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Changes in Ecosystem Nutrient Concentrations and Content in Coastal Forest Chronosequences

Introduction

Knowledge about quantities and changes in the distribution of nutrients (N, P, and S) occurring as a result of conversion of old-growth to second-growth forests is fundamental to understanding how forestry practices impact nutrient budgets and future site productivity.

The primary objective of this study was to quantify important nutrients contained within living, detrital, and soil components. This abstract reports findings from measurements of N, P, and S in Coastal Western Hemlock (CWH) forests at four chronosequence sites dominated by Douglas-fir (*Pseudotsuga menziesii*) on the east side (CWHxm subzone) of Vancouver Island, and at four chronosequence sites dominated by western hemlock (*Tsuga heterophylla*) on the west side (CWHvm subzone) of Vancouver Island (Trofymow et al. 1997). Each site contains stands of four ages: R - regeneration (3-9 years), I - immature (32-43 years), M - mature (66-99 years), and O - old growth (>200 years). Regeneration and immature stands were established following harvesting and slashburning while mature and old-growth stands were established through natural disturbances, predominantly fire.

Methods

At all eight sites, triangular plots were defined by establishing three subplot centres 30 m and 120° apart from a central benchmark. The subplots and transects connecting the subplot centres were used to measure living and detrital biomass (see Trofymow and Blackwell, this issue). For each of the species present, three trees in each plot, an entire upper canopy branch, and breast-height bole core were collected for chemical analysis. Living understory biomass and fine woody debris (<1cm in diameter) were destructively sampled on four 1.0-m^2 quadrats, one per subplot; samples were dried, weighed, and combined by plot for chemical analysis. Three forest floor samples were collected per subplot for bulk density analysis; these were dried, weighed and combined by subplot for chemical analysis. Samples of each size, species, and decay class of coarse woody debris on each transect were taken for density and chemistry measurements. Mineral soils were sampled in each subplot at three depths (0-10, 10-30, and 30-50 cm) for bulk density and chemistry. Total %N, and %S of organic samples (foliage, plant, wood, forest floor, and root/organic materials) and the <2 mm soil fraction were determined with LECO N (FP-228) and S (SC-132) combustion analyzers. Total P in organic samples was determined through wet oxidation in a microwave and measurement of P in the digest using a Technicon Autoanalyzer. Total P in mineral soils was determined by digestion in aqua regia and total P analysis by ICP spectrometry. For analysis of other soil P forms see Preston and Trofymow (this issue). Total nutrient content was determined by multiplying % concentration for each component sampled (N, P, and S) by its total mass. Nutrient budgets were calculated for each plot.

Results and Discussion

Total ecosystem N, P, and S contents increased with stand age, which was primarily a function of nutrient accumulations within the living and detrital pools (Table 1). For the same seral stage, nutrient contents of N, P, and S within living and detrital components were consistently higher in the CWHvm than in the CWHxm, and followed the order N>S>P when compared within the same subzone and seral stage. These increases were

TABLE 1. Nutrient quantities (kg/ha) of nitrogen, phosphorus, and sulphur for living, detrital, soil, and ecosystem totals summarized by subzone (CWHxm and CWHvm) and seral stage (regen., immature, mature, and old growth) for chronosequence plots.

	CWHxm subzone					CWHvm subzone				
	Mean Nutrient Content by Sere (kg/ha) (Standard Error)					Mean Nutrient Content by Sere (kg/ha) (Standard Error)				
	Regen.	Immature	Mature	Old Growth	Subzone Mean	Regen.	Immature	Mature	Old Growth	Subzone Mean
NITROGEN										
LIVING BIOMASS	81.0	596.5	817.1	683.2	544.5[a]	235.1	1001.4	821.2	1312.7	842.6[b]
	(19.1)	(47.5)	(64.1)	(51.5)	(166.7)	(132.8)	(211.8)	(56.0)	(371.1)	(266.3)
DETRITAL BIOMASS	293.5	244.3	225.7	380.5	286.0[a]	656.4	406.8	829.7	871.0	691.0[b]
	(54.7)	(42.8)	(40.7)	(68.1)	(53.5)	(260.5)	(29.3)	(192.6)	(211.5)	(179.5)
SOIL	929.9	1562.7	1412.6	812.3	1179.4[a]	3090.6	4827.8	5561.4	2979.4	4114.8[b]
	(304.7)	(428.7)	(498.5)	(183.9)	(270.9)	(687.0)	(628.8)	(557.7)	(736.7)	(831.9)
TOTAL	1304.4	2403.5	2455.4	1876.0	2009.9	3982.1	6236.0	7212.3	5163.1	5648.4
PHOSPHORUS										
LIVING BIOMASS	10.8	95.0	153.1	136.4	98.8[a]	14.3	127.6	139.0	190.1	117.7[a]
	(1.9)	(10.8)	(13.7)	(20.3)	(34.1)	(4.0)	(26.4)	(5.5)	(49.8)	(41.8)
DETRITAL BIOMASS	34.0	26.8	29.9	41.2	33.0[a]	68.5	31.3	70.4	79.1	62.4[b]
	(7.3)	(2.9)	(4.1)	(6.9)	(5.6)	(31.5)	(1.1)	(8.1)	(16.2)	(16.6)
SOIL	1797.9	1785.9	1741.3	1935.8	1815.2[a]	839.4	790.3	1430.0	1184.3	1061.0[b]
	(148.4)	(437.2)	(228.2)	(421.2)	(273.1)	(174.6)	(78.4)	(343.0)	(850.0)	(345.9)
TOTAL	1842.7	1907.7	1924.3	2113.4	1947.0	922.2	949.2	1639.4	1453.5	1241.1
SULPHUR										
LIVING BIOMASS	16.2	281.6	680.6	814.9	448.3[a]	37.6	452.3	771.3	1097.2	589.6[a]
	(4.7)	(31.9)	(100.7)	(84.2)	(189.2)	(14.7)	(8.3)	(31.0)	(309.2)	(241.6)
DETRITAL BIOMASS	111.5	69.9	143.6	131.2	114.1[a]	396.7	226.1	301.5	711.5	409.0[b]
	(18.8)	(7.0)	(37.6)	(26.1)	(26.4)	(139.4)	(34.1)	(45.9)	(153.8)	(125.8)
SOIL	165.2	179.9	143.5	131.8	155.1[a]	1128.5	498.2	981.5	509.4	779.4[b]
	(23.2)	(16.4)	(25.2)	(14.7)	(20.3)	(361.9)	(65.3)	(214.7)	(231.2)	(223.0)
TOTAL	292.9	531.4	967.7	1077.9	717.5	1562.8	1176.6	2054.3	2318.1	1778.0

Note: Quantities in this table are the mean for a seral stage and do not reflect the range of values across all sites within a subzone. Means followed by different letter are significantly different ($p<0.05$).

primarily a function of greater increases in mass with stand age in the CWHvm than in the CWHxm. For mineral soil, subzone effects were similar for N and S (quantities in CWHvm>CWHxm); however, P levels in the CWHxm were greater than CWHvm sites. Mineral soil nutrient quantities followed N>S>P in the CWHvm; however, within CWHxm the order was N>P>S.

Living biomass accounted for 10-33% of ecosystem N. Foliage and branches <2.5 cm accounted for 47-78% of the N for I, M, and O plots. Detrital N contents for CWHvm sites (407-871 kg/ha N) were much greater than for the same seral stage in CWHxm sites (225-380 kg/ha N), mainly due to higher detrital mass loadings in the CWHvm. Soil N content was much higher for CWHvm than for CWHxm sites. These subzone differences reflect higher soil N concentrations for CWHvm sites, which compensates for the lower soil mass in the shallower and rockier soils on the CWHvm sites.

Phosphorus contents in the living biomass were the lowest of three nutrients quantified, accounting for only 5-13% of the ecosystem total. Increases in total P content with stand age were primarily a function of increasing living biomass in the CWHxm and living and detrital mass in the CWHvm. Subzone differences for detrital P were less pronounced, with ranges of 31-70 kg/ha in the CWHvm and 27-41 kg/ha within the CWHxm. This subzone difference was considered to be a function of lower P concentrations in the CWHvm. Soil P content, a function of soil mass, was also much higher in CWHxm sites than in the CWHvm sites. These differences may be explained by higher leaching and eluviation rates associated with greater accumulations of detrital biomass in the wetter CWHvm climate.

Quantities of S within living biomass were considered important, representing 37-76% of the ecosystem total. Bolewood accounted for the majority (60-84%) of the living biomass total. As with N and P, seral effects on total ecosystem S were attributed to changes in living and detrital mass. Differences in soil S content between subzones, (CWHvm>CWHxm) were attributed to higher S concentrations. Higher concentrations on the west side of Vancouver Island were likely a result of precipitation inputs, which contain natural marine sources of sulphates and dimethylsulphoxides (Hurditch and Charley 1982).

Lower accumulations of N and S in CWHxm soil and detrital pools can also be attributed to an historically high fire frequency. Compared with CWHvm, CWHxm sites are warmer and drier and prone to fire, and stand-replacement events are thought to have occurred every 200-300 years; surface fires would have occurred even more frequently (Green et al. 1998). Within the CWHvm, stand-replacing fires appear to have been less frequent, occurring approximately every 600 years. Windthrow, landslides, and individual tree fall (gap dynamics) have been the dominant disturbance mechanism within this subzone (Green et al. 1998).

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