Litterfall and soil characteristics in canopy gaps occupied by vine maple in a coastal western hemlock forest

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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**: 703-711–000. In some low-elevation coastal British Columbia forests, canopy gaps can be occupied by the hardwood tree species, vine maple (*Acer circinatum*). The objective of this study was to determine how vine maple gaps influence litterfall, litter decomposition, and forest floor and mineral soil properties. Measurements were made on six vine maple gaps paired with six conifer canopy plots. Vine maple gaps had significantly less conifer litterfall during the autumn, higher pH, and higher concentrations of Ca, Mg and K in the forest floor, thinner forest floors, and a weak tendency for lower C/N ratios, higher pH values and higher total N concentrations in the surface mineral soil. Vine maple litter was found to decompose significantly faster than conifer litter and to have higher concentrations of N, P, Ca, Mg, K, Fe and Zn. Decomposition rates of vine maple litter and of conifer litter did not differ significantly between vine maple gap and conifer canopy plots. Larger vine maple clones had significantly thicker forest floors with higher concentrations of Ca, and higher N concentrations and lower C/N ratios in the surface mineral soil than gaps with smaller vine maple clones. The results indicate that vine maple gaps may improve the nutritional status of the sites that they occupy within conifer forests.

Key words: Litterfall, litter decomposition, soil-plant interactions, vine maple, canopy openings, canopy gaps

Ogden, A. E. et Schmidt, M. G. 1997. **Caractères de la litière fraiche et du sol dans les trouées d'une forêt côtière à pruche de l'Ouest ovvupées par l'érable circiné**. Can. J. Soil Sci. **77**: 703–711. Dans certaines forêts côtières de basse altitude de la Colombie-Britannique, les clairières peuvent être occupées par l'érable circiné (*Acer circinatum*). Nous avons cherché à déterminer dans quelle mesure ces clairières à érable circiné influent sur les dépôts et sur la décomposition de la litière ainsi que sur les propriétés des couches organiques et minérales du sol forestier. Des mesures en paires étaient prises dans 6 clairières à érable circiné jumelées à 6 placettes sous couvert de conifères. Dans les clairières, la litière nouvelle contenait significativement moins d'aiguilles de conifères en automne. La couche organique était plus mince, son pH plus élevé et elle contenait plus de Ca, de Mg et de K. Les horizons minéraux supérieurs affichaient des rapports C/N plus bas, un pH plus élevé et des concentrations en N total plus fortes. La litière d'érable circiné se décomposait significativement plus vite que la litière de conifères et elle était plus riche en N, P, Ca, Mg, K, Fe et Zn. Les taux de décomposition des deux types de litière n'étaient pas statistiquement différents selon qu'il s'agissait d'une placette de clairière ou d'une placette sous pruche de l'Ouest. La couche organique du sol était plus épaisse et plus riche en Ca et la couche minérale plus riche en Ca et en N avec un rapport C/N plus bas dans les placettes sous gros bouquets d'érables que là où les bouquets étaient moins développés. Ces observations montrent que les trouées à érable circiné peuvent améliorer l'état nutritionnel des emplacements qu'elles occupent au sein des forêts de conifères.

Mots clés: Litière nouvelle, décomposition de la litière, interaction sol-plante, érable circiné, clairière de priorité

Greater attention is now being given to hardwoods in forest research and resource management in British Columbia and elsewhere (Massie et al. 1994). Broad-leafed trees play a significant role in enhancing wildlife habitat, promoting biodiversity, vegetating riparian areas, and colonizing early successional stages (Haeussler et al. 1990). After disturbances, hardwoods are believed to maintain ecosystem resilience by establishing quickly, retaining soil nutrients, and reducing soil erosion (Perry and Maghembe 1989). Some researchers have studied the influence of hardwood species on soil properties, including nutrient pool sizes, acidity and nutrient supply rates (Binkley 1995). However, the relationship between hardwood species and long-term site productivity in coastal temperate rainforests of British Columbia and the American Pacific Northwest is poorly understood.

In conifer forests of the Pacific Northwest, hardwood species typically colonize early successional stages, and persist into later stages only in disturbed areas and riparian zones (Haeussler et al. 1990). In contrast, vine maple (*Acer circinatum*) is able to persist through the stem exclusion phase, and well-established patches have been found in old growth Douglas-fir (*Pseudotsuga menziesii*) forests (Spies et al. 1990; O'Dea et al. 1995).

In a recent study, vine maple was found to inhabit persistent openings in the forest canopy, called priority gaps, which were not created by treefall and were not edaphic in origin (McGhee 1996; Ogden 1996). Priority gaps are the result of small stature vegetation which has been able to maintain a competitive advantage since stand establishment, resisting the regeneration of taller canopy dominants and subsequent canopy closure (McGhee 1996). The origin of priority vine maple gaps is thought to be due to vine maple colonizing a site, and establishing a dense mat of stems early in stand development that is large enough to prevent the subsequent regeneration of these sites by conifers. As the stand develops around the vine maple patches, a canopy gap appears in the mid to late successional stages.

Canopy gaps may have greater nutrient availability due to a smaller sequestration of nutrients associated with lesser biomass, and to the increase in rates of decomposition and mineralization associated with higher levels of light, temperature and moisture (Pickett and White 1985). Vine maple litter is believed to provide a rich supply of nutrients to a site (Haeussler et al. 1990), and is thought to be associated with high rates of nutrient cycling (Krajina et al. 1982). Compared with Douglas-fir litter, vine maple litter has a higher concentration of N (Triska and Sedell 1976).

The goal of this study was to determine if rates of litterfall, and litter decomposition, and properties of the forest floor and mineral soil, in vine maple gaps differ from those in the surrounding forest. These properties may provide an indication of how vine maple gaps influence site productivity, and may help to explain the long-term impact of priority vine maple gaps on forest soils. The objectives of the study were:

1. To compare the following properties between vine maple gap and conifer canopy sites:
a. Rates of vine maple leaf and conifer needle litterfall, and nutrient inputs in litterfall.
b. Decomposition rates of vine maple leaf litter and conifer needle litter.
c. Properties of the forest floor (depth, mass per unit area, pH and nutrient concentrations) and mineral soil (bulk density, pH, organic matter and total N concentrations and C/N ratio).
2. To compare nutrient concentrations and decomposition rates between vine maple leaf litter and conifer needle (*Tsuga heterophylla* and *Pseudotsuga menziesii*) litter.

MATERIALS AND METHODS

Study Area

The study area is in the Seymour Demonstration Forest in the North Shore Mountains of the Coast Range (49°22′30″N, 123°00′25″W). The stand is a mature, second-growth forest dominated by *Tsuga heterophylla* (western hemlock) that was logged approximately 80 years ago. The dominant tree species are western hemlock (54%), Douglas-fir (27%) and western redcedar (*Thuja plicata*) (19%) (McGhee 1996). Canopy trees average 50.9 cm in diameter and 40 m in height (McGhee 1996). The study area is transitional between the moist maritime (CWHmm) and dry maritime (CWHdm) subzones of the Coastal Western Hemlock biogeoclimatic zone. Mean annual precipitation is approximately 2088 mm (Meidinger and Pojar 1991), most falling between the months of October and March with a pronounced dry period occurring in late summer. Less than 15% of total precipitation occurs as snowfall. Mean annual temperature is 7.8°C, with mean monthly temperatures remaining above 0°C (Meidinger and Pojar 1991). The soils are dominantly Orthic Humo-Ferric Podzols (Agriculture Canada Expert Committee on Soil Survey 1987), Mor is the dominant humus form (Klinka et al. 1981), and the parent material consists of compact basal till. Leaching of nutrients from the mineral soil is rapid in this wet climate and the soils are characteristically acidic, coarse-textured, low in clay minerals, and poor in nutrients (Meidinger and Pojar 1991).

Plot Selection

Measurements were made in six plots in vine maple gaps paired with six plots in the surrounding conifer forest. Paired plot comparisons are commonly used in evaluating differences in resources between canopy gaps and the surrounding closed canopy forest (Schemske and Brokaw 1981; Vitousek and Denslow 1986; Mladenoff 1987). Each conifer canopy plot was established at a distance of 25 m from a vine maple plot. The conifer canopy plots contained no evidence of vine maple (dead or alive) within 20 m of their centres and were dominated by conifers that made up the relatively closed canopy. The six gaps were chosen using three criteria: a canopy gap area between 15 m^2 and 180 m^2; a vine maple clone that was healthy; and a paired conifer canopy plot with similar slope angle, slope position, aspect and elevation. Ranges of slope, aspect and elevation for the plots are 4–20%, 70-154°, and 200–250 m, respectively.

It is likely that vine maples were present on the vine maple gap sites at least since the time of stand establishment, 80 years ago and thus the vine maple influence is quite long-term. Evidence for the long-term persistence of vine maple comes from a study by McGhee (1996) who studied the demography and persistence of vine maple in the same stand used in our study. Based on the absence of gap makers, the ages of vine maple clones and the spacing of conifers around vine maple gaps, she concluded that the vine maples maintained the gaps since the time of stand establishment through competitive inhibition of conifers and priority effects.

The ratio of the diameter of the gap to the height of the trees surrounding the gap (D/H ratio) of the vine maple gap plots ranged from 0.10 to 0.35. These estimates were obtained from gap area measurements of McGhee (1996) and tree height estimates on forest cover maps (Greater Vancouver Regional District 1988). The D/H ratio is an expression of opening size and can provide an indication of the influence of the gap on the microclimate of the understory (Geiger 1965); as the size of an opening decreases, temperatures remain more constant. Light increases with increased opening size, reaching a maximum when D/H = 2 (Pickett and White 1985).

Measurement of Litterfall and Litter Nutrient Concentrations

Ten litter traps were placed on each of the twelve plots to collect litterfall from 24 August 1993 to 20 September 1994. The litter traps were greenhouse trays (5 cm tall, 20 cm wide and 50 cm long) lined with 1 mm nylon mesh and holes in the bottom to allow for drainage. Litterfall was collected during three time periods: 24 August–16 November 1993 (autumn); 17 November 1993–13 June 1994 (winter/spring); and 14 June–20 September 1994 (summer). The autumn corresponds to the period in which all vine maple litter fell. The autumn collections were made weekly to minimize nutrient losses due to leaching. Collections for the other two periods were made once at the end of the period. Litterfall samples for the autumn collection were separated into the following components: vine maple leaf litterfall, conifer needle litterfall, and other material (bark, cones etc.).

For the samples collected in the autumn, three composite samples of vine maple leaf litter for each vine maple gap plot, and three composite samples of conifer needle litter for both vine maple gap and conifer canopy plots were formed. Each composite sample was composed of litterfall from three litter traps. The litterfall samples were analysed for concentrations of N, P, Ca, Mg, K, Mn, Fe, Zn, and Al (Parkinson and Allen 1975).

Measurement of Litter Decomposition

Litter decomposition was measured using methods similar to those of Prescott et al. (1993) and Taylor et al (1991). Standard samples were collected from littertraps placed beneath one site supporting predominantly western-hemlock and some Douglas-fir (3:1 ratio, on a tree density basis), and beneath two sites supporting vine maple. After litter samples were oven-dried at 70°C, 2 g samples of intact vine maple leaves were placed into 12 cm by 15 cm bags, and 2 g samples of the hemlock/Douglas-fir were placed into 6 cm by 12 cm bags. The bags were made of 2-ply 1-mm fibreglass mesh. Nine bags of each litter type were pinned to the forest floor on each site. Three bags from each site were collected at time intervals of 6 mo, 1 yr, and 2 yr. Litter was carefully removed from each litter bag, oven-dried at 70°C and weighed. Percent mass loss was calculated over each time period.

Forest Floor and Mineral Soil Sample Collection and Analysis

Forest floor and surface mineral soil samples were collected at three locations per plot along 3-m-long transects which were established across level topography at the centre of each plot. Sampling in pit or mound microsites was avoided. On vine maple gap plots, the centre of the transect was located beneath the vine maple foliage. At each sampling location bulk mineral soil samples were collected at 5 and 20 cm depths below the organic/mineral soil interface and a forest floor sample was obtained. Bulk density of the top 10 cm of mineral soil was determined at three locations on each plot using a bulk density cylinder. In addition, four bulk soil samples from 50 and 100 cm depths were collected from each plot.

Each forest floor sample was collected by measuring a 20 cm^2 area that was removed by inserting a shovel down to the mineral-organic soil interface. The depth of the forest floor (L, F and H horizons) was measured, and the oven-dried mass of each sample was determined. Mass of forest floor per unit area was calculated. The forest floor samples were analysed for concentrations of N, P, Ca, Mg, K, Mn, Fe, Zn, and Al (Parkinson and Allen 1975).

For the forest floor and the mineral soil samples collected at 5, 20, 50 and 100 cm depths at each site, pH was determined using a glass electrode-calomel electrode pH meter (Kalra and Maynard 1991). For the 5 and 20 cm depth samples, organic matter concentrations were determined using the mass-loss-due-to-ignition technique (Kalra and Maynard 1991). Total N concentrations were determined for the mineral soil at the 5 and 20 cm depths (Kalra and Maynard 1991). Organic carbon contents were calculated from the organic matter values using a conversion factor of 0.58 g carbon per gram organic matter. The C/N ratios for mineral soil samples from the 5 and 20 cm depths were calculated.

Statistical Analyses

The data were analyzed using analysis of variance (ANOVA, Steele and Torrie 1980) with the aid of SYSTAT (Wilkinson 1990). The litterfall and soil data were analyzed as a randomized complete block design, and we tested for the effect of site type (vine maple gap or conifer canopy) using the following model:

$$Y_{ijk} = u + B_i + S_j + e_{ijk}$$

where B is block (paired plots; i = 1, 2 ...6); S is site type (vine maple gap or conifer canopy; j = 1, 2); and e is random error within block × site type combination. Block and site type were considered a random and a fixed effect, respectively.

We tested for the effects of site type, litter type, and time on percent mass loss due to decomposition using the following model:

$$Y_{ijklm} = u + B_i + S_j + L_k + SL_{jk} + T_l + ST_{jl} + LT_{kl} + SLT_{jkl} + e_{ijklm}$$

where B is block; S is site type (j = 1, 2); L = litter type (1, 2); T = time (1, 2, 3) and e is random error within block × site type × litter type × time combination. Block was considered a random effect and site type, litter type and time were considered fixed effects. In this split-plot design there were six blocks, each block contained one plot of each of two site types (vine maple gap and conifer canopy), nine bags of two litter types (vine maple leaf and conifer needles) were set out on each plot, and three bags of each litter type were collected at three times since decomposition began (6 mo, 1 and 2 yr). A significance level of P = 0.10 was used in testing for significant differences. Regression analyses (n = 6) were performed to determine if gap characteristics, such as gap size, were related to litterfall, litter decomposition or soil properties.

RESULTS

Litterfall

In the vine maple gap plots in the autumn, the total amount of vine maple leaf litterfall was significantly lower than the amount of conifer needle litterfall (Fig. 1, P = 0.033). The amount of conifer needle litterfall was significantly less in the vine maple gap plots than in the conifer canopy plots (Fig. 1, P = 0.015) over the autumnal period. There was a weak tendency for smaller amounts of total litterfall (leaves and needles) beneath the vine maple gap plots than beneath the conifer canopy in the autumn (P = 0.12), but there were no significant differences in total annual litterfall (leaves

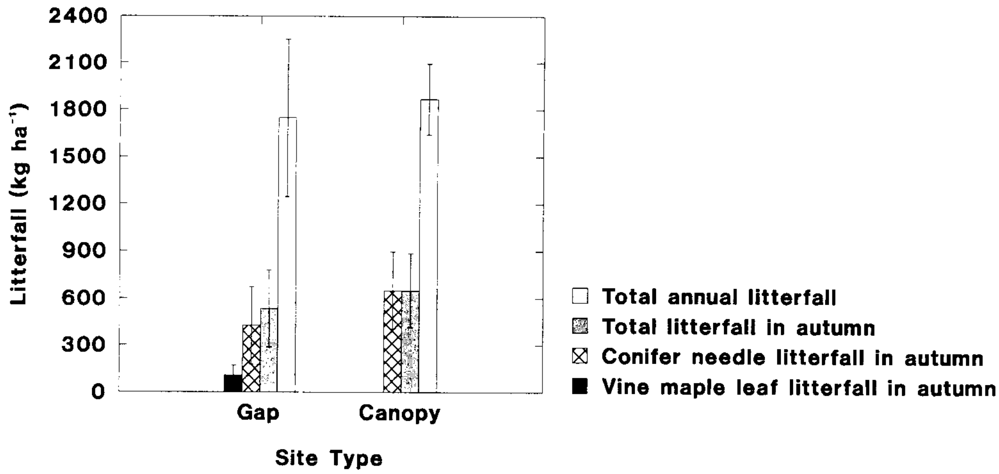

Fig. 1. Vine maple leaf and conifer needle litterfall in the autumn and total annual litterfall (leaves and needles in the autumn + leaves, needles and other material in the rest of the year) in vine maple gap plots and conifer canopy plots. Error bars represent one standard deviation from the mean.

and needles in the autumn + leaves, needles and other material in the rest of the year) between the two site types (Fig. 1, $P = 0.43$).

The larger the clone, the greater the amount of vine maple leaf litterfall ($P = 0.02$, $r^2 = 0.79$). The greater the amount of vine maple leaf litterfall, the lower the concentrations of P ($P = 0.06$, $r^2 = 0.64$) and K ($P = 0.03$, $r^2 = 0.71$) and the higher the concentration of Ca ($P = 0.01$, $r^2 = 0.82$) in the forest floor and the lower the C/N ratio of the surface mineral soil ($P = 0.04$, $r^2 = 0.70$).

Litterfall Nutrient Concentrations and Total Nutrient Inputs in Litterfall

For vine maple leaf litterfall in the autumn time period, concentrations of N, P, Ca, Mg, K, Fe and Zn were greater and concentrations of Mn and Al were lower than for conifer litterfall (Table 1). In vine maple gap plots, conifer needle litterfall contributed significantly greater amounts of N, P, Ca, Fe, Mn, Zn and Al than did vine maple leaf litterfall (Table 1). Concentrations of measured elements in conifer needle litterfall were not significantly different between vine maple gap and conifer canopy plots (Table 1). The inputs of P, Ca, Mg, K and Fe from conifer needle litterfall were significantly lower in vine maple gap plots than in conifer canopy plots (Table 1). However, the total input of all measured elements from vine maple leaf and conifer needle litterfall on vine maple gap plots did not differ significantly from the input of these elements from conifer needle litterfall on conifer canopy plots (range in P values was 0.40 to 0.94).

Litter Decomposition

There was no significant effect of site type (vine maple gap or conifer canopy) on percent mass loss of vine maple leaf and conifer needle litter ($P = 0.71$ for site type effect, Fig. 2). However, both litter type and time significantly affected percent mass loss ($P < 0.001$ for both) and there were significant interactions between litter type and time ($P = 0.012$) and site type, litter type and time ($P = 0.062$). The mass loss for vine maple leaf litter was greater than for conifer needle litter on both site types and at all times except for at two years on vine maple gap plots where mass loss for both litter types was similar (Fig. 2.) The greatest percentage mass loss for both litter types occurred within the first 6 mo of decomposition (Fig. 2). After 1 yr of decomposition, there was no sizable increase in mass loss of either litter type, compared with the mass loss for each litter type after 1 yr of decomposition.

Percent mass loss of vine maple leaf litter and of conifer needle litter in vine maple gap plots at the end of 1 yr were significantly related to clone size, aspect and percent open sky: the larger the clone, the lower the mass loss ($P = 0.10$, $r^2 = 0.55$; $P = 0.09$, $r^2 = 0.56$ for vine maple and conifer litter, respectively); the more south-facing, the greater the mass loss ($P = 0.05$, $r^2 = 0.65$; $P = 0.01$, $r^2 = 0.88$); the greater the percent open sky, the lower the mass loss ($P = 0.01$, $r^2 = 0.86$; $P = 0.08$, $r^2 = 0.57$). At the end of 1 year in vine maple gap plots the higher the concentration of Mn in the forest floor, the lower the percent mass loss of vine maple litter ($P = 0.10$, $r^2 = 0.54$) and conifer litter ($P = 0.01$, r^2=0.86).

Forest Floor and Mineral Soil Properties

Forest floor depth was significantly lower and forest floor mass had a weak tendency to be lower in vine maple gaps than in conifer canopy plots (Table 2). The depth of the forest floor in vine maple gaps was strongly related to clone size ($P = 0.03$, $r^2 = 0.72$): the larger the clone, the thicker the forest floor.

Mean bulk density values were not significantly different between vine maple gap and conifer canopy plots (Table 2), although larger canopy gaps had lower bulk densities ($P = 0.06$, r^2=0.64). The pH of the forest floor was significantly

Table 1. Concentrations and contents of elements in litterfall from the autumn time period for a) vine maple leaf and b) conifer needle litterfall on vine maple gap plots and for c) conifer needle litterfall on conifer canopy plots (mean of six replicates)

	Vine maple gap plots				Conifer Canopy Plots		a and b[z]	b and c[y]
	a) Vine maple litter		b) Conifer litter		c) Conifer Litter		*F*-test	*F*-test
					Concentrations (g kg^{-1})			
N	11.35	(1.41)	10.47	(1.46)	9.26	(1.61)	<u>0.001</u>	0.26
P	0.54	(0.28)	0.27	(0.05)	0.29	(0.04)	<u>0.001</u>	0.23
Ca	15.19	(3.17)	9.35	(1.29)	9.35	(1.54)	<u>0.001</u>	0.99
Mg	1.50	(0.33)	0.82	(0.11)	0.89	(0.14)	<u>0.001</u>	0.32
K	6.38	(1.89)	2.06	(0.19)	2.56	(0.84)	<u>0.001</u>	0.19
Fe	0.20	(0.05)	0.10	(0.03)	0.09	(0.02)	<u>0.001</u>	0.52
Mn	0.56	(0.19)	0.89	(0.33)	0.68	(0.02)	<u>0.001</u>	0.11
Zn	0.09	(0.02)	0.04	(0.01)	0.03	(0.00)	<u>0.001</u>	0.42
Al	0.14	(0.05)	0.26	(0.08)	0.23	(0.09)	<u>0.001</u>	0.43
					Contents (kg ha^{-1})			
N	1.19	(0.66)	4.61	(2.34)	5.98	(2.28)	<u>0.024</u>	0.101
P	0.05	(0.02)	0.13	(0.09)	0.30	(0.10)	<u>0.085</u>	<u>0.019</u>
Ca	1.54	(0.86)	4.38	(2.84)	6.38	(3.15)	<u>0.093</u>	<u>0.028</u>
Mg	0.17	(0.11)	0.36	(0.17)	0.59	(0.27)	0.11	<u>0.035</u>
K	0.65	(0.35)	0.93	(0.50)	1.77	(1.15)	0.33	<u>0.068</u>
Fe	0.02	(0.01)	0.04	(0.02)	0.06	(0.04)	<u>0.038</u>	<u>0.084</u>
Mn	0.05	(0.04)	0.35	(0.13)	0.42	(0.10)	<u>0.004</u>	0.42
Zn	0.007	(0.00)	0.02	(0.01)	0.02	(0.01)	<u>0.052</u>	0.46
Al	0.011	(0.00)	0.11	(0.03)	0.14	(0.03)	<u>0.004</u>	0.28

[z], [y] *P* values for *F*-test to test for significant differences between concentrations and contents of elements in litterfall from the autumn time period: for vine maple leaf and conifer needle litterfall on vine maple gap plots; and for conifer needle litterfall on vine maple gap and conifer canopy plots.
Underlined values indicate significant differences at $P < 0.10$.
Values in parentheses are standard deviations.

higher in vine maple gap plots as compared with conifer canopy plots (Table 2). There was a weak tendency for higher pH values in the mineral soil at 5, 20 and 50 cm depths beneath vine maple gap plots than beneath conifer canopy plots (Table 2).

Organic matter concentrations in surface mineral soils (5 and 20 cm depths) were not significantly different between vine maple gap and conifer canopy plots (Table 2). However, there was a weak tendency for higher total N concentrations and lower C/N ratios on vine maple gap plots at the 5 cm depth (Table 2). The larger the vine maple clone, the greater the N concentration at the 20 cm depth ($P = 0.08$, $r^2 = 0.59$); and the lower the mass of forest floor, the higher the N concentration ($P = 0.09$, $r^2 = 0.57$). The larger the vine maple clone the lower the C/N ratio at the 5 cm depth ($P = 0.07$, $r^2 = 0.60$).

Concentrations of Ca, Mg, K, and Al in the forest floor were significantly higher in vine maple gap plots than in conifer canopy plots (Table 3). The larger the clone, the lower the concentrations of P ($P = 0.06$, $r^2 = 0.64$) and K ($P = 0.04$ $r^2 = 0.70$), and the higher the concentration of Ca ($P < 0.00$, $r^2 = 0.98$) in the forest floor. Total mass per unit area of all measured elements except Zn were not significantly different for vine maple gap and conifer canopy plots (Table 3).

DISCUSSION

Litterfall — Amounts and Nutrient Inputs

As expected, the amount of conifer litterfall in the autumn was lower in vine maple gaps than in the conifer canopy. Lower amounts of conifer litterfall in vine maple gaps in the autumn are presumably due to the lower conifer leaf biomass in canopy gaps. We expected to find higher total amounts of litterfall in vine maple gaps than in conifer canopy sites due to the additions of large quantities of vine maple litter. Fried et al. (1990) found that total annual litterfall was substantially greater on bigleaf maple (*Acer macrophyllum*) sites than on Douglas-fir sites in Oregon, probably due to the high leaf biomass of bigleaf maples. However, in our study, there was a weak tendency for lower total amounts of litterfall in the vine maple plots as compared with the conifer canopy plots in the autumn, and there were no significant differences in total litterfall on an annual basis. The amounts of vine maple litterfall were lower than expected and did not offset the reduced amount of conifer litterfall associated with the vine maple gaps in the autumn.

The lack of significant differences in annual litterfall inputs between vine maple gap and conifer canopy plots may indicate that vine maple gaps are too small to have a major effect on annual litterfall input. The low diameter to height ratios of the vine maple gaps indicate that they would likely receive considerable windblown litter from the surrounding conifer forest. Fried et al. (1990) measured considerable amounts of Douglas-fir litterfall beneath bigleaf maple, attributing the high litterfall to winter storms. The lack of significant differences in total litterfall beneath vine maple gaps and the surrounding forest is consistent with findings of Ogden (1996), where temperature and moisture regimes were found to not significantly differ; and with the findings of McGhee (1996) that light regimes were not significantly different between vine maple gaps and the surrounding conifer forest.

The mean total annual leaf litterfall for the conifer canopy plots was 1867 kg ha^{-1} which is comparable to values found

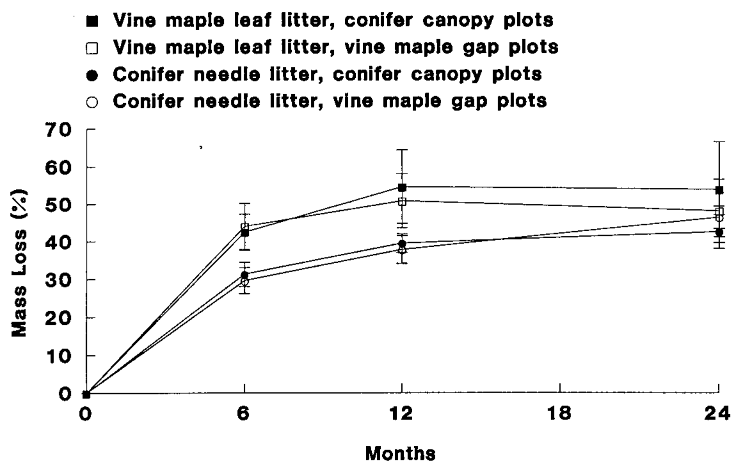

Fig. 2. Decomposition (percent mass loss) of vine maple and conifer litter (mix of western hemlock and Douglas-fir) in vine maple gap plots and conifer canopy plots at 6, 12 and 24 mo. Error bars represent one standard deviation from the mean.

in other studies of litterfall in similar forest types. In a summary of studies of litter production in western Washington Douglas-fir stands, Gessel and Turner (1976) report typical leaf litter values of 2100 kg ha^{-1} yr^{-1}. Dimock (1958) reports annual rates of litterfall of 1800 kg ha^{-1} in a 45-yr-old Douglas-fir stand in Washington State and Trofymow et al. (1991) report annual rates of litterfall of 1890 kg ha^{-1} in Douglas-fir stands located near Shawnigan Lake, British Columbia.

As expected, nutrient concentrations were found to be higher in vine maple leaf litter as compared with conifer needle litter. Concentrations of N, P, Ca, Mg, K, Fe, and Zn, in vine maple leaf litter were significantly higher than those of conifer needle litter, suggesting that over time, vine maple may improve the nutritional status of soils. These findings are consistent with those of Triska and Sedell (1976) who found higher concentrations of N in vine maple litter as compared with Douglas-fir litter and Russell (1973) who found vine maple foliage to be rich in N, P, Mg, Ca, Na, and K.

We had hypothesized that nutrient inputs in litterfall are higher in vine maple gaps compared with conifer canopy sites, but this was not found. Over the autumn time period, the total amounts of all measured nutrients input in litterfall did not differ significantly between vine maple gap and conifer canopy plots. Although the nutrient concentrations of vine maple litterfall were significantly greater than those of conifer litterfall, conifer litterfall contributed significantly greater amounts of nutrients to the forest floor in vine maple gaps over the autumn time periods than did vine maple litterfall. This is consistent with the finding of Russel (1973) that although vine maple makes an important relative contribution to the total understory biomass, the relative biomass contribution of vine maple may be low when all forest vegetation layers are considered.

Litter Decomposition

Consistent with findings from other studies on hardwood-conifer comparisons (Challinor 1968; Gessel and Turner 1974; Tappeiner and Alm 1975; Fried et al. 1990), we found that vine maple litter decomposes faster than conifer litter. It is likely that vine maple litter decomposes more rapidly than conifer litter due to a lower lignin content, higher nitrogen concentration and thin leaves (Haeussler et al. 1990). The rapid decomposition of vine maple litter — as postulated for bigleaf maple litter (Fried et al. 1990) — could benefit both maple and the surrounding conifers because nutrients rapidly become available to tree roots rather than being sequestered in the forest floor, as is the case under conifers.

There was no significant difference in the mass loss between vine maple leaf litter and conifer leaf litter at the end of 2 yr of decomposition on the vine maple gap plots. Edmonds (1980) found significant differences in mass loss after 1 yr, but not after 2 yr among different species. For the litter types in this study and in the study by Edmonds (1980), it is likely that only the very slowly decomposable material such as lignin remains after 2 yr of decomposition.

For both litter types, the greatest percentage of mass loss occurred within the first 5-mo period. After 2 yr of decomposition, there was no sizable increase in mass loss in either litter type compared with the mass loss reached after 1 yr of decomposition. Litter typically has an initial rapid phase of decomposition followed by a slower phase, due to the faster decomposing components breaking down first leaving behind the more slowly decomposing components such as lignin (Harmon et al. 1990). Harmon et al. (1990) found that vine maple leaf litter has a much larger amount of this “fast” component (29–40%) than Douglas-fir litter (7–13%).

No significant differences were found in mass loss of either litter type between vine maple gap plots and conifer canopy plots. Initially, the lack of significant differences was surprising because we had expected that environmental conditions, organism populations and nutrient availability would all be conducive to more rapid decomposition on vine maple gap sites. However, other work showed that amounts of precipitation, soil temperature, soil moisture (Ogden 1996) and amount of solar radiation reaching the forest floor (McGhee 1996) did not differ significantly between vine

Table 2. Soil properties for vine maple gap and conifer canopy plots (mean of six replicates)

	Vine maple gap		Conifer canopy		*F*-test
Bulk density, 5 cm (g cm^{-3})	0.56	(0.06)	0.59	(0.09)	0.53
Forest floor mass (g cm^{-2})	0.29	(0.14)	0.39	(0.03)	0.12
Forest floor depth (cm)	2.0	(0.5)	3.0	(1.1)	<u>0.098</u>
pH, forest floor	4.05	(0.4)	3.43	(0.3)	<u>0.023</u>
pH, 5 cm	4.23	(0.3)	4.02	(0.3)	0.12
pH, 20 cm	4.58	(0.2)	4.41	(0.2)	0.16
pH, 50 cm	4.56	(0.1)	4.33	(0.5)	0.17
pH, 100 cm	4.01	(0.2)	3.86	(0.4)	0.46
Organic matter concentration, 5 cm (g kg^{-1})	169	(28)	166	(32)	0.73
Organic matter concentration, 20 cm (g kg^{-1})	146	(21)	154	(45)	0.76
Total N concentration, 5 cm (g kg^{-1})	4.2	(1)	3.5	(0.8)	0.17
Total N concentration, 20 cm (g kg^{-1})	3.1	(0.3)	3.0	(1.0)	0.91
C/N ratio, 5 cm	24.2	(2.8)	28.3	(4.0)	0.14
C/N ratio, 20 cm	28.3	(3)	29.6	(3.9)	0.35

Underlined values indicate significant differences at $P < 0.10$
Values in parentheses are standard deviations.

maple gap and conifer canopy plots. Therefore, the lack of differences in decomposition rates between vine maple gap and conifer canopy plots may be partly explained by the lack of differences in environmental conditions on the sites. Similarities in environmental conditions between the two site types are likely due to the relatively low diameter to height ratios of the gaps. The microclimate of gaps with low ratios is moderated by the shade of surrounding trees (Smith 1986; Canham et al. 1990).

The slower rates of decomposition under larger clones may be partly due to cooler mid-day air temperatures in the summer and autumn and lower soil moisture contents throughout the year in larger gaps as compared with smaller gaps (Ogden 1996). A similar result was obtained by Zhang and Liang (1995) in a mixed montane forest in China where smaller developmental gaps (5 m diameter) had faster rates of decomposition than larger developmental gaps (30 m diameter or larger). Zhang and Liang (1995) observed that larger gaps received greater amounts of solar radiation at the forest floor than smaller gaps, and that larger gaps allow soil moisture to evaporate more quickly because of the reduced influence of the surrounding trees. The combination of higher and more stable moisture and temperature regimes in small gaps (and under the canopy) resulted in higher microbial activities and higher decomposition rates in small gaps.

Forest Floor and Mineral Soil Properties

Since vine maples are associated with rapid litter decomposition, and possibly greater levels of soil organism activity, the depth and mass of the forest floor on vine maple gap plots were expected to be lower than those on conifer canopy plots. Results showed that forest floors were significantly thinner and had a weak tendency for lower mass per unit area for the vine maple gap plots than for the conifer canopy plots. The apparent difference in depth was likely a reflection of faster decomposition of vine maple litter and lower inputs of conifer litter in the vine maple gap plots than in the conifer canopy plots.

Bulk density values were significantly related to gap size. The lower bulk densities in larger vine maple gaps compared with smaller vine maple gaps may be the result of vine maple creating a more favourable environment for earthworm activity (though this was not investigated in this study) resulting in greater mixing and aeration of the surface soil horizons. The lower bulk densities may also be partly the result of differences in rooting habit between vine maple and conifers.

The concentrations of nutrients in the forest floor of vine maple gap plots were expected to be higher than those of conifer canopy plots since we found higher concentrations of most nutrients in vine maple litter as compared with conifer litter. Total Ca, Mg and K were found to be significantly higher in the forest floor beneath vine maple. The mean total amounts of nutrients stored in the forest floor of vine maple gap plots and conifer canopy plots were not found to be significantly different, which was likely the result of the forest floor being significantly thinner in vine maple gap plots than in conifer canopy plots.

Table 3. Concentrations and contents of elements in the forest floor for vine maple gap and conifer canopy plots (mean of six replicates)

	Vine maple gap		Conifer canopy		*F*-test
	Concentrations (g kg^{-1})				
N	21.84	(2.60)	21.05	(2.05)	0.65
P	0.65	(0.07)	0.66	(0.15)	0.86
Ca	2.51	(1.12)	1.26	(0.50)	<u>0.095</u>
Mg	0.56	(0.13)	0.42	(0.11)	<u>0.005</u>
K	1.08	(0.20)	0.86	(0.13)	<u>0.077</u>
Fe	3.02	(1.86)	2.50	(0.93)	0.23
Mn	0.47	(0.29)	0.25	(0.18)	0.16
Zn	0.07	(0.01)	0.07	(0.01)	0.89
Al	3.12	(1.21)	2.59	(0.79)	<u>0.086</u>
	Contents (kg ha^{-1})				
N	656	(360)	802	(84)	0.43
P	19	(9)	25	(5)	0.31
Ca	71	(32)	46	(15)	0.25
Mg	15	(5)	16	(4)	0.77
K	31	(6)	33	(6)	0.77
Fe	65	(30)	92	(30)	0.18
Mn	11	(7)	9	(7)	0.45
Zn	2	(1)	3	(1)	<u>0.093</u>
Al	71	(19)	98	(31)	0.16

Underlined values indicate significant differences at $P < 0.10$
Values in parentheses are standard deviations.

In a similar study on bigleaf maples, Fried et al. (1990) found no consistent differences in the concentrations of P, K, Ca, or Mg in the upper mineral soils beneath bigleaf maples compared with those beneath Douglas-fir. They postulated that nutrients are cycled more rapidly in the bigleaf maple systems, and the rates of uptake of nutrients by bigleaf maple roots and the storage of nutrients in woody tissues could be sufficient to utilize the additional input of nutrients from litter. Fried et al. (1990) suggested that there may be more nutrients stored in the biomass of maples than conifers.

Since vine maple litter had higher concentrations of bases than conifer litter, pH levels were expected to be higher in vine maple gaps than in conifer canopy plots. The pH was found to be significantly higher in vine maple gap plots than in conifer canopy plots in the forest floor; and there was a weak tendency for higher pH values at 5, 20 and 50 cm depths. Similarly, pH in the upper 10 cm of mineral soil tended to be higher (not significantly) under bigleaf maple as compared with under Douglas-fir by Fried et al. (1990).

Due to the rapid rate of decomposition of vine maple litter, the relatively high N concentrations in vine maple litter, and possibly greater soil organism activity beneath vine maple, it was expected that organic matter and nitrogen concentrations would be higher and the C/N ratio would be lower beneath vine maple than beneath conifers. Surprisingly there were no significant differences in organic matter or nitrogen concentrations or in C/N ratios at either the 5 or 20 cm depths between vine maple gap and conifer canopy plots. However, there was a weak tendency for higher total N concentrations and lower C/N ratios in vine maple gaps at the 5 cm depth. In contrast to this study, Fried et al. (1990) found that total C and N concentrations were significantly greater under bigleaf maple, which is probably due to the large amount of litter produced by bigleaf maples. Fried et al. (1990) found no consistent difference in the C/N ratios in the surface mineral soil beneath bigleaf maple and Douglas-fir. In our study, larger clones had significantly lower C/N ratios in the upper 10 cm of mineral soil and therefore may have had higher N availability than smaller clones.

CONCLUSIONS

The results of this study suggest that vine maple growing within conifer forest may significantly affect some soil properties. This study is in agreement with the conclusions of Binkley (1995) that no species uniformly pushes all soil variables in favourable (or unfavourable) directions. However, the results suggest that vine maple may lead to improved soil fertility. Vine maple gaps had higher pH, and higher concentrations of Ca, Mg and K in the forest floor, and a weak tendency for lower C/N ratios and higher pH values and total N concentrations in the surface mineral soil. Vine maple litter was found to decompose significantly faster than conifer litter and to have higher concentrations of N, P, Ca, Mg, K, Fe and Zn which would contribute to the differences in forest floor and surface mineral soil properties.

Some measured properties did not significantly differ between vine maple gaps and the surrounding conifer forest. Surprisingly, total amounts of annual litterfall and rates of litter decomposition did not differ significantly between vine maple gaps and the surrounding conifer forest. The lack of differences may be due to the relatively small size of the gaps. Furthermore the relatively small contribution of vine maple litter compared with the total amount of litterfall, suggests that vine maple may require a greater length of time to significantly influence chemical soil properties. Some differences may not have been detected due to a relatively low power of the statistical tests (Toft and Shea 1983) and further research with a larger sample size would be recommended.

Over the course of several rotations, as suggested by Fried et al. (1990) for bigleaf maple, vine maple is likely to have beneficial influences on soil properties, offsetting its impact as a competitor and justifying its role on commercial sites. Concern for maintaining long-term soil productivity warrants a close examination of the influence of hardwood species on soil properties and the implication of removing hardwoods from commercial conifer forests.

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