decay and under the forest floor as controls. Solutions were analyzed for total dissolved organic carbon (DOC) and polyphenol concentrations. DOC was further separated by chemical fractionation. We also sampled soil from underneath CWD and from control areas without CWD. Samples were analyzed for pH, base saturation, exchangeable acidity, and several aluminum and iron fractions. The pH of CWD leachates was lower ($p \leq 0.001$) and contained more polyphenols ($p \leq 0.0001$) and DOC than control leachates, although chemical DOC fractions from CWD and the forest floor were similar. Surface mineral soils under CWD were lower in pH ($p \leq 0.005$), had more exchangeable acidity ($p \leq 0.002$) and more exchangeable aluminum ($p \leq 0.04$) and iron ($p \leq 0.06$) than forest floor soils. At depths greater than 5 cm, there were no differences between forest floor soils and soils under CWD. Our results suggest that CWD in the middle stages of decay acidifies the surface soil as it decomposes by decreasing exchangeable bases and increasing exchangeable acidity and aluminum. Soils under the most highly decayed CWD, or deeper soils were not affected by CWD. Although we hypothesized that well-decayed CWD would show a spatially explicit imprint on soils, the effect of CWD on soil chemistry was small and limited to surface mineral soils.

Introduction

The spatial variation of litter inputs and its associated effects on nutrient cycling and pedogenesis have not been well studied in old-growth forests where a mosaic of coarse woody debris (CWD) on the forest floor is a prominent feature. CWD may provide recalcitrant 'islands of carbon' in a forest floor spatial mosaic, which may be likened to the concept of 'islands of fertility' in desert ecosystems (Schlesinger et al. 1996). Spatial heterogeneity of litterfall in desert ecosystems has been shown to have cascading effects on nutrient cycling, pedogenesis, and ultimately on net primary productivity. Likewise, soils beneath CWD in old-growth forests may be quite different than soils under the forest floor because of differences in quantity and quality of leachate inputs. Indeed, there may be a spatially discrete wood imprint from large leaching inputs of organic matter that are rich in byproducts of

CWD decomposition, such as cellulose, hemicellulose, and lignin. However, current forest management regimes alter, and oftentimes decrease, the amount of CWD contributed to the forest floor compared to historic litter inputs. This may affect the spatial mosaic of CWD on the forest floor and potentially alter forest soil processes.

CWD may create a spatially discrete soil imprint through the release of carbon rich, acidic dissolved organic matter (DOM). DOM has been implicated in many soil processes such as humus formation, nutrient immobilization, podzolization, and the dissolution of soil minerals. The acidic organic components of CWD leachates may range from simple aliphatic acids to more complex aromatic and heterocyclic acids (Tan 1986) and are collectively termed DOM. DOM contains many different compounds that have varying chemical reactivity towards soil exchange surfaces and as such are difficult to identify. Therefore, fractionation methods have been developed to group DOM by functional chemical categories, rather than specific compounds. One method fractionates DOM into hydrophobic and hydrophilic compounds (Qualls and Haines 1991). Hydrophobic compounds include high molecular weight carboxylic acids and polyphenols and have been shown to displace loosely held hydrophilic compounds, as well as sulfates and some phosphates from soil exchange sites (Qualls and Haines 1991; Kasier and Zech 1996; Qualls 2000). Polyphenols are involved in many reactions that may affect soil organic matter formation and stabilization (Stevenson 1994).

Other components of DOM, such as low molecular weight organic acids, may comprise less than 10% of total dissolved organic carbon (DOC) in soils, but their ability to form strong complexes with metals can have a large influence on soil processes (Fox 1995; Tani and Higashi 1999). Organic acids such as oxalic acid are produced by wood-decaying fungi to aid in cellulose, hemicellulose and lignin degradation during wood decomposition (Dutton and Evans 1996) and may leach from CWD potentially changing soil processes in the underlying soil. Organic acids may affect soil processes by increasing the rate of soil weathering, changing soil pH, releasing cations from clays, and by increasing the effective solubility of aluminum and iron ions in soils solutions (Cromack et al. 1979; Jones 1998). Organic acids may also cause podzolization in some soils, which is the translocation of organic matter, aluminum, and iron to lower soil horizons (Fox and Comerford 1990; Browne 1995; David et al. 1995; Lundstrom et al. 2000). Many soils show evidence of podzolization without necessarily developing a spodic horizon (Birkeland 1984). Kayahara et al. (1996) investigated B horizon soils beneath CWD in British Columbia but found no evidence of podzolization or spodic horizon development. However, Crampton (1982) found podzolization of soils under individual tree canopies in the same ecosystem that he hypothesized was caused by the acidic stemflow of the trees.

Our objectives were to investigate the potential influence of CWD on a soil chemical imprint in an old-growth Douglas-fir-western hemlock forest in the Oregon Cascades. We hypothesized that the concentrations and fluxes of DOM leaching from CWD would be greater than concentrations of DOM leaching from the forest floor because CWD provides a spatially concentrated source of C. CWD leachates should also be much more acidic and rich in hydrophobic and polyphenol

compounds than forest floor leachates because CWD is rich in recalcitrant C compounds. These acidic inputs will bind to the soil exchange sites, complex metals, decrease soil pH and increase the exchangeable acidity in soils beneath CWD. Furthermore, base cations will be leached as base partners to maintain electrical neutrality with the organic ligands, which will decrease base saturation. Podzolization processes will control Al and Fe chemistry, binding Al and Fe to carbon compounds and eluviating these complexes to lower soil horizons. We therefore hypothesized that there will be a strong signal of podzolization as measured by the ratio of free iron compounds to free plus organically bound iron compounds.

Methods

Site description

Our study was conducted at the H.J. Andrews Experimental Research Forest in the Willamette National Forest in the western Oregon Cascades (44° 13' 53" N, 122° 13' 40" W). The climate is Mediterranean. Precipitation at the site averages 350 cm year⁻¹ and the average annual temperature is 10 °C. The elevation of the site is approximately 535 m. Soils are classified as coarse loamy mixed mesic Typic Hapludands (Dixon and Noller 2002). Bulk density at 0–5 cm averages 0.7 g/cm⁻³, and soil textures are silty loams and silty clay loams. Tree species include large *Pseudotsuga menziesii* (Mirb.) Franco (Douglas-fir) with smaller *Tsuga heterophylla* (Raf.) Sarg. (western hemlock) and *Thuja plicata* Donn ex D. Don (western red cedar) in the overstory.

Experimental design and field methods

We used Douglas-fir CWD that was classified into the five decay classes of Triska and Cromack (1979) and described thoroughly in Sollins et al. (1987): class 1, freshly fallen log with sound wood, intact bark and twigs intact; class 2, initial rotting of the sapwood, bark and heartwood sound, twigs absent; class 3, bark sloughs, sapwood decayed but still present, heartwood decayed but structurally sound; class 4 sapwood has rotted, bark absent, branches can be removed easily, and heartwood is thoroughly rotted; class 5, heartwood fragmented and settled into the ground as elongate mounds. All CWD was larger than 50 cm in diameter.

CWD leachates were sampled with zero-tension lysimeters that were made by cutting a 15.3 cm diameter PVC pipe into 10.2 cm long pieces and then cutting them lengthwise in half at a diagonal and capping the ends. Nipples and Tygon tubing were attached at the deeper end and connected to 1 L Nalgene bottles. Lysimeters were sealed against the logs with silicone caulking and checked frequently to ensure that no water could seep into the lysimeters from the outside of the log. Lysimeters were placed beneath five logs of decay classes 2–4. Class 5 logs

were too unstructured and well settled into the soil, so it was not possible to sample leachates with zero-tension lysimeters from this decay class. Forest floor leachates were collected with five zero-tension lysimeters made from 10 cm² plastic sandwich boxes and placed immediately beneath the forest floor in control areas where no logs were evident (hereafter referred to as forest floor leachates). Forest floor leachates were not sampled prior to the fall of 2000. Soil solution was sampled with five Prenart tension lysimeters that were installed at two depths (30 and 50 cm) beneath CWD of classes 2–4 and in control soils without CWD (hereafter called forest floor solutions). Soil solution and leachate were collected biweekly from the fall of 1999 until the spring of 2002 when water was available and road access was not blocked by snow. The first two samples were discarded to avoid a disturbance signal from lysimeter installation. All zero-tension and tension lysimeter samples were filtered immediately after collection through a Whatman GFF filter (0.7 µm pore size) and frozen until analyzed.

We sampled mineral soils under classes 4 and 5 CWD where we expected to find the most pronounced effect of CWD on soils. Soils were augured to a depth of 60 cm with a 10 cm diameter soil auger and homogenized by thoroughly mixing in a sample bag. A total of 10 class 4, 10 class 5 CWD, and 10 areas with no CWD (hereafter referred to as forest floor soils) were chosen from within the same area as the leachate and soil solution sampling. Five of the class 4 CWD were the same CWD used in the leachate and soil solution sampling. When this was the case, soil sampling was at least 1 m from the lysimeters. Control mineral soil samples were taken after removing the forest floor (hereafter referred to as forest floor soils). Soils were collected to a depth of 60 cm and homogenized within four depths: 0–5, 5–15, 15–30 and 30–60 cm.

Lab analyses

Solutions were analyzed for pH with an Orion Scientific electrode prior to filtration, filtered using an ashed GF/F filter and stored frozen until further analysis. Solutions were analyzed for DOC with a Shimadzu TOC analyzer. To determine the chemical behavior of the leachate, total DOC was further fractionated into hydrophilic and hydrophobic compounds using XAD-8 resin (Qualls and Haines 1991). Solutions collected at 30 and 50 cm were too low in DOC concentration to fractionate. Polyphenols were analyzed using the Folin–Denis method on a Shimadzu UV1201 spectrophotometer (Harmon and Lajtha 1999).

Field-moist soils were sieved through a 4 mm mesh and processed immediately for pH in a 2:1 water slurry, percent soil moisture, exchangeable cations in barium chloride (Hendershot et al. 1993), and exchangeable acidity in potassium chloride (Lajtha et al. 1999). Sub-samples were air-dried, ground to a 35 mesh, and extracted with dithionite–citrate to determine total secondary or ‘free’ Fe and Al (Fe_c and Al_c) (Lajtha and Schlesinger 1988; Ross and Wang 1993).

Additional sub-samples were powdered in a Spex mixer-mill to pass through 100 mesh for analysis of noncrystalline inorganic and organic complexed Al and Fe

(Ross and Wang 1993). Sodium pyrophosphate removed organically bound Fe and Al (Fe_p and Al_p) while ammonium oxalate removes both organically bound Al and Fe as well as amorphous Al and Fe (Fe_o and Al_o). All Al and Fe extracts were analyzed on a Liberty 150 inductively coupled plasma emission spectrometer after extraction.

Statistical analyses

Lysimeter data was graphed over time for visual inspection. If there was no effect of sampling date on the concentration, concentrations were averaged over the sampling period and the mean and standard errors were reported. Statistics were performed on the treatment means in SAS using analysis of variance (ANOVA) (SAS Institute, Cary NC, 2000). DOC concentrations varied considerably over time and thus were presented in graphs. Mineral soils were also compared at each depth using ANOVA. A pair-wise comparison of the means (Tukey) was performed only if the F -statistic was significant.

Results and discussion

Lysimeter solutions

We had hypothesized that there would be more DOC in CWD leachates than in leachates from the forest floor because of the large C 'islands' that CWD provides on the forest floor. Furthermore, we hypothesized that the CWD leachates would be much more acidic, and contain more hydrophobic and phenolic compounds than forest floor leachates because of the recalcitrant nature of the C 'islands'. There was considerable variation in DOC concentration in CWD and forest floor leachates with few apparent trends, however, concentrations of DOC leaching from class 3 CWD were generally highest (Figure 1(a)). To determine if more water leaches through the forest floor than CWD and thus dilutes the concentration of DOC in forest floor leachates, we determined the flux of C in leachates (Figure 1(b)). Concentration differences were not a function of the amount of water leaching through the CWD because class 3 CWD still contributed more C to the underlying soil through C inputs than the other decay classes or the forest floor. Contrary to our hypotheses that the most decayed wood would leach the largest amount of C, the DOC leaching from decay class 4 was much more variable and often lower in DOC than forest floor leachates. Classes 4 and 5 CWD is thoroughly degraded, lignin rich, and mostly insoluble (Prescott et al. 1990), which may explain why DOC concentrations were lower under these older decay classes. DOC in soil solutions at 30 and 50 cm were low and extremely variable (data not presented).

CWD leachates in zero-tension lysimeters were approximately thirty times more acidic than leachates from under the forest floor ($p \leq 0.001$, Figure 2), but there was no difference in the pH of leachates from under different decay classes of CWD.

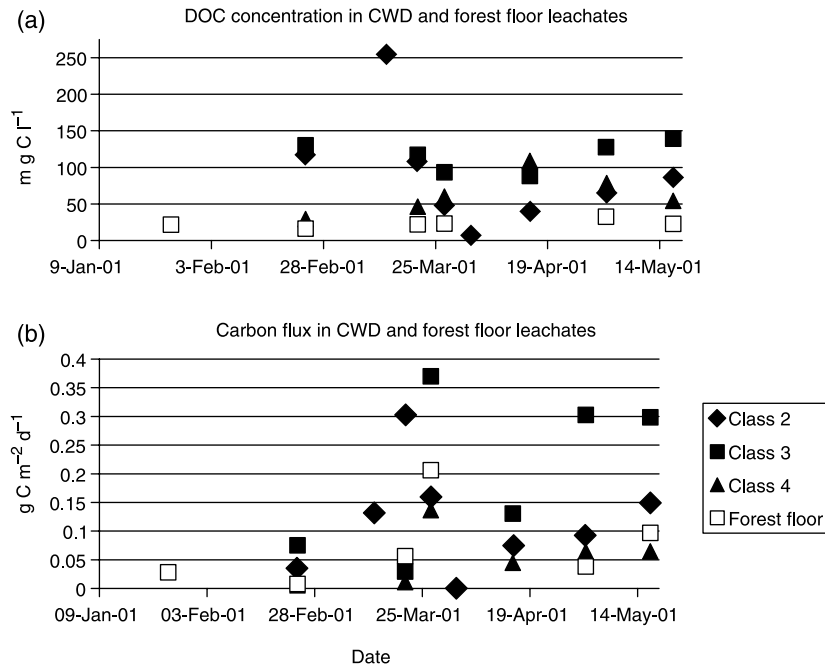


Figure 1. (a) Mean DOC concentrations collected from zero-tension lysimeters under CWD of decay classes 2, 3, and 4 and collected from under the forest floor. Leachates from under the forest floor were not collected prior to fall of 2000. (b) Flux of C in leachates from zero-tension lysimeters under CWD of decay classes 2, 3, and 4 and from under the forest floor.

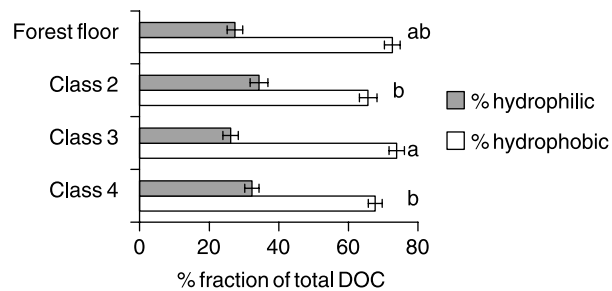


Figure 2. Mean pH of leachates across all dates from under CWD of decay classes 2, 3, and 4, and from under the forest floor. Bars represent one standard error and letters represent statistical difference using Tukey's HSD multiple comparison test. Treatments with different letters are significantly different at $p = 0.05$.

However, chemical fractionation did detect significant differences in leachate quality between CWD decay classes where pH did not. Class 3 leachate contained significantly more hydrophobic compounds and correspondingly, less hydrophilic compounds than leachates from classes 2 or 4 CWD ($p \leq 0.015$, Figure 3). While

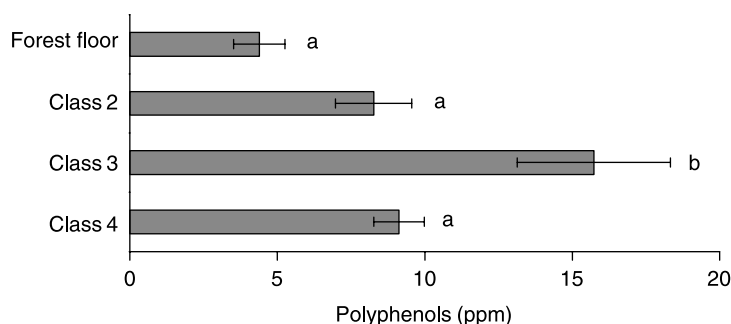


Figure 3. Mean percent hydrophobic and hydrophilic DOC across all collection dates in samples collected with zero-tension lysimeters from under CWD of decay classes 2, 3, and 4 and from under the forest floor. Bars represent one standard error and letters represent statistical difference using Tukey's HSD multiple comparison test. Treatments with different letters are significantly different at $p = 0.05$.

there were detectable differences among decay classes, the percentage of hydrophobic acids of total DOC in class 3 leachate was not different than forest floor leachate, suggesting that there are more hydrophobic acids leaching from the forest floor than previously suspected. Although Yano et al (in review) found large differences in hydrophobic compounds between litter and wood extracts in the lab, they found no differences in hydrophobics in leachates from wood amended plots and the forest floor. Similarly, Yavitt and Fahey (1985) found little difference in the ratio of hydrophobic to hydrophilic DOC between leachates from the forest floor and the interstitial water of class 4 CWD. Qualls et al. (1991) found that of 27% of litterfall that was soluble, only approximately 18% was leached as DOM from the forest floor horizon. This indicates that there is a long residence time for the organic matter in the forest floor, during which time many humification processes can occur such as condensation, oxidation and enzymatic reactions. Qualls et al. (1991) suggest that this may explain why there is a large proportion of hydrophobic compounds leaching through the forest floor and also likely explains why we found little differences between CWD and forest floor leachates.

Because certain chemical components of DOM, such as polyphenols, can be both hydrophobic and hydrophilic, the hydrophobic/hydrophilic chemical fractionation method may have been inadequate to determine quality differences between CWD and forest floor leachates. Polyphenols are components of the lignocellulose in CWD and are also the by-products of decomposition and thus, we suspected that there would be a much larger concentration of polyphenols in solutions under CWD in the middle stages of decay. Indeed, zero-tension leachate from class 3 CWD had higher concentrations of polyphenols than class 2 CWD, class 4 CWD, and forest floor leachates ($p \leq 0.0001$). At 30 cm, there was no difference in polyphenols among forest floor solutions (3.29 ppm, $se = 0.25$) and soil solutions under CWD; the mean from class 2 was 5.52 ($se = 1.36$), the mean from class 3 was 5.97 ($se = 1.04$), and the mean from class 4 was 5.03 ($se = 1.47$). At 50 cm, there was no difference between control solutions (3.81, $se = 0.43$) and leachates from under

Table 1. Mean pH values, exchangeable acidity in cmol kg^{-1} , and base saturation for soils under decay classes 4 and 5 CWD and forest floor soils at four depths. One standard error is in parentheses. Letters represent statistical difference using Tukey's HSD multiple comparison test. Treatments with different letters are significantly different at $p = 0.05$.

Analysis	Depth (cm)	Forest floor	Class 4 CWD	Class 5 CWD
pH	0–5	5.5 (0.09) ^a	5.01 (0.14) ^b	5.19 (0.08) ^{ab}
	5–15	5.79 (0.09)	5.52 (0.10)	5.64 (0.08)
	15–30	5.98 (0.06)	5.87 (0.11)	5.91 (0.07)
	30–60	5.93 (0.11)	5.97 (0.09)	6.07 (0.06)
Exchangeable acidity	0–5	3.93 (0.84) ^a	11.86 (2.11) ^b	10.01 (1.52) ^b
	5–15	3.01 (1.02)	5.07 (1.61)	11.22 (6.03)
	15–30	3.76 (0.97)	5.78 (1.81)	6.98 (1.70)
	30–60	8.09 (1.37)	6.58 (0.74)	8.74 (1.42)
Percent base saturation	0–5	56.20 (6.96) ^a	14.87 (5.19) ^b	22.52 (6.94) ^b
	5–15	63.20 (8.01)	50.61 (10.20)	34.35 (9.92)
	15–30	57.93 (12.35)	60.28 (8.66)	44.06 (5.88)
	30–60	47.09 (7.00)	37.82 (5.40)	43.23 (5.54)

class 4 CWD (3.68, $\text{se} = 0.42$). Concentrations of soluble polyphenols were generally similar to those reported by Yavitt and Fahey (1985).

Mineral soils

Mineral soil analyses in our study were significant only in the surface soils suggesting that there was only a limited imprint of CWD on soil chemistry and that the spatial effect of CWD on soils may not be as significant as we had hypothesized. Previous studies have shown the effect of CWD on nutrient cycling in soils to be small, because few differences in soil C, N, or P have been found under CWD (Busse 1994; Kayahara et al. 1996; Krzyszowska-Waitkus et al., in review; Spears et al., in press).

We hypothesized that the acidic leachate would have a strong impact on the pH of the soil through leaching inputs and indeed, soil pH was much lower in soils under CWD of all decay classes than in forest floor soils. Soils at 0–5 cm were more acidic under class 4 CWD than mineral soils under the forest floor ($p \leq 0.005$, Table 1), but there was no difference between soils under classes 4 and 5. Soil pH increased with depth under all treatments and did not differ among decay classes or the forest floor at deeper soil depths. Acidic soils under CWD may have several causes, including hydrolysis of Al^{3+} , adsorption of OH^- to complexes, organic matter, and H^+ ions. The release of Al^{3+} from the soil matrix, as the matrix is broken down during chemical weathering, creates H^+ ions as the Al is rapidly hydrolyzed.

Exchangeable acidity was higher in 0–5 cm soils under class 4 CWD and under class 5 CWD than forest floor soils ($p \leq 0.002$, Table 1). One component of

Table 2. Mean Al and Fe concentrations in cmol kg^{-1} for soils under decay classes 4 and 5 CWD and forest floor soils at four depths. One standard error is in parentheses. There were no statistical differences among treatments at any depth.

Analysis	Depth (cm)	Forest floor	Class 4	Class 5
Fe_d	0–5	22.42 (2.33)	21.01 (1.27)	22.83 (0.98)
	5–15	25.76 (1.56)	26.57 (1.27)	26.48 (1.98)
	15–30	24.69 (1.22)	21.48 (0.81)	26.28 (2.12)
	30–60	24.64 (2.09)	24.05 (1.92)	25.15 (1.92)
Fe_p	0–5	5.31 (0.36)	6.23 (0.41)	6.06 (0.45)
	5–15	4.99 (0.50)	5.26 (0.49)	4.80 (0.48)
	15–30	4.22 (0.64)	4.09 (0.62)	4.27 (0.49)
	30–60	2.40 (0.29)	3.21 (0.36)	2.30 (0.37)
Fe_o	0–5	18.49 (1.03)	17.82 (1.11)	18.10 (1.15)
	5–15	15.61 (1.10)	16.99 (1.20)	12.92 (0.89)
	15–30	12.38 (0.63)	12.34 (0.79)	11.14 (0.96)
	30–60	10.14 (0.73)	10.40 (0.75)	9.60 (0.53)
Al_d	0–5	13.58 (2.15)	12.46 (1.03)	11.17 (1.24)
	5–15	11.29 (1.19)	12.19 (1.19)	9.68 (0.61)
	15–30	8.66 (0.95)	8.79 (0.86)	7.12 (0.73)
	30–60	6.46 (0.84)	7.17 (0.63)	5.82 (0.75)
Al_p	0–5	7.86 (0.71)	8.67 (0.47)	7.77 (0.87)
	5–15	7.99 (0.70)	8.53 (0.56)	6.69 (0.59)
	15–30	7.02 (1.20)	6.72 (0.71)	6.24 (0.92)
	30–60	4.44 (0.64)	5.08 (0.36)	3.73 (0.64)
Al_o	0–5	19.90 (2.88)	18.29 (2.35)	16.30 (2.61)
	5–15	19.43 (2.93)	20.96 (2.99)	15.20 (2.69)
	15–30	14.48 (1.89)	16.12 (2.71)	11.58 (1.89)
	30–60	10.07 (1.50)	11.30 (1.26)	8.12 (1.05)

Fe_d , Al_d : dithionite-citrate extractable Fe and Al; Fe_o , Al_o : ammonium oxalate extractable Fe and Al; Fe_p , Al_p : sodium pyrophosphate extractable Fe and Al.

exchangeable acidity is aluminum and thus exchangeable Al was also found to be much higher in soils under class 4 CWD than in soils under the forest floor, particularly in surface soils ($p \leq 0.008$). There was a strong positive correlation between exchangeable Al and exchangeable acidity for 0–5 cm samples ($p \leq 0.0001$, $R^2 = 0.68$) because exchangeable Al is one component of exchangeable acidity. Overall exchangeable Al accounted for 40% of the total exchangeable acidity and the remainder may be from protons or the acidic functional groups on soil organic matter contributed through the acidic CWD leachates. Higher exchangeable Al in soils under CWD reflects an increased amount of Al dissolution from soil matrices. Acidic organics such as organic acids have been shown to release Al from soil minerals. One previous study has suggested that there were more organic acids, particularly citric acid, under CWD of class 4 than in control soils (Krzyszowska-Waitkus, personal communication). However, no study has directly investigated the effect of low molecular weight organic acids on soil

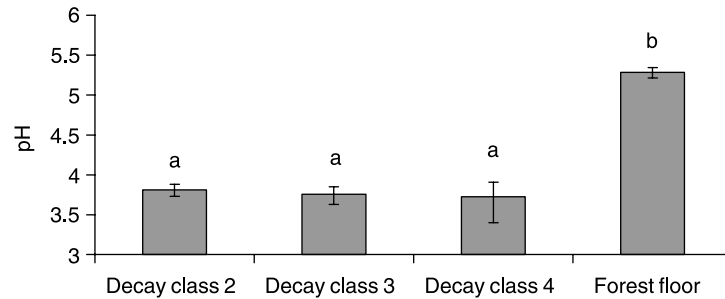


Figure 4. Mean polyphenol concentrations across all collection dates in samples collected with zero-tension lysimeter under CWD classes 2, 3, and 4 and under the forest floor. Bars represent one standard error and letters represent statistical difference using Tukey's HSD multiple comparison test. Treatments with different letters are significantly different at $p = 0.05$.

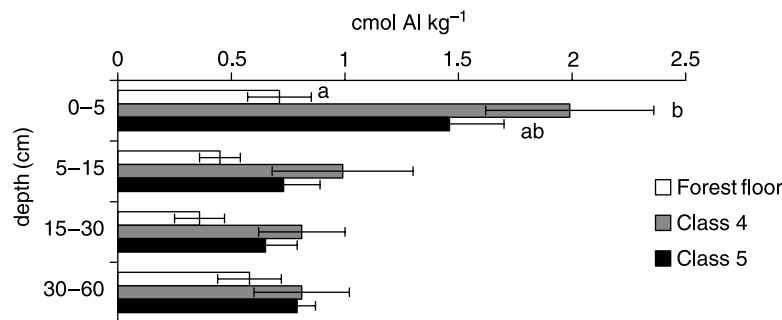


Figure 5. Mean exchangeable aluminum concentrations (extracted in barium chloride) in cmol kg^{-1} from four soil depths below CWD of decay classes 4 and 5 and forest floor soils. Bars represent one standard error and letters represent statistical difference using Tukey's HSD multiple comparison test. Treatments with different letters are significantly different at $p \leq 0.05$.

chemistry beneath CWD and therefore, further study is necessary to elucidate the mechanisms of soil acidification under CWD.

A correspondingly low base saturation was found in soils that had high exchangeable acidity. Acidic organics from the CWD probably leach the base cations to lower soil horizons and thus, percent base saturation tends to increase with depth as the higher soil horizons are actively leached of base cations. Base saturation was much lower in 0–5 cm soils under classes 4 and 5 CWD than in forest floor soils ($p \leq 0.001$, Table 1). Base saturation increased with depth up to 30 cm for all soils, perhaps reflecting a redistribution of cations to lower soil horizons under CWD. However, there were no statistical differences in deeper soils and there was a large amount of variation, which may indicate that a sample size of 10 may not have been powerful enough to detect the differences in heterogeneous soils.

Kaiser et al. (2000) suggest that hydrophobic DOM replaces Al and Fe organic compounds on soil exchange sites, thereby causing Al and Fe to leach to the lower

horizons, and thus, hydrophobic DOM may be responsible for the transport of Al and Fe compounds to deeper soils forming the Bs horizons of podzol soils. Although we found that the concentration of hydrophobic acids was twice as large as the concentration of hydrophilic compounds in CWD leachates, trends indicated only a slight increase in the Fe and Al compounds in lower soil horizons. Free, organically bound, and amorphous Al and Fe concentrations were not significantly different between soils under CWD or soils under the forest floor (Table 2). The ratio of organically bound iron to free iron plus organically bound iron did not indicate a spodic horizon under CWD. Eluviation of Al and Fe bound organic material may be occurring but the replacement of these compounds may be occurring just as rapidly and therefore, may obscure any visible sign of podzolization in these soils. Indeed, Kayahara et al. (1996) suggest that the rich base status of volcanic soils may reduce any effect of acidity associated with weathering and eluviation.

Conclusions

Although we had hypothesized that the profound spatial effects of CWD on soils chemistry would be most evident under class 5 CWD after the log had thoroughly decomposed, most of the chemical analyses in this study suggested that CWD mildly affects surface soil chemistry. Surface mineral soils under CWD were lower in pH, had more exchangeable acidity and more exchangeable aluminum than forest floor soils. Acidic leachates were most likely responsible for the increase in acidity in the mineral soil below CWD. Perhaps earlier decay classes may have a larger effect on soil chemistry when larger amounts of acidic organics leach from the CWD.

The effect of CWD on soil heterogeneity may not be a profound, spatially discrete effect, but rather a surficial spatial pattern that changes on a more moderate time span than previously believed. However, the scope of this study is limited to Douglas-fir CWD decaying at the H.J. Andrews experimental site and more extensive research in different ecosystems is needed to determine whether the patterns that we observed are generalizable.

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