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Influence of decaying wood on chemical properties of forest floors and surface mineral soils: a pilot study

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Summary — Samples of forest floors and spodic horizons from pedons with and without a large accumulation of decaying wood were collected from 2 forest stands in southwestern British Columbia. The samples were analyzed to determine chemical properties which would be useful measures of the possible influence of decaying wood on soil nutrient status and soil development in subsequent studies. There were several significant differences between chemical properties of forest floors and those of spodic horizons. The most distinguishing characteristic of decaying wood seemed to be high concentrations of humic acids (> 14%). Relative to the pedons without decaying wood, 1) the forest floors with decaying wood and the spodic horizons beneath were more acidic; 2) the spodic horizon was lower in potassium, and in the case of the Douglas-fir stand, lower in calcium and magnesium as well; 3) greater accumulation of amorphous inorganic aluminum in the spodic horizon occurred beneath decaying wood in the western hemlock stand and 4) a greater tendency towards accumulation of amorphous organic aluminum and iron occurred beneath decaying wood in the Douglas-fir stand. It appears that the influence of decaying wood on soils is site-specific and related to forest floor properties, such as acidity and the level of lipids and humic and fulvic acids. Further comparative studies examining the influence of decaying wood on soil nutrient status and soil development should be carried out using spatially independent replicated sampling and proposed soil chemical analyses over a wide range of stands and soils.

decaying wood / humus forms / soil nutrients / soil development

Résumé — Influence du bois en décomposition sur les propriétés chimiques de la couverture morte et des sols minéraux de surface : une étude pilote. *Des échantillons de couverture morte et d'horizons spodiques prélevés dans des pédons recouverts ou non d'une importante couche de bois en décomposition ont été récoltés dans 2 peuplements forestiers du sud-ouest de la Colombie britannique. Les échantillons ont été analysés afin de déterminer si certaines propriétés chimiques pourraient être utilisées comme mesure de l'influence probable du bois en décomposition sur le statut* *nutritif du sol et la pédogenèse en vue d'études ultérieures. Plusieurs différences significatives ont été trouvées entre les propriétés chimiques de la couverture morte et celles des horizons spodiques. Les concentrations élevées en acides humiques (> 14%) (tableau II) semblent être la caractéristique la plus distinctive du bois en décomposition. En comparaison avec les pédons non recouverts de bois en décomposition, i) les couvertures mortes avec bois en décomposition et les horizons spodiques sous-jacents étaient plus acides (tableau II) ; ii) l'horizon spodique était faible en potassium, et dans le cas du peuplement de sapin de Douglas, plus faible en calcium et en magnésium (tableau III) ; iii) une plus grande accumulation d'aluminium inorganique amorphe dans l'horizon spodique sous la couche de bois en décomposition dans le peuplement de pruche de l'ouest (tableau V) ; et iv) une plus grande tendance à l'accumulation d'aluminium inorganique amorphe et de fer sous la couche de bois en décomposition dans le peuplement de sapin de Douglas (tableau V). Il semblerait que l'influence du bois en décomposition sur les sols est spécifique à chaque site et serait relié aux propriétés de la couverture morte, telles que l'acidité et le niveau de lipides et d'acides humiques et fulviques. Des études supplémentaires comparatives examinant l'influence du bois en décomposition sur le statut nutritif du sol et la pédogenèse devraient être entreprises en utilisant un échantillonnage répété et indépendant dans l'espace et couvrant une large étendue de peuplements et de sols.*

bois en décomposition / type d'humus / élément nutritif / pédogenèse

INTRODUCTION

The importance of coarse woody debris (CWD) in a forest ecosystem has been stressed by numerous authors, both for its beneficial effect on forest productivity and as a component of wildlife habitat. In a definitive review of the ecological role of CWD in forests, Harmon *et al* (1986) concluded that CWD is an important functional component of temperate forest ecosystems but that our understanding of its true importance is rudimentary.

Little attention has been paid to the relationship between CWD and forest soils. Harvey *et al* (1981, 1989) emphasized the importance of decaying wood (DW) on drier sites with respect to site productivity. Krajina (1969) suggested that in the Coastal Western Hemlock and Mountain Hemlock biogeoclimatic zones of British Columbia, increased podzolization and loss of soil nutrients could occur under the influence of DW. Numerous field observations in these zones suggest that albic horizons are either thicker or newly developed beneath accumulations of DW.

Previous studies carried out in coastal British Columbia were based on unstratified sampling designs and could not determine the influence of DW on tree growth (Lowe and Klinka, 1981; Kabzems and Klinka, 1987; Carter and Klinka, 1990; Klinka and Carter, 1990). Humus form studies in coastal forests did indicate that DW-dominated forest floors were more acidic and had lower nutrient content than forest floors derived from other materials, but did not determine the influence of DW on tree growth and underlying mineral soils (Klinka *et al,* 1990). Thus, there are considerable unknowns and uncertainties about the influence of DW on mineral soils, as no quantitative data are available.

Yet, forest management in British Columbia is under increasing pressure to maintain long-term site productivity and biological diversity by modifying harvesting and slash treatment practices. Such practices affect DW, which, in turn, may affect long-term site productivity and biological diversity. Knowledge of the relationships between DW and soils, plants and animals is then critical to allow implementation of the best possible practices which do, in fact, maintain long-term site productivity and biological diversity. Poor knowledge of the relationship between DW and soils provided the impetus for this pilot study.

The biotic factor is basically expressed in the characteristics of forest floor materials, among which DW — the most ubiquitous plant debris in coastal western North American forests — represents a large addition of ligneous materials to the forest floor. The ecosystem concept implies that the influence of DW on soils, like that of any other organic materials, will be ecosystem-specific, that is 1) it will depend on the combination of environmental and biotic factors affecting a given site, 2) it will vary from one type of forest ecosystem to another and 3) it may be positive or negative depending on one's viewpoint. Therefore, it is necessary to adopt an ecosystem-specific approach to study the influence of DW on soils.

The experimental approach adopted was a comparative analysis of paired pedons with each pair consisting of 1 pedon with accumulation of DW and another without DW. The pedons were examined for the differences in morphological and chemical properties of forest floor and mineral soil, and each accumulation of DW was examined for the origin (species) and age of decay.

The objectives of the present study were limited 1) to test the usefulness of the adopted experimental approach and 2) to determine which chemical properties would measure the possible influence of DW on i) the nutrient status of the forest floor and surface mineral soil and ii) soil development.

MATERIALS AND METHODS

Two study sites were located in Pacific Spirit Park, Vancouver, British Columbia, 110 m above sea level. The park lies within the Dry Maritime Coastal Western Hemlock(CWHdm) biogeoclimatic subzone, which delineates the sphere of influence of a dry cool mesothermal climate (Klinka *et al*, 1991). The park has a mean annual precipitation of 1 258 mm and a mean annual temperature of 9.8°C. Soils are typically coarse textured (loamy sand to sandy loam, with a clay content of 1 to 2%) Orthods (Soil Survey Staff, 1975) or Humo-Ferric Podzols (Canada Soil Survey Committee, 1978) derived from glacial marine (beach) deposits which overlie compacted glacial morainal (mainly granitic) materials, in gently undulating terrain. The cation exchange capacity and base saturation of the spodic horizon in the study area was in the range of 15 to 26 cmol kg^{-1} and 3 to 5%, respectively.

Each site supported the growth of a naturally established, unmanaged, fully stocked, even-aged stand, which developed following the cutting of the original old-growth forest in 1910 and a fire in 1919. The first stand was dominated by *Tsuga heterophylla* (Raf) Sarg (western hemlock) and had a well-developed moss layer dominated by *Plagiothecium undulatum* ([Hedw] BSG); the second stand was dominated by *Pseudotsuga menziesii* (Mirb) Franco (Douglas-fir) and had a well-developed herb layer, with abundant *Polystichum munitum* ([Kauf] Presl) and *Dryopteris expansa* ([Presl] Fraser-Jenkins & Jermy). Using the methods described by Green and Klinka (1994), the western hemlock site was estimated to be slightly dry and nitrogen-poor, while the Douglas-fir site was considered to be fresh and nitrogen-rich.

At each site, a well-decayed log of Douglas fir, which was longer than 1 m, had a diameter larger than 30 cm, and showed approximately 50% (by volume) incorporation into the forest floor, was located. A well-advanced stage of decay of the log was indicated by 1) the presence on the log of a bryophyte community and regeneration of western hemlock; 2) a friable and soft consistency of its wood, which allowed the entire length of a finger to be pushed into it; 3) barely recognizable original structures and 4) disintegration of the material with only gentle pressure. As the selected logs as well as a great number of logs at a similar stage of decay in each stand were cut at one or both ends apparently at the time of cutting in 1910, we estimated that they had been decaying for approximately 85 years.

At each site, a 2.50-m wide trench was dug through the center of the decaying log deep enough to expose an approximately 30-cm thick layer of the underlying spodic horizon (a study pedon). As close as possible and where there was no DW present in the forest floor, another

2.50-m wide trench was dug to the same depth as that with DW. Forest floors and mineral soils were described and identified according to Green *et al* (1993) and Soil Survey Staff (1975), respectively. Forest floors and the uppermost 10 cm layer of the underlying spodic horizons were sampled using five 10 x 10 cm discontinuous sampling units taken 50 cm apart along the lateral dimension of each pedon. Forest floor samples consisted of a uniform column of all organic materials (except recently shed litter) cut by knife from the ground surface to the boundary with mineral soil. Samples of spodic horizons consisted of a uniform column of soil cut by a trowel from the top of the horizon to a depth of 10 cm. A total of 10 samples per pedon and 20 samples per study site were collected. All samples were air-dried to constant mass; forest floor samples were then ground in a Wiley mill to pass through a 2-mm sieve, while mineral soil samples were sieved through a 2-mm sieve to separate coarse fragments.

All chemical analyses were done by Pacific Soil Analysis Inc (Vancouver, BC) and the results were expressed per unit of soil mass (table I). Soil pH was measured with a pH meter and glass plus reference electrode in water and 0.01 M $CaCl_2$ using a 1:5 suspension for forest floor material and a 1:1 suspension for mineral soil. Exchange acidity was determined by the barium chloride-trietholamine method (Thomas, 1982). Total C was determined using a Leco Induction Furnace (Bremner and Tabatabai, 1971). Total N was determined by semimicro-kjeldahl digestion followed by determination of NH_4-N using a Technicon Autoanalyzer (Anonymous, 1976). Mineralizable N was determined by an anaerobic incubation procedure of Powers (1980) with released NH_4 determined colorimetrically using a Technicon Analyzer.

Extractable P was determined using 1) a Bray dilute acid ammonium fluoride extraction (Olsen and Sommers, 1982) and 2) the extraction procedure of Mehlich (1978) followed by analyses of P using a Technicon Autoanalyzer. Extractable SO_4-S was determined by ammonium acetate extraction (Tabatabai, 1982) and turbidimetry. Extractable Ca, Mg and K were determined by extraction with Morgan's solution of sodium acetate at pH 4.8 (Lavkulich, 1981) and atomic absorption spectrophotometry. Cation exchange capacity was determined using 1 M NH_4OAc adjusted to pH 7, followed by estimated of NH_4-N using a Technicon Autoanalyzer (Rhoades, 1982). Sodium pyrophosphate-extractable Fe and Al were extracted overnight at 25°C using sodium pyrophosphate solution as described by Bascombe (1968).

Forest floor samples were subjected to sequential fractionation with 1) 1:1 ethanol:ben-

Table I. List of chemical properties selected for the study.

Symbol	*Property and unit*	*Symbol*	*Property and unit*
pH_H	Soil pH in water	L	Lipid fraction (%)[a]
pH_C	Soil pH in 0.01 M $CaCl_2$	CB	Carbon in fraction B(%)[a]
EA	Exchange acidity (cmol kg^{-1})	sB	Sugars in fraction B (%)[a]
C	Total C (%)	CH	Carbon in humic acid (%)[a]
N	Total N (%)	CF	Carbon in fulvic acid (%)[a]
C/N	Carbon/nitrogen ratio	CH/CF	CH/CF ratio[a]
mN	Mineralizable N (mg kg^{-1})	Fep	Pyrophosphate-extractable Fe (%)
Ca	Extractable Ca (mg kg^{-1})	Alp	Pyrophosphate-extractable Al (%)
Mg	Extractable Mg (mg kg^{-1})	Feo	Oxalate-extractable Fe (%)[b]
K	Extractable K (mg kg^{-1})	Alo	Oxalate-extractable Al (%)[b]
CEC	Cation exchange capacity (cmol kg^{-1})	Fed	Dithionite-extractable Fe (%)[b]
PB	Extractable phosphorus (Bray) (mg kg^{-1})	Ald	Dithionite-extractable Al (%)[b]
PM	Extractable phosphorus (Mehlich) (mg kg^{-1})	Sid	Dithionite-extractable Si (%)[b]
SO_4-S	Extractable SO_4-S (mg kg^{-1})		

[a] Determined only for forest floor samples; [b] determined only for mineral soil samples.

zene, yielding fraction A or lipids; 2) cold 0.1 M H_2SO_4, yielding fraction B, which was further analyzed for carbon and hexose content and 3) cold 0.1 M NaOH extraction yielding an extract used for further fractionation into humic and fulvic acid fractions, with each being analyzed for carbon content. The methods of sequential fractionation are described in detail in Lowe (1974) and Lowe and Klinka (1981).

Mineral soil samples were also analyzed for oxalate Fe and Al and dithionite Fe, Al and Si. Oxalate Fe and Al were extracted using acid ammonium oxalate extraction, and dithionite Fe, Al and Si were extracted using citrate-bicarbonate-dithionate extraction, with extracted Fe, Al and Si being determined by atomic absorption spectrophotometry as described by McKeague *et al* (1971).

To quantify visual differences in the development of albic and spodic horizons between the study pedons, we devised the following formulas for proposed albic and spodic indices:

$$AI = t(V/C) \quad [1]$$

where AI is the albic index calculated for each sample of albic horizon; t is its thickness (cm) and V and C are the numerical values of its Munsell value and chroma; and

$$SI = (10 - H)(10/(V^*C) \quad [2]$$

where SI is the spodic index calculated for each sample of spodic horizon and H, V and C are the numerical values of its Munsell hue, value and chroma.

Single factor analysis of variance and Tukey's test (Zar, 1984) were used to determine differences in soil chemical variables between samples stratified according to forest floor material (presence or absence of DW) and stand type (western hemlock [WH] or Douglas fir [DF]). The variables were examined for correlation, using Pearson correlation coefficients, and tested for normality, using probability plots (Chambers *et al*, 1983), and homogeneity of variance, using Bartlett's procedure (Zar, 1984). All data were analyzed using the SYSTAT statistical package (Wilkinson, 1990).

RESULTS

Morphological analysis

Due to the design of the study, the thickness of the forest floor was necessarily different between the pedons with and without DW (table II). A 2-fold thicker forest floor in the DF stand was due to selecting a larger decaying log. The thickest and lightest albic

Table II. Means (n = 5) of morphological properties measured for the study pedons beneath forest floors with (w) and without (f) decaying wood in the western hemlock (WH) and Douglas-fir (DF) stands.

Property	*wWH*	*fWH*	*wDF*	*fDF*
Dominant humus form	Lignomor	Hemimor	Lignomoder	Mormoder
Thickness of forest floor (cm)	10.6^b	6.0^c	20.0^a	4.4^c
Thickness of albic horizon (cm)	6.4^a	1.0^b	1.1^b	1.5^b
Dominant color of albic horizon	10YR5/2	10YR4/1	10YR4/3	10YR4/3
Albic index	23.9^a	3.8^b	1.5^b	2.1^b
Dominant color of spodic horizon	5YR4/5	5YR4/6	2.5YR3/4	5YR4/5
Spodic index	2.9^b	2.1^b	7.5^a	2.2^b

^{abc} Values in the same row with the same superscript are not significantly different ($P \leq 0.05$, Tukey's test).

horizon that had the highest albic index was found in the pedon beneath DW (Lignomor) in the WH stand, while all other pedons had a similar albic index (table II). One of the 5 sampling units beneath DW in the WH stand had an atypically thick albic horizon, with an albic index of 70. Without this unit, the mean albic index for this pedon would have been 12.3 compared to 23.9 when this unit was included. The darkest and reddest spodic horizon that had the highest spodic index was found in the pedon beneath DW (Lignomoder) in the DF stand, while the spodic horizons in all other pedons had similar color.

Univariate analysis

In the WH stand, the only significant differences found were for CH concentrations, which were higher, and for SO_4-S concentrations, which were lower, in the forest floor with DW (Lignomor) than in that without it (Hemimor) (table III). In the DF stand, there were many differences between the pedons with and without DW (Lignomoder and Mormoder, respectively). The Lignomoder was more acid, had higher C/N and CH/CF ratios, higher C, Mg and CH concentrations and higher EA and CEC but lower N, mN, K,

Table III. Means (n = 5) of chemical properties measured for the forest floors with (w) and without (f) decaying wood in the western hemlock (WH) and Douglas-fir (DF) stands.

Property	*wWH (Lignomor)*	*fWH (Hemimor)*	*wDF (Lignomoder)*	*fDF (Mormoder)*
pH_H	3.5^b	3.6^b	3.5^b	4.1^a
pH_C	3.0^b	3.1^b	2.9^c	3.6^a
EA (cmol kg^{-1})	106^b	94^b	143^a	64^c
C (%)	43.6^b	39.5^b	51.6^a	24.0^c
N (%)	1.10^a	0.97^a	0.50^b	0.86^a
C/N	40^b	41^b	115^a	28^b
mN (mg kg^{-1})	314^a	300^a	130^b	360^a
Ca (mg kg^{-1})	$1\,856^a$	1773^a	2063^a	2183^a
Mg (mg kg^{-1})	203^b	175^b	257^a	165^b
K (mg kg^{-1})	354^a	423^a	121^c	249^b
CEC (cmol kg^{-1})	108^{ab}	105^{ab}	135^b	88^a
PB (mg kg^{-1})	27^a	35^a	15^b	16^b
PM (mg kg^{-1})	31^{ab}	39^a	20^b	20^b
SO_4-S (mg kg^{-1})	9^b	15^a	3c	7^b
L (%)	4.2^a	4.0^a	2.2^b	2.4^b
CB (%)	0.21^b	0.32^{ab}	0.09^c	0.27^{ab}
sB (%)	0.20^a	0.26^a	0.11^b	0.22^a
CH (%)	14.8^b	9.63^c	39.6^a	6.96^c
CF (%)	6.41^a	6.84^a	4.85^b	4.74^b
CH/CF	2.32^b	1.41^b	8.32^a	1.45^b
Fep (%)	0.11^b	0.14^b	0.02^c	0.20^a
Alp (%)	0.23^{ab}	0.21^{ab}	0.11^c	0.26^a

^{abc} For a given chemical property, values with the same superscript are not significantly different ($P \leq 0.05$, Tukey's test). Symbols for chemical properties are given in table I.

SO_4-S, CB, sB, Fep, and Alp concentrations than the Mormoder.

The spodic horizon beneath the Lignomor in the WH stand had higher pH_H and Ca and Mg concentrations but lower K and SO_4-S concentrations than that beneath the Hemimor (table IV). In the DF stand, the spodic horizon beneath the Lignomoder was more acid and had lower Ca, Mg and K concentrations but higher Alp concentrations than that beneath the Mormoder. The amount of organically complexed (pyrophosphate-extractable) relative to poorly crystalline (oxalate-extractable) forms of Al varied between 23 (beneath the Hemimor) and 34% (beneath the Lignomor) in the WH stand and between 39 (beneath the Mormoder) and 46% (beneath the Lignomoder) in the DF stand (table IV). Thus, the spodic horizons beneath DW in both stands also tended to have higher Feo and Alo concentrations, which is indicative of a more strongly developed spodic horizon.

McKeague *et al* (1971) reported that the amount of Fe and Al extracted from spodic horizons increases from pyrophosphate to oxalate to dithionite extraction. In this study, similar amounts of Fe and Al from spodic horizons were extracted by pyrophosphate and dithionite, but substantially larger amounts were extracted by oxalate (table V). The ratio (Fep + Alp)/(Fed + Ald) was

Table IV. Means (n = 5) of chemical properties measured for spodic horizons beneath the forest floors with (w) and without (f) decaying wood in the western hemlock (WH) and Douglas-fir (DF) stands.

Property	*wWH (Lignomor)*	*fWH (Hemimor)*	*wDF (Lignomoder)*	*fDF (Mormoder)*
pH_H	5.1^a	4.7^b	4.7^b	5.4^a
pH_C	4.6^a	4.5^a	4.2^b	4.8^a
EA (cmol kg^{-1})	17.8^b	17.1^b	23.9^a	20.5^{ab}
C (%)	1.50^b	1.58^b	2.58^a	2.38^a
N (%)	0.05^b	0.06^b	0.10^a	0.10^a
C/N	30^a	26^{ab}	26^{ab}	23^b
mN (mg kg^{-1})	6^b	6^b	10^{ab}	12^a
Ca (mg kg^{-1})	96^b	19^c	54^b	278^a
Mg (mg kg^{-1})	7^b	2^c	4^b	14^a
K (mg kg^{-1})	10^b	17^a	7^b	14^a
CEC (cmol kg^{-1})	18.3^a	15.6^a	22.1^a	19.9^a
PB (mg kg^{-1})	6^a	6^a	5^{ab}	3^b
PM (mg kg^{-1})	5^a	4^a	5^a	3^a
SO_4-S (mg kg^{-1})	7^b	39^a	13^b	4^b
Fep (%)	0.14^b	0.21^{ab}	0.35^a	0.26^{ab}
Alp (%)	0.66^c	0.73^{bc}	1.17^a	0.93^b
Feo (%)	0.62^a	0.57^a	0.64^a	0.54^a
Alo (%)	2.82^a	2.12^a	2.52^a	2.36^a
Fed (%)	0.14^c	0.15^{bc}	0.31^a	0.23^{ab}
Ald (%)	0.52^b	0.52^b	1.11^a	0.86^a
Sid (%)	0.04^b	0.04^b	0.07^a	0.07^a

[abc] For a given chemical property, values with the same superscript are not significantly different ($P \leq 0.05$, Tukey's test). Symbols for chemical properties are given in table I.

Table V. Means (n = 5) of extractable Fe and Al measured for spodic horizons beneath the forest floors with (w) and without (f) decaying wood in the western hemlock (WH) and Douglas-fir (DF) stands.

Property	*wWH (Lignomor)*	*fWH (Hemimor)*	*wDF (Lignomoder)*	*fDF (Mormoder)*
(Fep + Alp) (%)	0.80^{b}	0.94^{b}	1.52^{a}	1.19^{b}
(Feo + Alo) (%)	3.44^{a}	2.69^{a}	3.16^{a}	2.90^{a}
(Fed + Ald) (%)	0.66^{c}	0.67^{c}	1.44^{a}	1.09^{b}
Organic (Fe + Al) (%)	0.80^{b}	0.94^{b}	1.52^{a}	1.19^{b}
Amorphous inorganic (Fe + Al) (%)	2.64^{a}	1.75^{a}	1.64^{a}	1.71^{a}

[abc] For a given property, values with the same superscript are not significantly different ($P \leq 0.05$, Tukey's test). Symbols for chemical properties are given in table I.

>0.5 (from tables IV and V), which is required for the spodic horizon by Soil Survey Staff (1975). Based on the different concentrations of extractable Fe and Al and their interpretations by McKeague *et al* (1971), the spodic horizons beneath DW had either a higher accumulation of amorphous metal inorganic complexes (in the WH stand) or amorphous metal-organic complexes (in the DF stand) compared to those beneath the forest floors without DW. Due to the presence of relatively low concentrations of Fed and Ald, the values of (Fed – Feo) and (Ald – Alo) were negative, indicating that dithionite extraction included predominantely amorphous metal-organic complexes, and that the concentrations or stability of crystalline oxides were low.

DISCUSSION

The primary objective of this pilot study was to determine which of the many possible measurements of forest floor and mineral soil samples were most likely to be of value in future studies, whether in relation to humus form or soil development or soil nutrient status. Of particular concern was the need to restrict the number of laboratory measurements as much as possible because of cost and time constraints. It must also be recognized that relationships between chemical properties of DW and underlying mineral horizons are not yet fully understood. Against this background, the present result will be briefly discussed in an attempt to assess on the basis of current knowledge 1) what kind of data should be collected in future comparative studies and 2) what potentially significant hypotheses could provide foci for future investigations on a more appropriate sample basis.

Based on acidity, C/N and mN concentrations, there was a trend of increasing forest floor nutrient status from Lignomoder to Lignomor and Hemimor to Mormoder. Except for SO_4-S, the nutrient status of the Lignomor and the Hemimor was considered similar, while that of the Lignomoder was considered to be different from that of the Mormoder. Based on Ca and Mg concentrations, the spodic horizon beneath the Lignomor was considered base-richer relative to that beneath the Hemimor, and the spodic horizon beneath the Lignomoder was considered base-poorer relative to that beneath the Mormoder.

This simplistic interpretation suggests that the influence of DW on soil nutrient status varies with site. In very acid and relatively base-low Spodosols, such as in the WH stand, the influence appears to be very slight, perhaps slightly favorable, while in less-acid and relatively base-high Spodosols, such as in the DF stand, this influence appears to be negative due to increased soil acidity and depletion of bases from spodic horizons. A strong acidity of DW microsites apparently does not inhibit vigorous growth of acidiphilous plants in coastal British Columbia (Klinka *et al,* 1989, 1990). Even under marginal light conditions, very strongly acid DW provided more favorable substrates for abundant growth of western hemlock seedlings, *Dryopteris expansa, Plagiothecium undulatum* and *Vaccinium parvifolium* than similarly very strongly acid Hemimors, probably due to a high waterholding capacity. No acidiphilous plants were found on friable and less-acid Mormoders.

Spodosols (or Podzols) are defined by the presence of a spodic horizon characterized by the accumulation of active amorphous, organic-sesquioxide material (*eg* Buol *et al,* 1973; Birkeland, 1974; Soil Survey Staff, 1975; Peterson, 1976; MacKeague *et al,* 1983). This material consists essentially of organic matter and Al with or without Fe. Thus, the amount of organic-sesquioxide material in the spodic horizon can be regarded as an index of the degree, and perhaps the intensity, of Spodosol development (Lowe and Klinka, 1981).

Translocation of organic matter and sesquioxides must be influenced by conditions and processes in the forest floor, particularly with respect to the production, release and persistence of organic acids (ligands) capable of mobilizing Fe and Al. Consequently, the study of relationships between forest floor properties and the degree of development of albic and spodic horizons should give insight into the influence of DW on Spodosol development.

McKeague *et al* (1983) stated that thicker and deeply tongued albic horizons develop beneath a decaying log under conditions which include an above average surface stability, supply of leaching water or source of soluble organic matter. Lipids are known to accumulate in strongly acidic, poorly decomposing forests floors (*eg* Lowe, 1974; Lowe and Klinka, 1981).

Albic and spodic index appeared to have provided a useful single composite measure of the strength in the morphological development of albic and spodic horizon. Comparison of albic and spodic indices suggested that morphological characteristics of surface mineral soil horizons may be influenced by DW, and that this influence may vary with site. In the WH stand, DW apparently promoted eluviation whereas in the DF stand, illuviation. The presence of an inverse relationship between albic and spodic indices ($r = -0.22$, $P < 0.05$) indicated that DW does not necessarily promote the simultaneous development of albic and spodic horizons in the same pedon. Increased podzolization, expressed in an increased spodic index and accumulation of Al (without a significant accumulation of organic matter), seems to have occurred in the pedons with DW in both stands (tables II and IV); however, not all differences were statistically significant so the data must be considered as suggestive rather than conclusive.

The selection of recommended measurements is based on the following criteria: 1) significance in differentiating the pedons with and without DW and 2) rapid, inexpensive and reliable analytical procedure. Accepting these criteria, we concluded that the following properties might be omitted from the properties listed in table I: pH_c, PB, PM, CB, sB and forest floor Fep and Alp.

Because of the relatively small number of samples and sites sampled, the relationships discussed in this pilot study should be viewed as hypotheses requiring testing (see later). To examine these questions, additional experimental studies may be needed each with specific requirements to confirm the findings of comparative studies either in relation to the soil nutrient status or to soil development.

1) DW influences properties of the forest floor and the underlying mineral soil by inhibiting N mineralization and increasing acidity, loss of nutrients, eluviation and illuviation.

2) The influence of DW on vegetation and soil is site-specific, that is, it varies with climate (biogeoclimatic zone), humus form, soil (soil particle size, base status, moisture regime, nutrient regime) and vegetation.

3) High concentrations of lipids, humic acids and fulvic acids are the forest floor constituents responsible for eluviation and illuviation.

4) The spatial pattern of DW on a site corresponds to that of understory vegetation and humus form and accounts for much of the variation in the chemical properties of the surface mineral soil.

CONCLUSION

Decaying wood appeared to have affected some properties of the forest floor and/or surface mineral soil in each of the 2 stands studied. In the western hemlock stand, decaying wood seemed to have no significant influence on soil nutrient status, but negatively affected this status in the less-acid, base-richer soil in the Douglas-fir stand. In the Douglas-fir stand, the presence of decaying wood seemed to inhibit N mineralization and increase forest floor acidity, C/N ratio, and particularly, humic acid concentrations. Compared to the pedons without decaying wood, the forest floors with decaying wood and the spodic horizons beneath tended to be more acidic and the spodic horizons lower in potassium. Relative to pedons without decaying wood, a thicker albic horizon and greater accumulation of amorphous inorganic aluminum in the spodic horizon occurred beneath decaying wood in the western hemlock stand, and a tendency towards greater accumulation of amorphous inorganic aluminum and dithionite aluminum and iron occurred beneath decaying wood in the Douglas-fir stand.

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