Detrital Carbon Fluxes and Microbial Activity in Successional Douglas-fir Forests

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Introduction

Understanding changes in detrital carbon fluxes as forests develop is critical to improving the accuracy and reliability of C budget models. During forest development, C fixed by trees accumulates not only in trees but also in detrital pools such as the forest floor and coarse woody debris, and in the soil. Carbon enters these pools mainly through processes of litter fall and tree mortality. Other than losses from stand disturbances such as harvesting or fire, C is lost from soil and detrital pools through respiration of roots and soil organisms, with the latter derived from decay of plant detritus. Rates of decomposition and soil respiration are influenced by several factors, the primary factors being soil temperature and moisture, though the numbers and kinds of soil organisms and amounts and types of litter are also important (Hendrickson et al. 1982).

Study objectives were to: (1) measure key detrital fluxes (litter fall, litter decomposition, and soil respiration) and microbial activity to see how they differ with stand age and (2) monitor soil temperature and moisture (see Benton this issue) to then (3) determine how variation in detrital C fluxes was related to soil abiotic condition. The initial findings reported here address the first objective. The study was conducted for four years on three east Vancouver Island sites (VWS, VWN, KOK described in Trofymow et al. 1997); each site contained Douglas-fir (*Pseudotsuga menziesii*) stands of four different ages (R - regeneration, 4-6 years; I - immature, 32-43 years; M - mature, 77-99 years; and O - old growth, 288-316 years), for a total of 12 plots.

Methods

Overstory litter fall was measured in the I, M, and O plots over four years using nine litter traps (Trofymow et al. 1991) per plot, sampled every three months. Litter was dried, sorted into needles, twigs, cones, and other materials, and each component was weighed. Cumulative litter decay was measured using litter bags (Trofymow and CIDET Working Group 1998) over four years in all 12 plots. There were three material types (Douglas-fir needles, western hemlock (*Tsuga heterophylla*) wood chips, hemlock wood blocks), two mesh sizes (0.3 or 3.0 mm), and two placements (forest floor surface or buried 5-10 cm below surface). Three combinations were tested: (1) surface fine mesh bags with the three materials; (2) surface fine or coarse mesh bags with chips or blocks; and (3) surface or buried blocks in fine or coarse mesh bags. Four sets of bags of each combination were placed in each of four subplots in each plot. All bags were installed in October 1992, and a set of bags was sampled from each subplot each year to determine mass remaining. Annual decay rates were measured in all 12 plots starting in October 1992, using aspen chopsticks placed at the forest floor surface or buried 2 cm below. Sticks were replaced each year for four years and remaining mass determined each year. Surface soil respiration was measured monthly for one year at each site (VWN - 1993/94, VWS - 1994/95, KOK - 1995/96) and once each season in all 12 plots in 1996/97. CO_2 evolution was measured over a one-day period using the inverted cylinder method containing 1.0N NaOH base traps (Anderson 1982) with three cylinders per plot. Microbial biomass and activity were measured seasonally for four years in samples of forest floor collected adjacent to the CO_2 traps in all 12 plots. Basal respiration (activity) and substrate-induced respiration (biomass) were measured in the laboratory using a multichannel infrared gas analyzer (Chang and Trofymow 1996). Forest floor %C was analyzed using a LECO CR-12 C analyzer.

Results and Discussion

Total annual rates of litter fall over all three years ranged from 2200-4500 kg ha^{-1} yr^{-1}, were highest

in 1996/97, and varied significantly (P=.0052) by sere. Seral stage rankings based on annual litter fall were O>M>= I (Figure 1). Rates of fall of needle, cone, and other components also differed by seral stage, with stages ranked O>M>= I.

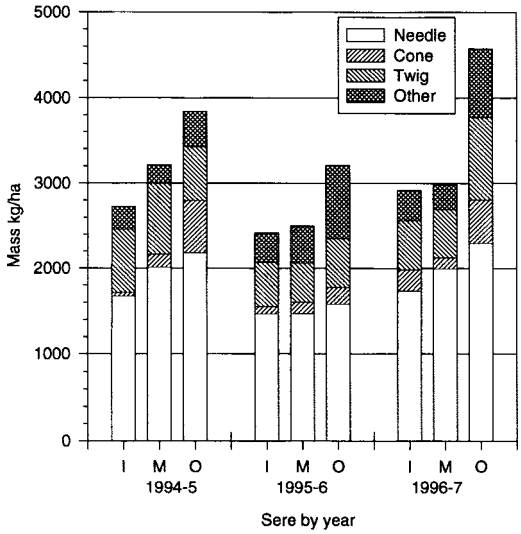

Figure 1. Annual litter fall by component in immature, mature, and old-growth Douglas-fir forests.

Decomposition of the three surface-placed material types differed, with types ranked by % mass remaining, blocks>chips>needles. Significant sere and site effects also occurred. Seral rankings based on % mass remaining were R>I=M=O for most years while site rankings were KOK>VWN>VWS. Site effects on decay followed mean site temperatures, with KOK being the coolest and VWS the warmest of the sites. Mesh size had no significant effect on decay of chips or blocks. Block placement had a significant impact on decay but depended on seral stage. Seral stage rankings based on % mass remaining were R>I=M=O for surface blocks and I=O=M>R for buried blocks (Figure 2). Similar sere by placement, and site effects, were seen in annual mass loss of the chopsticks. These effects were likely due to increased drying of surface litter in regeneration plots compared to forested plots. Buried materials likely experienced similar moisture conditions in all seral stages but the R plots were warmer and hence increased decay.

Average daily rates of soil respiration ranged from 0.5 to 3.7 mg CO_2-C m^2 day^{-1} and showed seasonal trends with peaks in early summer with

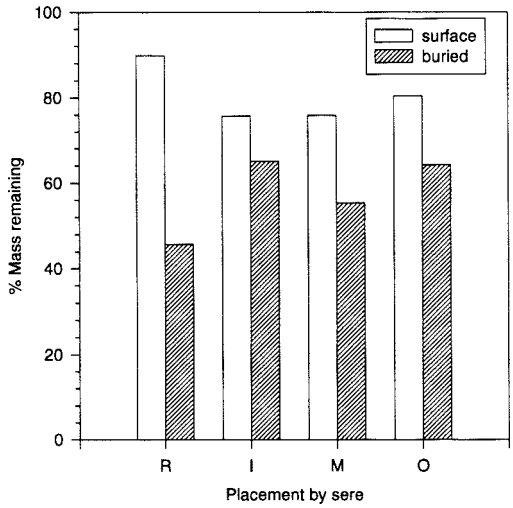

Figure 2. Decay of surface and buried blocks after three years, in regenerating, immature, mature, and old-growth Douglas-fir forests.

high temperatures and adequate moisture, declining respiration as soil dried, and a small mid-autumn peak as surface soils moistened with rain. The small autumnal peak was more apparent in the forested plots. In the year that all plots were measured (1996/97), significant sere and site effects were seen. Site rankings based on soil respiration were VWS>KOK>= VWN (1.9, 1.6, 1.5 mg CO_2-C m^2 day^{-1}, respectively) while seral stage rankings were O= I>= M>= R (1.9, 1.8, 1.6, 1.4 mg CO_2-C m^2 day^{-1}, respectively).

Forest floor microbial activity and biomass were weakly but significantly related to % C (R^2= 0.12, 0.25) and % moisture (R^2= 0.23, 0.10). Forest floor % C was lowest in R plots and the VWS site (Table 1), while % moisture was lowest in August for all years except 1995 when it was lowest in May. Even when expressed on a C basis (activity or biomass per g forest floor-C), both microbial activity and biomass were lowest in regeneration plots and similar amongst the three forested plots (I, M, O).

The lower microbial activity and biomass in the regeneration plots is likely related to the absence of fresh overstory litter, while the reduction in soil respiration is likely due to reduced litter and fine roots. With canopy closure and resumption of overstory litter fall in the forested plots, microbial community activity and biomass recover. Surface soil temperature and moisture

TABLE 1. Sere and site effects on average forest floor (LFH) moisture, %C, basal respiration, and microbial biomass. Means differ if following letter differs.

Effect	H_2O/Dry g/g	LFH %C	Basal R. ugC/hr/g	Biom. mgC/g
Sere				
REG	1.4 b	36 c	12 b	2.4 b
IMM	1.7 a	41 ba	22 a	4.8 a
MAT	1.6 ba	38 bc	21 a	4.4 a
OLD	1.7 a	42 a	24 a	5.0 a
Site				
VWS	1.5 b	35 b	15 b	2.6 b
VWN	1.9 a	43 a	22 a	5.1 a
KOK	1.4 b	41 a	22 a	4.7 a

conditions likely affected decomposition and microbial activity, with the most extreme differences occurring between the regeneration and forested plots and between higher and lower elevation sites.

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