The influence of understory vine maple on forest floor and mineral soil properties in coastal temperate forests

N. C. Tashe and M. G. Schmidt[1]

Acer
nderstory tree species. We studied the influence of vine maple, growing in the understory of
uga menziesii (Mirb.) Franco] and western hemlock [*Tsuga heterophylla* (RAF.) Sarg.], on
perties. Fifteen (in a 75-yr-old stand) and 12 (in a 130-yr-old stand) plots containing vine
ots without the influence of vine maple. Mull humus was dominant under vine maples, while
der conifers at the 130 yr-old stand. Common to both stands in the upper mineral soil were
exchangeable bases under vine maple. At the 75-yr-old stand, the forest floor had a higher
e base concentration, while the mineral soil had a lower C:N ratio, greater NO_3^- availability and lower available P concentration and content under vine maple compared to conifers. The 130-yr-old stand had less available P content and greater concentrations of mineralizable N and exchangeable Mg in the forest floor under vine maple. Results suggest that the presence of vine maple may enhance the availability of N and exchangeable bases, but may adversely affect P availability.

Key words: Vine maple, soil-plant interactions, forest floor, *Acer circinatum*

Tashe, N. C. et Schmidt, M. G. 2003. **Incidence du sous-étage de l'érable circiné sur le sol forestier et sur les propriétés du sol minéral dans les forêts tempérées de la côte**. Can. J. Soil Sci. **83**: 35–44. L'érable circiné (*Acer circinatum* Pursh) se rencontre couramment dans le sous-étage arboré des forêts côtières du nord-ouest du Pacifique. Les auteurs se sont intéressés aux incidences de cette essence sur le sol forestier et les propriétés du sol minéral quand elle forme le sous-étage des peuplements de douglas taxifolié [*Pseudotsuga menziesii* (Mirb.) Franco] et de pruche occidentale [*Tsuga heterophylla* (RAF.) Sarg.]. Ils ont pour cela comparé 15 parcelles (d'un peuplement de 75 ans) et 12 parcelles (d'un peuplement de 130 ans) présentant des érables circinés à des parcelles similaires sans cette essence. Le mull domine sous les érables alors que sous les conifères du plus vieux peuplement, on retrouve surtout du mor. Dans les deux peuplements, la couche supérieure du sol minéral renferme plus de N minéralisable et de bases échangeables là où pousse l'érable circiné. Le sol forestier du peuplement de 75 ans se caractérise par un pH plus élevé et une concentration supérieure de bases échangeables, mais le sol minéral a un rapport C/N plus faible, une plus grande quantité de NO_3^- disponible et une plus faible concentration de P disponible là où pousse l'érable circiné, comparativement aux endroits où il n'y avait que des conifères. Le sol du peuplement de 130 ans contenait moins de P disponible et une plus grande concentration de N minéralisable et de Mg échangeable là où l'érable circiné s'était implanté. Ces résultats donnent à penser que l'érable circiné peut accroître l'apport de N et de bases échangeables, mais réduire la concentration de P disponible.

Mots clés: Érable circiné, interactions sol-plante, sol forestier, *Acer circinatum*

Understory trees contribute to considerable spatial variation in soil properties, often improving the nutrient status of the soil-litter system (Klemmedson 1987; Klemmedson 1994). Understory tree species such as Gambel oak (*Quercus gambelii* Nutt.) and New Mexican locust (*Robinia neomexicana* Gray) have been shown to ameliorate the poor nutrient status of ponderosa pine (*Pinus ponderosa* Laws) forests of central Arizona (Klemmedson 1987; Klemmedson 1994).

Vine maple (*Acer circinatum* Pursh) is a tree commonly found in the understory of mature coniferous forests along the Pacific Northwest Coast (Fig. 1). Although most studies have looked at the role of vine maple as a competitor for resources with commercial trees (Haeussler et al. 1990), recent research suggests that vine maple may improve site conditions to the benefit of surrounding Douglas-firs despite its relatively small stature (Ogden and Schmidt 1997). Vine maple was found to have significantly higher ($P < 0.1$) pH in the upper mineral soil, and significantly greater concentrations of Ca, Mg, and K in the forest floor relative to sites dominated by conifers (Ogden and Schmidt 1997). The study by Ogden and Schmidt (1997) was carried out in an 80-yr-old stand of western hemlock [*Tsuga heterophylla)* (Raf.) Sarg.] and Douglas-fir [*Pseudotsuga menziesii* (Mirb.)] in coastal British Columbia. Wardman and Schmidt (1998) reported a significantly greater site index for Douglas-firs adjacent to vine maple (42.6 m) relative to

[1]*To whom correspondence should be addressed (e-mail: margaret_schmidt@sfu.ca).*

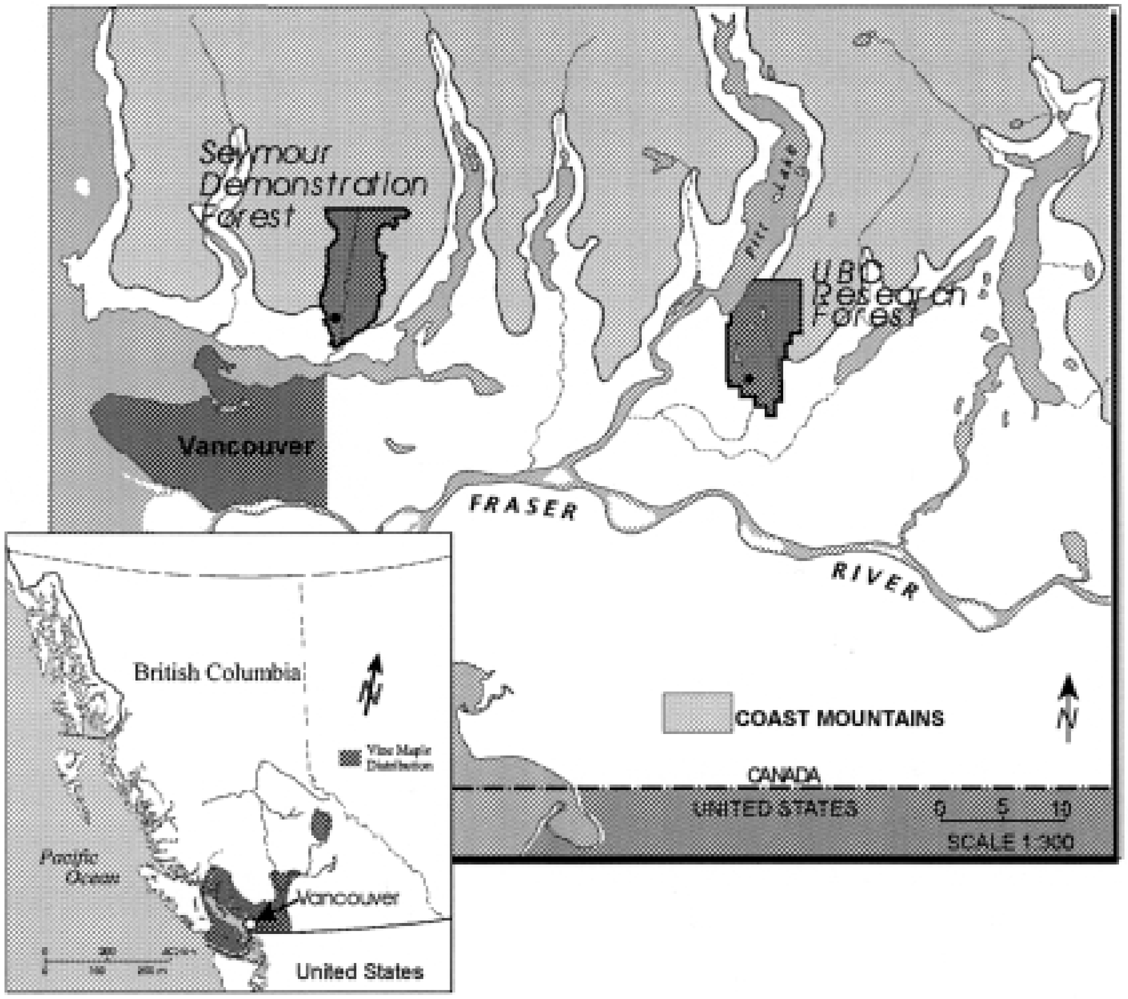

Fig. 1. The locations of the two study areas. Inset map shows the distribution of vine maple in British Columbia [modified from Haeussler et al. (1990)].

Douglas-firs located in conifer-dominated areas (40.1 m). Wardman and Schmidt (1998) carried out their study in a 75-yr-old Douglas-fir-dominated stand adjacent to the stand studied by Ogden and Schmidt (1997). The greater site index may be attributed to improved nutrient availability on sites occupied by vine maple as greater N and B concentrations were found in the current-year foliage of Douglas-fir adjacent to vine maple relative to the surrounding conifer forest (Tashe and Schmidt 2001). The sites used by Tashe and Schmidt (2001) were the same ones used for this paper.

The retention of nutrients within ecosystems generally depends on the soil and vegetation (Pastor and Bockheim 1984). Research conducted by Pastor and Bockheim (1984) showed that understory sugar maple (*A. saccharum* Marsh.) may be important as a secondary sink for nutrients because of its ability to cycle nutrients under low light conditions. Vine maple is similar to sugar maple in that it occurs in the understory of mature forests and is highly shade tolerant. Most hardwood tree species growing in temperate coastal forests are not shade tolerant (Haeussler et al. 1990); therefore, the influence of vine maple on soil properties is likely to be more persistent than other hardwood trees of the Pacific Northwest. Once vine maple is established, it is one of the longest-lived understory trees. For example, Anderson (1969) at Mary's Peak, Oregon, discovered individuals up to 142 yr of age. In addition, the relative role of vine maple in nutrient cycling may be disproportionately greater than that of other understory species because of its rich foliar nutrient content and heavy annual leaf fall (Ogden and Schmidt 1997; Tashe and Schmidt 2001).

The goal of our research was to provide further insight into the influence of vine maple on site fertility by assessing forest floor and mineral soil properties beneath vine maple growing in the understory of Douglas-fir forests. Measured properties include: pH, total C, mineralizable N, available P and exchangeable bases in the forest floor and surface mineral soil; humus form; mineral soil bulk density; and availability of NO_3^-, NH_4^+, and P in the upper mineral soil as measured by ion-exchange resin bags. This study advances previous work by providing information on an increased

Table 1. Site characteristics for the two study stands

	75-yr-old stand (n = 15)				130-yr-old stand (n = 12)			
	Vine maple plot		Conifer plot		Vine maple plot		Conifer plot	
Elevation (m)	259	(17.7)	259	(16.6)	249	(7.2)	251	(7.5)
Aspect (°)	144	(12.5)	155	(13.9)	221	(27)	217	(22)
Slope (°)	15.6	(4.2)	15.7	(3.9)	8.9	(3.5)	10.0	(3.7)
Soil classification	Duric Humo-Ferric Podzol				Gleyed Dystric Brunisol			
Textural class of B horizon	Sandy loam		Sandy loam		Loamy sand		Loamy sand	
Diameter of largest vine maple stem (cm)	10.4	(3.0)	no vine maple		13.5	(3.3)	no vine maple	
Minimum vine maple influence (yr)	43.5	(12.7)	–		56.0	(13.9)	–	

[z]Values in parentheses are standard deviations

number of soil properties, using a larger sample size, and adding another study location to observe if the influence of vine maple was similar at two locations.

METHODS

Study Sites and Sampling Design

Our study was conducted in two stands, a 75-yr-old stand in Seymour Demonstration Forest (recently renamed Lower Seymour Conservation Area, 49°22′30″N, 123°00′25″W) and a 130-yr-old stand in Malcolm Knapp Research Forest (49°21′40″N, 122°31′20″W), both of which are located in the Lower Mainland of British Columbia, Canada (Fig. 1). The 75-yr-old stand is approximately 15 km northeast of Vancouver and the 130-yr-old stand is approximately 60 km east of Vancouver. The two stands are located within a transition between moist maritime (CWHmm) and dry maritime (CWHdm) subzones of the Coastal Western Hemlock (CWH) biogeoclimatic zone (Meidinger and Pojar 1991). Climate data were obtained from the nearest weather stations monitored by Environment Canada. The 75-yr-old stand has a mean annual precipitation of 3870 mm and a mean annual temperature of 9.0°C. The 130-yr-old stand has a mean annual precipitation of 2194 mm and a mean annual temperature of 9.6°C. The study stands are dominated by coastal Douglas-fir [*P. menziesii* (Mirb.) Franco] and western hemlock [*T. heterophylla* (Raf.) Sarg.], and also contain a small component of western red cedar (*Thuja plicata* Donn.). The 75-year-old stand regenerated naturally after logging and has an average canopy height of 40 m (Wardman and Schmidt 1998). The 130-yr-old stand originated after a wildfire and has attained a canopy height of approximately 50 m. The soil at the 75-yr-old stand is a sandy loam Duric Humo-Ferric Podzol, derived from ablation till and colluvium. The 130-yr-old stand is derived from morainal and colluvial parent materials and is a sandy loam Gleyed Dystric Brunisol.

The sampling design involved the establishment of 15 vine maple plots paired with conifer plots of similar slope, aspect, and elevation at each study location (Table 1). Three plots were later excluded at the 130-yr-old site due to the potential influence of red alder (*Alnus rubra* Bong.). A vine maple plot was defined by the extent of its foliage; therefore, plots varied in size from approximately 50 to 190 m^2. Conifer plots were equivalent in size to their vine maple plot counterparts and were at least 15 m away from vine maple foliage. A more detailed description of the study stands and sampling design is presented in Tashe (1998) and Tashe and Schmidt (2001).

Forest Floor and Mineral Soil Collection and Analysis

Three randomly located forest floor and mineral soil samples were collected from each plot. An 18-cm by 18-cm template was used to cut out the forest floor samples. Depth measurements of organic horizons were taken from the mean of the midpoint depths of the four faces of the excavation created when the sample was removed. One excavation from each plot was used for a detailed qualitative description, following the humus form classification system of Green et al. (1993) and the Canadian System of Soil Classification (Canadian Agricultural Services Coordinating Committee 1998).

Mineral soil samples were collected using a bulk density corer that penetrated to a depth of 7 cm from the surface of the mineral soil and had a volume of 550 cm^3. Depths of Ah and Ae horizons were measured at the locations where forest floor samples were collected and horizon depths were averaged per plot. A subsample of each mineral soil sample was oven-dried and used to calculate bulk density. The remaining mineral soil sample was air-dried and passed through a 2-mm sieve. The fine fraction of each air-dried soil sample was composited on a plot basis and used for chemical analysis.

Both forest floor and mineral soil samples were analyzed for pH, total C, available N, available P, and exchangeable cations. Exchangeable pH was measured with a Radiometer pH meter using a calcium chloride (0.01 M $CaCl_2$) solution (Kalra and Maynard 1991). Total C was measured on a Leco Carbon Analyzer CR12. Mineralizable N availability was measured using an anaerobic Waring-Bremner incubation (Powers 1980) for 2 wk at 30°C, followed by colorimetric analysis on a Technicon Autoanalyzer. A Bray P_1 extraction followed by ammonium molybdate and ascorbic acid color development determined available P (Bray and Kurtz 1945; Kalra and Maynard 1991). An ammonium acetate (1.0 M NH_4OAc) extraction left undisturbed for 12 h was analyzed on an Atomic Absorption Spectrophotometer to determine exchangeable Ca, Mg, K, and Na (Greweling and Peech 1965).

Table 2. Depths of the forest floor and A horizons for vine maple and conifer plots in a 75-yr-old stand (n = 15) and a 130-yr-old stand (n = 12)

Property	75-yr-old stand (n = 15)						130-yr-old stand (n = 12)					
	Vine maple plots		Conifer plots		P (t-test)	Power (1-B)	Vine maple plots		Conifer plots		P (t-test)	Power (1-B)
	Depth (cm)						Depth (cm)					
L (fresh)	0.25	(0.1)[z]	0.30	(0.18)	0.3	0.15	0.08	(0.09)	0.05	(0.05)	0.2	0.16
L	1.41	(0.34)	1.48	(0.58)	0.6	0.06	1.44	(0.31)	1.54	(0.51)	0.5	0.08
F	1.11	(0.76)	1.09	(0.69)	0.9	0.03	0.96	(0.43)	0.95	(0.87)	0.97	0.03
H	0.48	(0.30)	0.41	(0.22)	0.4	0.1	0.34	(0.31)	0.32	(0.18)	0.98[y]	0.04
Ah	1.50	(1.37)	1.01	(0.70)	0.3[y]	0.23	2.91	(0.99)	2.20	(0.97)	0.09	
Ae	1.04	(1.08)	1.86	(1.11)	0.07[x]	1.35	(0.99)	0.96	(1.11)		0.2[y]	0.14
Total forest floor	3.26	(1.04)	3.28	(0.74)	0.9	0.03	2.83	(0.43)	2.86	(1.17)	0.9	0.03
Ah plus H	1.98	(1.51)	1.42	(0.72)	0.3	0.24	3.25	(1.13)	2.52	(1.09)	0.1	0.33
Forest floor plus Ah	4.76	(1.88)	4.29	(1.01)	0.3	0.13	5.73	(1.23)	4.86	(1.17)	0.07y	

[z]Values in parentheses are standard deviations.
[y]Values were log transformed to meet underlying statistical assumptions.
[x]Underlined values indicate significance at $P < 0.10$.
[w]Wilcoxan Signed-Rank Test was used to determine probability value.

Ion-exchange Resins Preparation, Collection, and Analysis

Availability of NO_3^-, NH_4^+, and P in the upper mineral soil was measured using ion-exchange resin bags (Binkley and Matson 1983). Resin bags were 7 cm by 7 cm in dimension and constructed of nylon. A 16–50 mesh mixed-bed resin (1:1 equivalent mixture of strongly acidic cation and strongly basic anion) from JTBaker Laboratory Inc. was used. Ten grams of wet resin were placed in each bag. The bags were then rinsed for 30 min in a 50 mL solution of 1 M NaCl then washed in deionized water to remove excess salt. The methods used were similar to those of Hubner et al. (1991).

In each plot, five mixed bed exchange resin bags (Munson et al. 1993) were evenly spaced 85 cm from a wooden stake. Bags were placed horizontally 10 cm below the organic and mineral horizon boundary (Munson et al. 1993). Placement of the resin bags avoided coarse woody debris, large rocks, and extreme sites. Resin bags were placed out in early May 1997 and collected at the end of August 1997.

Upon collection, each ion exchange resin sample was poured into 100 mL of 1 M KCl (Binkley and Matson 1983), and the extraction solutions were left undisturbed for 24 h. Before nutrient concentrations were measured, samples were filtered to exclude soil and root debris and then composited on a plot basis. Concentrations of NO_3^-, NH_4^+, and P were measured colorimetrically using a LaChat Autoanalyzer.

Statistical Analyses

To test for differences in forest floor and mineral soil properties between vegetation types (vine maple and conifer) paired t-tests were carried out for each variable at each location. Separate analyses were carried out for each location to determine if the influence of vine maple differed between the two study stands.

All quantitative data were statistically analyzed using SYSTAT 7.0 (1997) with a significance level (α) of 0.10. Where the null hypothesis was not rejected, power analysis was performed to determine the risk of making a Type II error, or falsely accepting the null hypothesis (Peterman 1990). Power (1-β) was computed using a program developed by Borenstein and Cohen (1988). All data were tested for normality using normal probability plots. Variables not conforming to the underlying assumptions of parametric tests were log transformed to achieve normality, or if unsuccessful, a non-parametric test was used.

RESULTS AND DISCUSSION

Humus Form and Horizon Depth

We had anticipated thinner depths of L and F horizons and thicker H and Ah horizons under vine maple due to the faster decomposition rate of vine maple litter relative to conifer needles (Haeussler et al. 1990; Ogden and Schmidt 1997). We found no statistical differences between vine maple and conifer plots for the depths of the L, F or H horizons at either site (Table 2). The similar depths of the forest floor horizons for vine maple and conifer plots may in part be due to a greater input of litterfall in the autumn in the vine maple plots than in the conifer plots (Tashe and Schmidt 2001). Greater litterfall input could offset faster decomposition rates of vine maple litter relative to conifer needles. Furthermore, it appears that though vine maple litter decomposes faster than conifer litter over short periods of time (up to 1 yr), mass loss after longer periods (2 yr or more) may not be different than for conifers (Ogden and Schmidt (1997). Thus differences in decomposition rates between vine maple and conifers may not influence forest floor depth as much as originally expected.

Our results for forest floor depth differ from those of Ogden and Schmidt (1997) who found that vine maple plots had significantly thinner forest floors than conifer plots, whereas no differences in forest floor depth were noted in this study. Contradictory results between studies may in part be attributed to differences in the dominant conifer species [Douglas-fir in our study; western hemlock in Ogden and Schmidt's (1997) study], sample size, selection of plots, study location, methods of measurement, and inherent forest floor variability.

Vine maple plots as compared to conifer plots had thinner Ae horizons at the 75-yr-old forest and thicker Ah horizons at the 130-yr-old forest (Table 2). The thicker Ah horizons for vine maple plots at the 130-yr-old stand may be due to

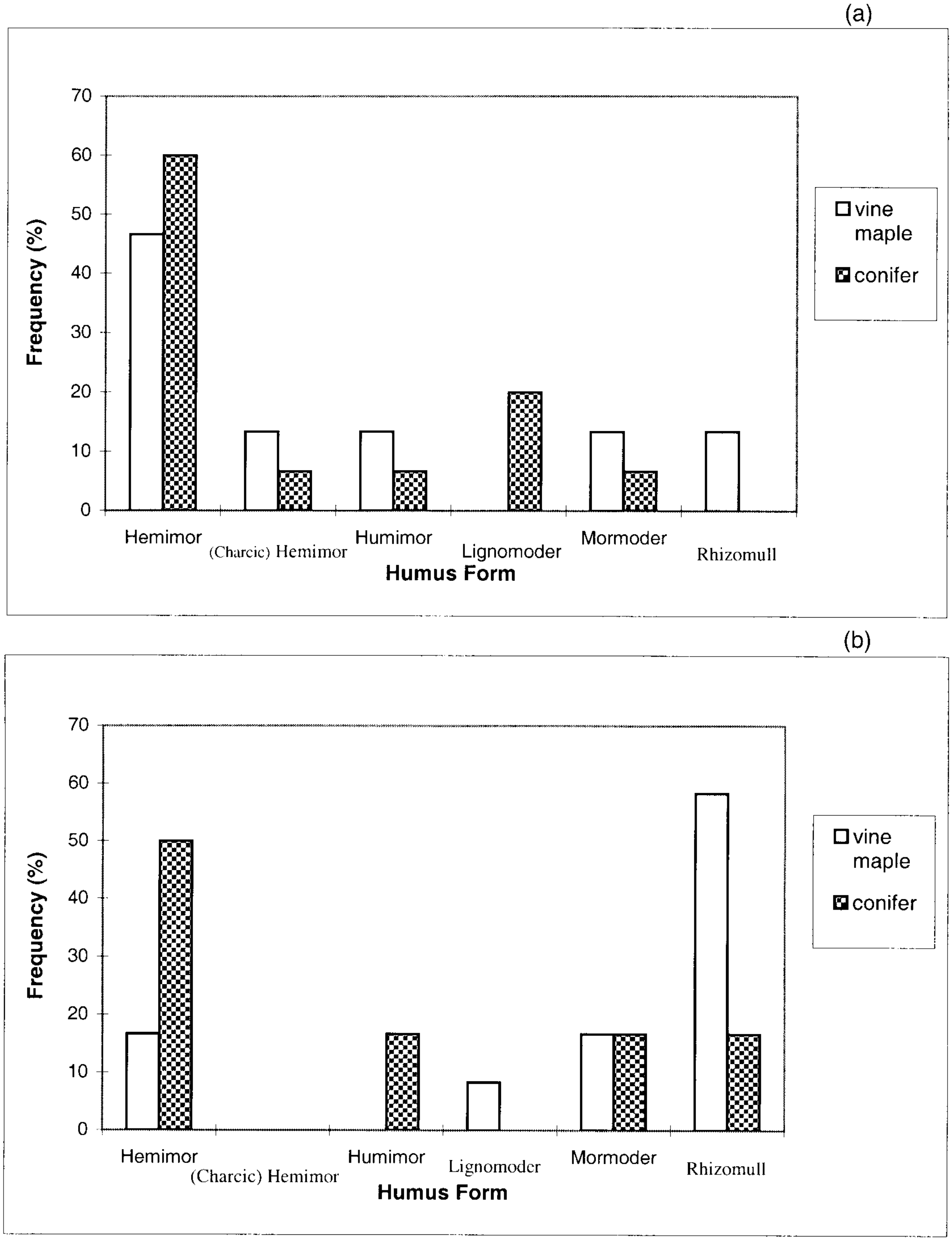

Fig. 2. Humus forms on vine maple and conifer plots for the 75-yr-old stand (a) and the 130-yr-old stand (b).

the rapid decomposition and incorporation of nutrient-rich vine maple litterfall (Ogden and Schmidt 1997). High concentrations of N for litterfall in vine maple plots (Ogden and Schmidt 1997; Tashe and Schmidt 2001) may increase rates of litter decomposition, especially in the early stages of decay (Prescott 1995). Broad-leaved trees such as red alder, whose litter is rich in N, have faster rates of litterfall decomposition than conifers (Edmonds 1980). Furthermore, other hardwoods such as black cottonwood are known to form humus-rich forest floors under their canopies (Haeussler et al. 1990). The thicker Ah horizons may also be due to different and possibly more active biotic communities being supported under vine maple, which could affect rates of organic matter being incorporated into the mineral soil.

We expected different humus forms to have developed under the two vegetation types. Vine maple, with its rapid litter decomposition relative to conifers, was expected to form moder humus (Krajina et al. 1982). On the other hand, mor humus was expected under conifer plots as they form in acidic conditions associated with coniferous forests (Green et al. 1993). At the 75-yr-old stand, mor humus dominated both conifer and vine maple plots (Fig. 2) with the majority of vine maple (47%) and conifer plots (60%) classified as Hemimor. At this stand, Rhizomull humus was found in two of the vine maple plots (13%), but none occurred in the conifer plots. At the 130-yr-old stand, mor humus dominated under the conifer canopy and mull humus forms in vine maple plots (Fig. 2). The humus form in the majority of conifer plots was Hemimor (50%), and for the majority of vine maple plots it was Rhizomull (58%).

Our results suggest that vine maple within conifer forest does influence humus form, but that this influence is not consistent within a stand or between stands. Vine maple appeared to have little influence on humus form at the 75-yr-old stand. The majority of conifer plots (11 of 15) had mor humus and four had moder humus. The same number of vine maple plots (11 of 15) had mor humus, two had moder humus, and two had mull humus. The only indication of an influence on humus form at the 75-yr-old stand, is that two vine maple plots had mull humus, whereas no conifer plots had mull humus.

The influence of vine maple on humus form is more apparent at the 130-yr-old stand. Eight of the 12 conifer plots had mor humus, whereas only 2 of the 12 vine maple plots had this humus form. Seven vine maple plots had mull humus and only two conifer plots had this humus form. The results suggest that mull humus tends to form under vine maple at the 130-year-old stand and to some degree at the 75-yr-old stand, but that mull humus also can form under conifers and mor humus can form under vine maple.

Differences in humus form between vine maple and conifer plots in our study follow the trend that mull forest floors are generally formed under hardwood forests and mor forest floors are most often found under coniferous forests (Fisher and Binkley 2000). The results indicate that the type of litter significantly influenced the development of the forest floor in our study. It is likely that the litter type affected the soil biotic community found beneath vine maple and conifers and this lead to differences in humus forms. Further research concerning differences in soil biotic communities beneath the two vegetation types would be useful.

Carbon and Nitrogen

We found greater C concentration and content in the mineral soil beneath vine maple than conifers at the 130-yr-old stand (Table 3). The greater C values found for vine maple plots are likely due to the rapid rate of decomposition of vine maple litter (Ogden and Schmidt 1997) and possibly greater soil organism activity beneath vine maple. The higher total C concentrations are reflected in the deeper Ah horizons found below vine maple at the 130-yr-old stand (Table 2). In contrast to our study, Ogden and Schmidt (1997) did not find a significant difference between organic matter concentration or content in mineral soils at either of two depths (0–5 cm and 20–25 cm) beneath vine maple and conifers in an 80-yr-old stand. Similar to our findings, Fried et al (1990) found significantly greater total C concentrations beneath bigleaf maple (*A. macrophyllum* Pursh) than beneath Douglas-fir in 35- to 60-yr-old stands in Oregon.

We found evidence that vine maple may positively influence indicators of N availability in both the forest floor and mineral soils. Mineralizable N concentration as measured by an anaerobic incubation in the lab was greater under vine maple than under conifers in the mineral soil at both study stands and in the forest floor at the 130-yr-old stand (Tables 3 and 4). Total N concentration and content were greater in the mineral soil beneath vine maple than beneath conifers at the 130-yr-old stand (Table 3). Greater N availability below vine maple may be due to the rapid decomposition rates of vine maple litter (Ogden and Schmidt 1997), relatively high N concentrations in vine maple litter (Tashe and Schmidt 2001), and possibly greater soil organism activity beneath vine maple.

Nitrogen available to plants can be reflected in C:N ratios (Brady and Weil 2002). A significantly lower C:N ratio was anticipated for vine maple plots relative to conifer plots. The C:N ratio of the surface mineral soil at the 75-yr-old stand was lower for vine maple plots (Table 3). The lower C:N ratios in mineral soil under vine maple (24) at the 75-yr-old stand as compared to conifer plots (26) may be ecologically significant, as ratios below 25 generally result in greater N mineralization (Brady and Weil 2002). Contrary to expectations, the forest floor C:N ratio was not significantly lower for vine maple plots at either study location (Table 4). The lack of statistical difference in C:N ratios between vegetation types may be due to similar inputs of conifer litterfall to each vegetation type (Tashe and Schmidt 2001).

Data obtained using ion exchange resin bags indicated significantly greater NO_3^- availability in vine maple plots as compared to conifer plots at the 75-yr-old stand (Table 3). Nitrate concentration at the 75-yr-old stand was more than twice as high for vine maple plots relative to conifer plots (Table 3). The greater N availability in the soil corresponds to the higher mineralizable N levels measured in bulk soil samples. In a study on Vancouver Island in British Columbia, Binkley and Matson (1983) used ion-exchange resins and found that N availability was greater for 20-yr-old Douglas-fir stands with red alder as compared to stands without the hardwood component.

The trend for greater N availability for vine maple plots observed in our study is similar to the findings of other researchers for other hardwoods. Perry et al. (1987) conducted a study in the Oregon Coast Range, measuring N dynamics for 25- to 35-yr-old Douglas-fir-dominated forests with and without hardwoods (dominantly bigleaf maple). Their results show that the nutrient cycle was significantly altered with the removal of the hardwood component of the forest. With hardwoods, the stand averaged 520 kg ha^{-1} more total N in the top 12 cm of mineral soil, 20% more N mineralized from soil lab incubations, and a lower soil C:N ratio. Similarly, research conducted by Fried et al. (1990) on bigleaf maple in the eastern margin

Table 3. Mineral soil properties at 0- to 7-cm depth for vine maple and conifer plots in a 75-yr-old (n = 15) and a 130-yr-old stand (n = 12)

	75-yr-old stand						130-yr-old stand					
Property	Vine maple plots		Conifer plots		*P* (t-test)	Power (1-β)	Vine maple plots		Conifer plots		*P* (t-test)	Power (1-β)
Bulk density (g cm^{-3})	0.71	(0.14)[z]	0.74	(0.13)	0.60	0.08	0.70	(0.12)	0.74	(0.14)	0.45	0.11
Gravel content (%)	46.9	(8.6)	43.3	(7.1)	0.22	0.23	42.2	(7.7)	41.0	(5.0)	0.68	0.06
pH	4.45	(0.34)	4.35	(0.19)	0.32	0.16	4.38	(0.21)	4.21	(0.33)	0.08[y]	
Total C (g kg^{-1})	54.5	(12.7)	53.1	(16.4)	0.78	0.04	75.4	(22.4)	59.1	(9.7)	0.04	
Total C (kg ha^{-1})	26358	(4714)	26431	(5087)	0.97	0.03	35269	(5613)	30371	(6536)	0.03	
Total N (g kg^{-1})	2.28	(0.51)	2.04	(0.61)	0.25	0.20	3.21	(1.12)	2.46	(0.37)	0.05	
Total N (kg ha^{-1})	1102	(182)	1014	(167)	0.21	0.26	1496	(302)	1263	(272)	0.05	
C:N ratio	24.0	(2.6)	26.0	(2.5)	0.05		24.0	(3.7)	24.3	(4.0)	0.87	0.04
Min. N (mg kg^{-1})	62.5	(21.7)	48.7	(20.3)	0.10		65.7	(17.6)	47.6	(8.8)	0.009	
Min. N (kg ha^{-1})	30.0	(9.0)	24.0	(7.5)	0.08[x]		31.0	(6.0)	24.4	(5.6)	0.02	
Avail P. (mg kg^{-1})	5.78	(1.53)	9.05	(7.52)	0.005[x]		20.0	(10.10)	35.7	(34.40)	0.5[x]	0.30
Avail. P (kg ha^{-1})	2.86	(0.96)	4.71	(3.80)	0.005[x]		9.50	(4.30)	18.7	(18.50)	0.4[x]	0.36
Exch. Ca (cmol$_c$ kg^{-1})	1.84	(1.15)	1.30	(0.56)	0.20	0.35	2.32	(1.05)	1.70	(0.83)	0.08	
Exch. Mg (cmol$_c$ kg^{-1})	0.14	(0.07)	0.11	(0.05)	0.20	0.25	0.24	(0.12)	0.17	(0.08)	0.05	
Exch. K (cmol$_c$ kg^{-1})	0.11	(0.06)	0.07	(0.02)	0.02[x]		0.14	(0.05)	0.11	(0.03)	0.03[x]	
TEB[w] (cmol$_c$ kg^{-1})	2.13	(1.29)	1.52	(0.63)	0.08[x]		2.73	(1.17)	2.02	(0.92)	0.07	
NH_4^+ (µg resin bag^{-1})	438	(313)	556	(344)	0.31	0.15	331	(193)	399	(233)	0.50	0.11
NO_3^- (µg resin bag^{-1})	1855	(1049)	883	(554)	0.005		2344	(1650)	2331	(2180)	0.98	0.03
P (µg resin bag^{-1})	3.43	(5.24)	4.74	(6.34)	0.53	0.09	8.43	(9.09)	13.7	(28.8)	0.58	0.08

[z]Values in parentheses are standard deviations.
[y]Underlined values indicate significant differences at $P < 0.10$.
[x]Values were log transformed to meet underlying statistical assumptions.
[w]TEB = total exchangeable bases (Ca, Mg, K, Na).

Table 4. Forest floor properties for vine maple and conifer plots in a 75-yr-old (n = 15) and a 130-yr-old stand (n = 12)

	75-yr-old stand						130-yr-old stand					
Property	Vine maple plots		Conifer plots		*P* (t-test)	Power (1-β)	Vine maple plots		Conifer plots		*P* (t-test)	Power (1-β)
Forest floor (kg ha^{-1})	62374	(43143)[z]	53593	(23091)	0.76[y]	0.10	23023	(7449)	30088	(15020)	0.15[y]	0.28
pH	4.01	(0.37)	3.77	(0.31)	0.05[x]		4.15	(0.35)	4.04	(0.40)	0.22	0.10
Total C (g kg^{-1})	457	(35)	479	(19)	0.04		459	(41)	483	(46)	0.08	
Total C (kg ha^{-1})	28909	(21615)	25630	(11168)	0.99[y]	0.07	10468	(3287)	14770	(8479)	0.08[y]	
C:N ratio	32.2	(3.3)	32.7	(2.9)	0.48	0.06	30.6	(3.0)	31.0	(3.0)	0.77	0.05
Min. N (mg kg^{-1})	439	(203)	381	(138)	0.14	0.14	209	(62)	166	(99)	0.08[y]	
Min. N (kg ha^{-1})	30.7	(27.9)	21.2	(14.1)	0.93[y]	0.04	4.70	(1.64)	4.26	(2.33)	0.57	0.07
Avail P. (mg kg^{-1})	214	(48)	199	(34)	0.29	0.15	169	(33)	182	(52)	0.32	0.11
Avail. P (kg ha^{-1})	13.1	(7.8)	10.6	(4.4)	0.28	0.17	3.82	(1.18)	5.73	(3.75)	0.08	
Exch. Ca (cmol$_c$ kg^{-1})	20.4	(4.4)	17.7	(3.1)	0.08		22.0	(6.0)	19.2	(3.1)	0.17	0.27
Exch. Mg (cmol$_c$ kg^{-1})	2.77	(0.41)	2.47	(0.57)	0.14	0.36	3.18	(0.99)	2.68	(0.51)	0.09	
Exch. K (cmol$_c$ kg^{-1})	1.61	(0.35)	1.68	(0.50)	0.60	0.06	1.35	(0.42)	1.25	(3.60)	0.27	0.10
TEB[w] (cmol$_c$ kg^{-1})	24.9	(4.7)	22.0	(3.5)	0.08		26.6	(6.9)	23.2	(3.6)	0.13	0.30

[z]Values in parentheses are standard deviations.
[y]Values were log transformed to meet underlying statistical assumptions.
[x]Underlined values indicate significant differences at $P < 0.10$.
[w]TEB = total exchangeable bases (Ca, Mg, K, Na).
Total N values were reported in Tashe and Schmidt (2001).

of the Oregon Coast Range showed that total soil N concentration in the mineral A horizon was significantly greater under bigleaf maple than under Douglas-fir. The presence of locust in 400-yr-old Ponderosa pine forests of central Arizona also significantly increased N concentration in the top 5 cm of mineral soil (Klemmedson 1994). Van Cleve et al. (1986) Forest floors formed under black spruce [*Picea mariana* (Mill.) B.S.P.] and white spruce [*Picea glauca* (Moench) Voss] in Alaska contained 4 and 15 times less extractable N than the more fertile paper birch (*Betula papyrifera* Marsh.) forest floor (Van Cleve et al. 1986).

Phosphorus

Our results suggest that P availability may be negatively influenced by vine maple. Available P concentrations and contents in the mineral soil at the 75-yr-old stand and available P contents in the forest floor at the 130-yr-old stand were lower beneath vine maple than beneath conifers (Tables 3 and 4). The mechanisms by which vine maple could negatively influence P availability are unclear. Differences in soil pH do not explain the negative effect of vine maple on P availability as pH levels for the forest floor and surface mineral soil at both sites were either not significantly different between vegetation types or were higher for vine maple as compared to conifer plots. The potential negative influence of vine maple highlights the point made by Binkley (1995) that no one species is entirely favorable to site conditions. Brozek (1990) reported similar results to ours as he found lower P availability and accelerated depletion of extractable P in 50-yr-old stands of red alder near Seattle, Washington.

The potential negative influence of vine maple on P availability was not reflected in the measurements of P obtained using ion exchange resins. No significant differences were found in P availability between vegetation types at either site using the ion exchange resin method (Table 3). The power of the statistical tests were very low, however, and thus there may be a difference in PO_4-P availability that was not detected by our study.

Exchangeable Bases and pH

We expected to find greater concentrations of exchangeable Ca, Mg, and K and higher pH in the forest floor and mineral soil under vine maple due to inputs of base-rich vine maple litter (Ogden and Schmidt 1997). Our results suggest that vine maple influences the base status of the forest floor and mineral soil (Tables 3 and 4). Total exchangeable base concentration was greater in the forest floor at the 75-yr-old stand and in the mineral soil at both study stands for vine maple plots as compared to conifer plots (Tables 3 and 4). The influence on bases varied by the particular cation in question (Ca, Mg or K), by substrate (forest floor or mineral soil), and by stand. Calcium was significantly influenced in the forest floor at the 75-yr-old stand and in the mineral soil at the 130-yr-old stand. Magnesium was affected in the forest floor and mineral soil at the 130-yr-old stand. Potassium differed between vegetation types in the mineral soil at both study stands, but not in the forest floor at either stand.

Similar to our results, Fried et al. (1990) found a trend towards greater concentration of total K in the A horizon of bigleaf maple plots relative to Douglas-fir plots. The presence of New Mexican locust, an understory tree species like vine maple, significantly increased the concentrations of Ca and K in the forest floor and mineral soil in Ponderosa pine forests in central Arizona (Klemmedson 1994).

The greater concentrations of bases were reflected in the soil pH. Vine maple plots had higher pH for the forest floor at the 75-yr-old stand and for the mineral soil at the 130-yr-old stand as compared to conifer plots (Tables 3 and 4). Ogden and Schmidt (1997) had also found higher pH for the forest floor under vine maple, relative to western-hemlock-dominated stands.

Comparison of Study Stands

Some major differences are apparent between the two study stands (Tables 3 and 4). The forest floor mass is twice as large, regardless of species, at the 75-yr-old stand as compared to the 130-yr-old stand (Tashe 1998). The contents of total C, total N, mineralizable N and available P are noticeably higher in the forest floor and lower in the mineral soil for the 75-yr-old stand as compared to the 130-yr-old stand (Tashe 1998). It is possible that differences in stand age, textural class and soil moisture partially account for differences between the study stands.

It appears that vine maple may have had a greater influence on soil properties at the 130-yr-old stand as compared to the 75-yr-old stand. More significant differences were found for soil properties between vine maple and conifer plots at the 130-yr-old stand as compared to the 75-yr-old stand. Four and five of 13 measured forest floor properties differed between the two vegetation types at the 75-yr-old and 130-yr-old stands, respectively (Table 4). Eight and 11 of 19 measured properties of the mineral soil differed between the two vegetation types at the 75-yr-old and 130-yr-old stands, respectively (Table 3).

The influence of vine maple on properties of the forest floor and mineral soil was consistent between the two study stands for five chemical variables and was inconsistent between the study stands for 21 variables (Tables 2–4; Fig. 3). Only six of the chemical variables were not significantly influenced by vine maple at either of the study stands.

CONCLUSIONS

Understory vine maple in Pacific Coastal forests was shown to have an impact on some forest floor soil properties. Our results suggest that vine maple can positively influence pH and the availability of N and exchangeable bases. At the 75-yr-old stand the following properties were higher in vine maple plots as compared to conifer plots: pH and exchangeable Ca concentration in the forest floor; and concentrations of mineralizable N, exchangeable K and NO_3^- in the mineral soil. Properties that were positively influenced by vine maple at the 130-yr-old stand include: mineralizable N and exchangeable Mg concentrations in the forest floor and pH and concentrations of total C, total N, mineralizable N and exchangeable Ca, Mg, and K in the mineral soil. Although vine maple positively influenced the previously specified soil properties, our data suggest that vine maple may have a negative influence on P availability. Available P concentrations and contents in the mineral soil at the 75-yr-old stand and available P contents in the forest floor at the 130-yr-old stand were lower under vine maple than conifers.

For a small number of soil properties (5) the influence of vine maple was consistent for the two study stands, but for most soil properties (21) the influence of vine maple differed between the two stands. For some properties, it is possible that there are significant differences between the vegetation types at both study stands, but that these differences were not detected due to low power of the statistical tests. These differences could be investigated further by making measurements on a larger number of paired plots within study stands. For some properties it is possible that vine maple has a variable influence depending on site characteristics (e.g., stand age). Further research could be designed to investigate the influence of relevant factors (such as stand age or soil textural class) on the effect of vine maple on soil properties.

Research is needed to explore the mechanisms that lead to differences in soil properties beneath vine maple. In particular we suggest that a link between soil biotic communities and soil properties beneath vine maple be pursued.

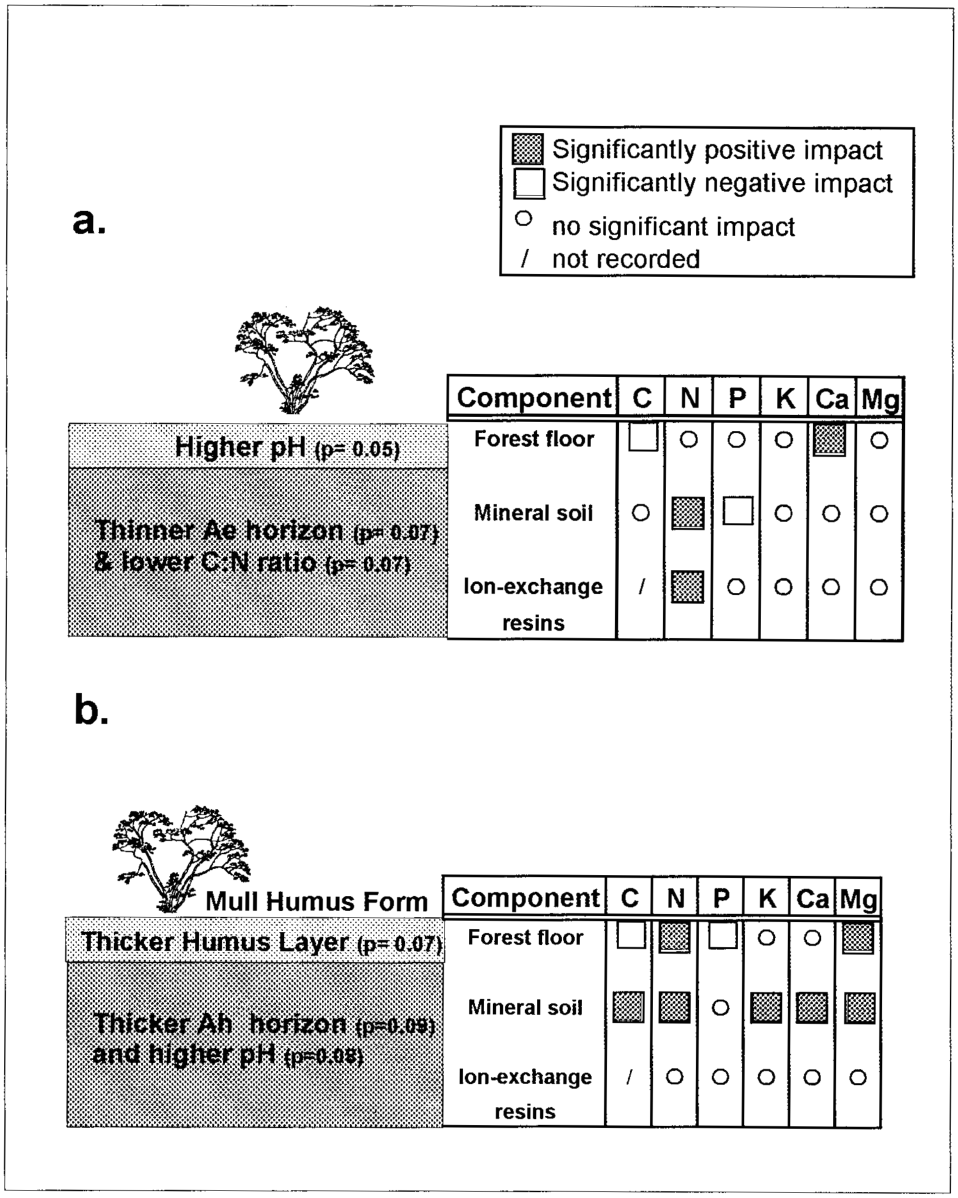

Fig. 3. Summary diagram showing properties that were significantly different ($P = 0.10$) between vine maple and conifer plots in the mineral soil and forest floor of the 75-yr-old stand (a) and the 130-yr-old stand (b).

Differences in humus form beneath vine maple and conifers suggest that there may be differences in soil biotic communities beneath the two vegetation types.

ACKNOWLEDGEMENTS

We are grateful for the assistance provided by our many field and lab assistants, Pacific Soil Analysis Limited, and Dr. Les Lavkulich for allowing us the use of the lab facilities at the University of British Columbia. We appreciate the co-operation provided by the staff of UBC Malcolm Knapp Research Forest near Maple Ridge, BC, and the Greater Vancouver Regional District for allowing us access to the study sites. Financial support for this research came from Forest Renewal British Columbia and the Natural Sciences and Engineering Research Council.

Anderson, H. G. 1969. Growth form and distribution of vine maple on Mary's Peak, western Oregon. Ecology **50**: 127–130.

Binkley, D. 1995. The influence of tree species on forest soils processes and patterns. Pages 7–33 *in* J. D. Mead and I. S. Cornforth, eds. Proceedings of the Trees and Soil Workshop, Lincoln University, Agronomy Society of New Zealand Special Publication No. 10. Lincoln University Press, Canterbury, New Zealand.

Binkley, D. and Matson, P. 1983. Ion exchange resin bag method for assessing available forest soil nitrogen. Soil Sci. Soc. Am. J. **47**: 1050–1052.

Borenstein, M. and Cohen, J. 1988. Statistical power analysis: A Computer Program. L. Erlbaum Associates, Hillsdale, NJ.
Brady, N. C. and Weil, R. R. 2002. The nature and properties of soil. 13th ed. Prentice Hall, Upper Saddle River, NJ. 960 pp.
Bray, R. H. and Kurtz, L. T. 1945. Determination of total, organic, and available forms of phosphorus in soils. Soil Sci. **59**: 39–45.
Brozek, S. 1990. Effect of soil changes caused by red alder (*Alnus rubra*) on biomass and nutrient status of Douglas-fir (*Pseudotsuga menziesii*) seedlings. Can. J. For. Res. **20**: 1320–1325.
Canadian Agricultural Services Coordinating Committee. Soil Classification Working Group. 1998. The Canadian system of soil classification. 3rd ed. Agriculture and Agri-Food Canada, Ottawa, ON. Publ. 1646. 187 pp..
Edmonds, R. L. 1980. Litter decomposition and nutrient release in Douglas-fir, red alder, western hemlock, and Pacific silver fir ecosystems in western Washington. Can. J. For. Res. **10**: 327–337.
Fisher, R. F. and Binkley, D. 2000. Ecology and management of forest soils. 3rd ed. John Wiley & Sons, New York, NY. 489 pp.
Fried, J. S., Boyle, J. R., Tappeiner II, J. C. and Cromack, K. Jr. 1990. Effects of bigleaf maple on soils in Douglas-fir forests. Can. J. For. Res. **20**: 259–266.
Green, R. N., Trowbridge, R. L. and Klinka, K. 1993. Towards a taxonomic classification of humus forms. Forest Science Monograph 29. Society of American Foresters. Bethesda, MD. 49 pp.
Greweling, T. and Peech, M. 1965. Chemical soil tests. New York State College of Agriculture. Bulletin 960.
Haeussler, S., Coates, D. and Mather, J. 1990. Autecology of common plants in British Columbia: A literature review. British Columbia Ministry of Forests and Canadian Forest Service. FRDA Report 158. Victoria, BC. 272 pp.
Hubner, C., Redi, G. and Wurst, F. 1991. *In situ* methodology for studying N-mineralization in soils using anion exchange resins. Soil Biol. Biochem. **23**: 701–702.
Kalra, Y. P. and Maynard, D. G. 1991. Methods manual for forest soil and plant analysis. Forestry Canada Information Report NOR-S-319. Victoria, BC. 116 pp.
Klemmedson, J. 1987. Influence of oak in pine forests of central Arizona on selected nutrients of forest floor and soil. Soil Sci. Soc. Am. J. **51**: 1623–1628.
Klemmedson, J. 1994. New Mexican locust and parent material: influence on forest floor and soil macronutrients. Soil Sci. Soc. Am. J. **58**: 974–980.
Krajina, V. J., Klinka, K. and Worrall, J. 1982. Distribution and ecological characteristics of trees and shrubs of British Columbia. Faculty of Forestry, University of British Columbia, Vancouver, BC. 131 pp.
Meidinger, D. and Pojar, J. 1991. Ecosystems of British Columbia. Ministry of Forests, Special Report Series 6. Victoria, BC. 330 pp.
Munson, A. D., Margolis, J. A. and Brand, D. G. 1993. Intensive silviculture treatment: impacts on soil fertility and planted conifer response. Soil Sci. Soc. Am. J. **57**: 246–255.
Ogden, A. E. and Schmidt, M. G. 1997. Litterfall and soil characteristics in canopy gaps occupied by vine maple in a coastal western hemlock forest. Can. J. Soil Sci. **77**: 703–711.
Pastor, J. and Bockheim, J. G. 1984. Distribution and cycling of nutrients in an aspen-mixed-hardwood-spodosol ecosystem in northern Wisconsin. Ecology **65**: 339–353.
Perry, D. A., Choquette, C. and Schroeder, P. 1987. Nitrogen dynamics in conifer-dominated forests with and without hardwoods. Can J. For. Res. **17**: 1435–1441.
Peterman, R. M. 1990. Statistical power analysis can improve fisheries research and management. Can. J. Aquat. Sci. **47**: 2–15.
Powers, R. F. 1980. Mineralizable soil nitrogen as an index of nitrogen availability to forest trees. Soil Sci. Soc. Am. J. **44**: 1314–1320.
Prescott, C. E. 1995. Does nitrogen availability control rates of litter decomposition in forests? Plant Soil **168-169**: 83–88.
SYSTAT 7. 1997. SPSS Inc., Chicago, IL.
Tashe, N. C. 1998. The impact of vine maple on the biogeochemical nutrient cycle of conifer-dominated coastal forests in southwestern British Columbia. M.Sc. Thesis, Simon Fraser University, Burnaby, BC. 109 pp.
Tashe, N. C. and Schmidt, M. G. 2001. The impact of vine maple on site fertility of coastal temperate forests. For. Ecol. Manage. **147**: 263–279.
Van Cleve, K., Heal, O. W. and Roberts, D. 1986. Bioassay of forest floor nitrogen supply for plant growth. Can. J. For. Res. **16**: 1320–1326.
Wardman, C. W. and Schmidt, M. G. 1998. Growth and form of Douglas-fir adjacent to persistent vine maple gaps in southwestern British Columbia. For. Ecol. Manage. **106**: 223–233.