Effects of Converting Coastal Old-growth Forests to Managed Forests: Changes in Site Carbon and Nutrient Contents During Post-disturbance Succession

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Over the past decade, two important questions have been raised concerning the harvest and conversion of old-growth temperate forests to second-growth, managed forests: 1) Does conversion lead to changes in the site carbon balance, resulting in net releases of carbon to the atmosphere (Harmon *et al.* 1990; Kurz *et al.* 1992)? 2) Does conversion lead to a loss of site nutrient capital and thus threaten future productivity (Kimmins 1985; Kimmins *et al.* 1990)?

While good information on changes during secondary succession in timber biomass and to some extent nutrient contents can be obtained from yield tables, much fewer data are available on the amounts of carbon and nutrients in coarse woody debris (Trofymow and Beese 1990) and soil organic matter; on how the amounts change during post-harvest succession; and on whether in mature second-growth forests the amounts recover to those in climax forests (Kimmins *et al.* 1985). These carbon and nutrient pools are substantial: in older forests, coarse woody debris can represent up to 45% of the aboveground carbon and 21% of the aboveground nitrogen and phosphorus (Harmon *et al.* 1986).

In 1991, Forestry Canada, Pacific and Yukon Region, initiated a program of research to study the changes occurring as a result of conversion of coastal old-growth to second-growth forests (Pollard and Trofymow, in these proceedings). This ENFOR study complements many of the other studies in that program by providing a broader measure of several relatively static ecosystem variables. Other studies in the program focus on more dynamic variables or measures of biological diversity. To expand and regionalize the field study results, additional ecosystem site and soil classifications are being done with funding from FRDA and the B.C. Ministry of Forests. Results from the field study are also to be used to calibrate a carbon emissions model being developed with FRDA and B.C. Ministry of Forests funding (Barclay, in these proceedings). Samples material from the survey are also to be made available to an ENFOR-funded study by C. Preston (see Preston, in these proceedings), for characterization of organic matter.

This report summarizes information on plot establishment and layout and methods used in the carbon and nutrient survey. Data analysis and results are scheduled for completion by March 1994.

Objectives

The overall study objective is to establish how the amounts and distribution of carbon and nutrients on a site change during post-harvest succession, and how closely they recover to pre-harvest levels. This will be done by studying chronosequences in two coastal forest types in the CWHxm and CWHvm. The study has three phases. In the first year, potential chronosequences were located, final selections made and plots established. In the second year, the field sampling phase was further divided into three parts: in the first, measurements were made to determine the mass of trees, understory, coarse woody debris, forest floor materials, and soils in each plot; in the second, representative samples of the different material types from each plot were taken for determination of carbon and nutrient concentrations; and in the third, ecosystem classification descriptions were completed for each plot. In the final phase, a data base and summary of the distribution of nutrients among the various components is to be prepared and data analyzed for differences in site carbon and nutrient contents.

Methods

Plot establishment

In the initial phase of the study, 31 potential locations were identified and examined (Trofymow 1991) before the final selection of the 10 chronosequences on southern Vancouver Island was made (Pollard and Trofymow, in these proceedings). A plot location and establishment report for all 10 locations used in the survey (Blackwell 1992) includes written and sketch maps describing the road directions and distances to plots at each location, forest cover maps identifying individual plots and basic site description data for each plot.

At all 10 chronosequences, triangular plots were established for the survey. From each benchmark, three 30 m radial lines were run to define three subplot centres 120° apart. These subplot and plot centres were marked with 1.5-m flagged and painted cedar stakes and with 15-cm spikes inserted into the soil. At most locations the orientations of the subplots were random, although at the three intensive locations subplots were arranged 0°, 120°, and 240° from the centre benchmark. The subplot centres define the corners of an equilateral triangle, 51 m on the side, used for coarse woody debris and forest floor measurements, standing biomass measurements and understory vegetation, fine woody debris, forest floor and soil measurements and sampling (Figure 1). Because of the detailed sampling on the intensive plots, 60 x 60 m plots were established, superimposed upon the triangular plots and sharing a common centre benchmark (Blackwell and Trofymow, Figure 1, in these proceedings).

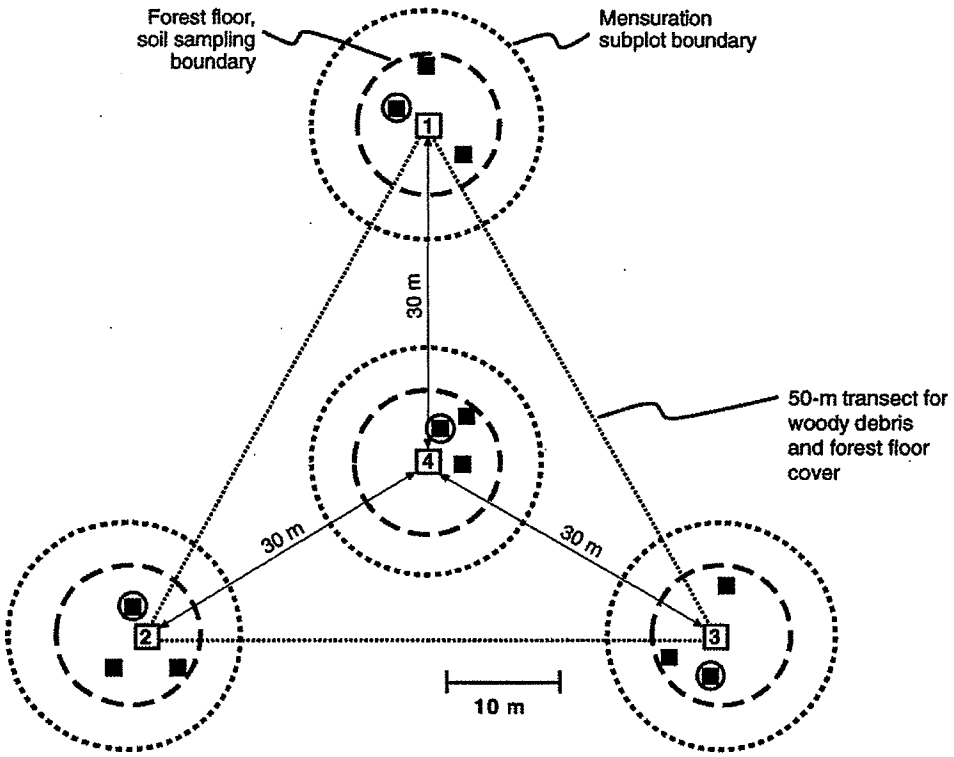

FIGURE 1. Forestry Canada coastal forest chronosequences. Carbon and nutrients measurements and sampling.

Plot measurements and sampling

Field work occurred between May and October 1992. Initially all 10 chronosequences were to have been surveyed, but following a review of time requirements and funding in May 1992, work was reduced to 8 chronosequences, four east island locations (Greater Victoria Watershed South, Victoria Greater Watershed North, Koksilah, Nanaimo River) and four west island locations (Renfrew, Red/Granite Creek, Nitinat, Klanawa). To facilitate sample identification and sample processing, all plots were given unique plot numbers. Table 1 shows the correspondence in plot numbering between the initial plot establishment report (Blackwell 1992) and the survey.

Mensurational measurements of overstory trees (DBH, height to live crown, and total height) by species and class were made according to methods described by Luttmerding *et al.* (1990, Chapter 5). Stumps and standing dead trees >7.0 cm diameter were also measured. Three of the four previously established subplots were measured. Tree inventory plots were circular with a 5 or 10 m radius depending upon tree density (Blackwell and Trofymow, in these proceedings). In some regeneration plots, trees <3 m height were a significant component of the biomass and thus total height and caliper measurements were also made. Tree biomass, carbon, and nutrient loadings will be calculated using appropriate biomass regression equations and nutrient concentration data from other studies on coastal tree species.

TABLE 1. Plot coding table for the Forestry Canada coastal forest chronosequences plots described in the plot establishment report (Blackwell 1992). Specific chronosequences can be referred to by the full name, a two- or three-letter designation (bolded letters), or number (Chr. No.). Plot numbers used in the establishment report (Plot Est. No.) are shown along with a unique plot number (Plot No.). Unique plot numbers are not consecutive to allow for the addition of other plots at a chronosequence. Plots sampled in 1992 are underlined.

Chronosequence name	Chr. No.	Plot Est. No.	Plot No.
Victoria Watershed South	1	1	1
		2	2
		2a	3
		3	4
		3a	5
		4	6
		5	7
Victoria Watershed North	2	1	11
		2	12
		3	13
		3a	14
		4	15
Koksilah	3	1	21
		2	22
		3	23
		4	24
		5	25
Nanaimo River	4	1	31
		2	32
		3	33
		4	34
		–	35
Loon Lake	5	1	41
		2	42
		3	43
		4	44
Renfrew	6	1	51
		2	52
		3	53
		4	54
Red/Granite Creek	7	1	61
		2	62
		3	63
		5	64
Nitinat	8	1	71
		2	72
		3	73
		4	74
Klanawa	9	1	81
		2	82
		3	83
		4	84
		5	85
Mt. Ozzard	10	1	91
		2	92
		2a	93
		3	94
		4	95

Living understory biomass and fine woody debris (FWD), <1 cm in diameter, were determined by destructive sampling of four 1.0 m^2 plots, one at each subplot. Vegetation was separated into three categories: mosses and lichens, grasses and herbs, and shrubs. Individually labelled bags were returned to the Pacific Forestry Centre for drying at 70°C and weighing. Large volume samples were chipped and subsampled before being ground through a 2 mm mesh Wiley mill. Chemical analyses include total carbon, nitrogen, phosphorus and sulfur. Understory and FWD mass will be calculated using the overall subplot average and carbon and nutrient loading calculated from concentration data.

Forest floor load was estimated by removing and bagging all forest floor down to mineral soil in 12 samples, 20 x 20 cm in area, three samples from within 5 m of each of the four subplot centres. Decayed wood encountered during excavation was collected and bagged separately. Samples were screened through a 4-mm sieve and live roots >4 mm were separated and samples dried at 50°C. Following weighing, the three samples per subplot were combined and 1-L subsamples were taken and ground through a 2-mm mesh Wiley mill. Chemical analyses include total C, N, P, S, 1.0 M $CaCl_2$ pH, CEC, and exchangeable cations. Forest floor mass will be calculated by applying the overall subplot average to the percentage area occupied by forest floor, calculated from the forest floor transect measurements. Carbon and nutrient loadings will be calculated using average forest floor mass and concentration data.

Samples of mineral soil were collected at each subplot from 0-10 cm and 10-30 cm for determinations of bulk density and chemical analysis. Bulk density, determined by the volume of sand/silica chips needed to fill a plastic lined hole, and coarse fragment determination (rocks >2.5 cm) were made in the field for all soil pits for the layers 0–10 cm and 10–30 cm. Samples at 30-50 cm were taken for chemical analysis from all four subplots and for bulk density at one subplot. Lower soil depths could not be sampled in all plots because of the presence of bedrock. Samples were sieved through a 4-mm sieve to separate most of the gravels, then through a 2 mm sieve, and the fractions dried, and weighed. Medium roots and organic matter were separated from the >2mm fraction by water flotation, dried, weighed, and ground through a 2 mm mesh Wiley Mill for chemical analysis. The <2-mm fraction was analyzed for colour, texture, total C, N, P, S, 1.0 M $CaCl_2$ pH, dithionate extractable Fe and Al, CEC, and exchangeable cations. Mineral soil carbon and nutrient loadings will be calculated using bulk density and concentration data for the 0–10, 10–30, and 30–50 cm depths.

Forest floor depth and substrate type were measured at 75 points at 2-m intervals along each of three 50-m transects located on the sides of the triangle joining the three subplot centres. Substrate types included decayed wood, undisturbed forest floor over decayed wood, coarse woody debris, exposed bedrock, exposed mineral soil, surface water, and organic matter other than forest floor. Forest floor depths and percentage cover data are used in calculation of forest floor load.

Amounts of coarse woody debris, >1 cm diameter, were determined by the line intercept method using three 50-m transects connecting the three subplot centres and following methods as described by Trowbridge *et al.* (1989) and modified by Blackwell *et al.* (1992). Where possible, materials >7.0 cm were identified as to species and decay class (I, II, III, IV, V) (Sollins 1982) and two 3- to 5-cm discs of the 7.1–12.0 cm and >12.0 cm of each class of wood identified were collected for relative density determinations and chemical analysis. Highly decayed material was excavated and volumes estimated in the field. Three 15-cm length samples of each of the three smaller size classes, 1.1–3.0, 3.1–5.0, 5.1–7.0 cm (nine samples) were randomly collected for relative density measurements and chemical analysis. Sample volumes were determined in the laboratory by measuring their specific gravity relative to water. Samples were dried at 70°C and weighed, and then a subsample was sawn, chipped, ground through a 2-mm mesh in a Wiley mill, and analyzed for total C, N, P, and S.

Ecosystem site, soil description, and classification information was collected for each plot following the procedures in Luttmerding *et al.* (1990, Chapter 2). These included photographs, measurements, and descriptions of slope, aspect, soils, humus form, geology, biogeoclimatic zone variant, and indicator and overstory species cover. A single soil pit, dug to parent material in each plot, was used to describe soil horizons and depths. Increment cores of six dominant or co-dominant trees were taken in each plot to determine stand age.

Results

Two reports are to be completed by February 1993, compiling field data sheets for the plot measurements and sampling and the site and soil descriptions. Chemical analyses are to be completed by April 1993. Data base preparation and summaries are to be complete by August 1993.

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