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Quantitative Characterization of Field-estimated Soil Nutrient Regimes in the Subalpine Coastal Forest

Introduction

Site classification in the biogeoclimatic ecosystem classification system is based on three differentiating properties: climatic regimes (expressed by biogeoclimatic subzones or variants), soil moisture regimes (SMRs), and soil nutrient regimes (SNRs). A SNR represents a segment of a regional soil nutrient gradient, *i.e.*, soils which provide similar levels of plant-available nutrients over a long period. SNRs are identified in the field using a number of easily observable soil morphological properties and indicator plant species. However, we need to know to what extent soil nutrient properties support these indirect field-estimates. There have been several studies that quantitatively characterize regional soil nutrient gradients in different climatic regions, but no study has yet been done in the subalpine coastal forest (Mountain Hemlock zone). Influenced by a maritime subalpine boreal climate, high-elevation coastal soils differ from low-elevation soils by having a thicker forest floor and a higher organic matter content. In the study summarized here, relationships between soil chemical properties and field-estimated SNRs are examined and soil chemical properties and field-identified SNRs are related to the site index of Pacific silver fir (*Abies amabilis* (Dougl. ex Loud.) Forbes) - one of the major timber crop species in the Coastal Western Hemlock and Mountain Hemlock zones.

Study Stands and Procedure

Study stands were selected across the entire native range of Pacific silver fir in southwestern British Columbia. The study area included Vancouver Island and the adjacent mainland south of the line extending from Port McNeill to Lillooet. The study stands had regenerated naturally after a major disturbance (wind, fire or clearcutting) and were deliberately selected across the widest range of climate, soil moisture, and soil nutrient conditions. Elevation was measured by a Thommen pocket altimeter. The SMR and SNR of each stand were identified using easily observable soil morphological properties and indicator plants. Site index (m @ 50 yr bh) for each plot was obtained from stem analysis (also see *Scientia Silvica* Number 19).

A total of 79 stands in the montane and subalpine portion of the coastal forest were selected for the study. A 0.04 ha plot was established in each stand and a composite sample was taken of the entire forest floor and the first 30 cm of the mineral soil in 12 randomly selected points. The composite samples were air-dried, prepared for laboratory analysis, and analyzed for the following nutrient properties: pH, total C (tC), total N (tN), mineralizable-N (min-N), and extractable Ca (eCa), Mg (eMg), K (eK), P (eP), and S (eSO_4-S). All properties were expressed as concentration on a dry mass basis. To describe the quality of organic matter and N-availability, C:N ratio was calculated.

Samples were stratified only according to three field-identified SNRs (poor, medium, and rich), since very poor and very rich sites were infrequent and did not support suitable stands. To evaluate the potential of every single property to discriminate between field-estimated SNRs, analysis of variance and multiple comparison of means (using Bonferroni's adjustment) for each variable were carried out. Prior to analysis, several variables had to be transformed to meet the requirements of homogeneity of variance and normality. To examine the ability of forest floor and mineral soil nutrient properties to discriminate between field-identified SNRs, we used stepwise, jack-knifed discriminant function analysis. This procedure gave information on how well SNR group membership could be predicted by soil nutrient measures.

Regression analysis was applied to examine the relationship between soil nutrient properties and site index of Pacific silver fir. Since climate has a large influence on site index, especially on montane sites, elevation was always entered as a covariate. To minimize the influence of SMR, we only used fresh and moist sites in the analysis (n = 42).

Results

In general, the selected nutrient properties showed the trends of increase or decrease along the soil nutrient gradient that were reported in several previous SNR studies (Table 1, Figure 1). In order from poor to rich SNRs, the forest floor pH, tN, min-N, and the sum of eCa, eMg, and eK (SEB) increased, and tC and C:N decreased, with pH, tC, and SEB separating rich sites from poor and medium sites, and tN, C:N, and min-N separating poor sites from rich sites. In the same order, the mineral soil pH, tC, tN, min-N, and SEB increased and C:N decreased, with min-N and SEB separating rich sites from poor and medium sites, and tN and C:N separating rich sites from poor sites. The mean values for forest floor eP and eSO_4-S did not show any differences.

Table 1. Means and standard errors of means for the measured forest floor and 0 - 30 cm mineral soil nutrient properties according to field-identified soil nutrient regimes. Values in the same row with same superscript are not significantly different ($\alpha = 0.05$); properties without superscripts do not show significant differences between soil nutrient regimes.

Soil nutrient regime	Poor	Medium	Rich
Number of samples	23	35	21
Forest floor			
pH	3.9±0.1^{a}	4.0±0.1^{a}	4.3±0.1^{b}
Total C (g kg^{-1})	446±4.3^{b}	439±5.1^{b}	412±9.5^{a}
Total N (g kg^{-1})	7.7±0.4^{a}	9.3±0.4^{ab}	10.1±0.6^{b}
C:N ratio	64.7±5.8^{b}	51.6±3.2^{ba}	44.7±3.5^{a}
Mineralizable-N (mg kg^{-1})*	124±6^{a}	158±13^{ab}	172±17^{b}
Extractable SO_4-S(mg kg^{-1})	59±4	57±3	55±4
Extractable P (mg kg^{-1})	90±8	84±7	87±10
Sum of extractable Ca, Mg, and K (g kg^{-1}) (SEB)*	3.6±0.3^{a}	3.9±0.3^{a}	5.4±0.6^{b}
Mineral soil			
pH	4.6±0.1^{ba}	4.5±0.1^{a}	4.8±0.1^{b}
Total C (g kg^{-1})	45.7±5.6	55.3±5.2	63.9±7.4
Total N (g kg^{-1})*	1.7±0.3^{a}	2.8±0.5^{ab}	4.5±1.1^{b}
C:N ratio	34.2±3.5^{b}	28.4±1.9^{ba}	22.4±2.3^{a}
Mineralizable-N (mg kg^{-1})*	9.1±1.8^{a}	15.3±2.2^{a}	33.3±4.9^{b}
Extractable SO_4-S (mg kg^{-1})	8.0±0.7^{a}	10.3±0.6^{b}	8.8±0.5^{ab}
Extractable P (mg kg^{-1})*	17±4	10±2	15±4
Sum of extractable Ca, Mg, and K (g kg^{-1}) (SEB)*	0.14±0.04^{a}	0.16±0.03^{a}	0.59±0.15^{b}

*Variables have been transformed using natural logarithm or square root for the analysis.

Discriminant function analysis using forest floor, mineral soil, and both forest floor and mineral soil properties showed (i) a weak but significant relationship between forest floor nutrient properties and SNRs, and (ii) a moderately strong relationship between mineral soil nutrient properties and SNRs. Of the forest floor properties, pH, eCa, C:N, and tN loaded highly on the first axis; of the mineral soil properties, min-N, eCa, and eMg loaded highly on the first axis, and eSO_4-S loaded highly negatively on the second axis. The discriminant function analysis that used only forest floor properties correctly allocated 48% of the samples to the field-estimated SNRs; the analysis based only on mineral soil properties correctly allocated 62% of the samples to the field-estimated SNRs; and the analysis based on both forest floor and mineral soil properties correctly allocated 63% of the samples to the field-estimated SNRs. However, after reclassification of incorrectly allocated samples according to the discriminant functions, 90% of samples were allocated correctly to field-estimated SNRs using the same set of variables (Figure 2).

After adjusting for elevation, site index of Pacific silver fir was found to be significantly related to forest floor and mineral soil C:N ratios and tN, and to the forest floor min-N, with C:N of the forest floor and mineral soil showing the strongest relationship (Table 2). Site index was not significantly related to the mineral soil min-N. Field-estimated SNRs explained a similar proportion of variation of site index as the direct soil nutrient measures (Table 2). When adjusted to the mean elevation of 1103 m, site index of Pacific silver fir on fresh and moist sites increased from 12.3 m on poor sites to 18.2 m on rich sites (Table 3).

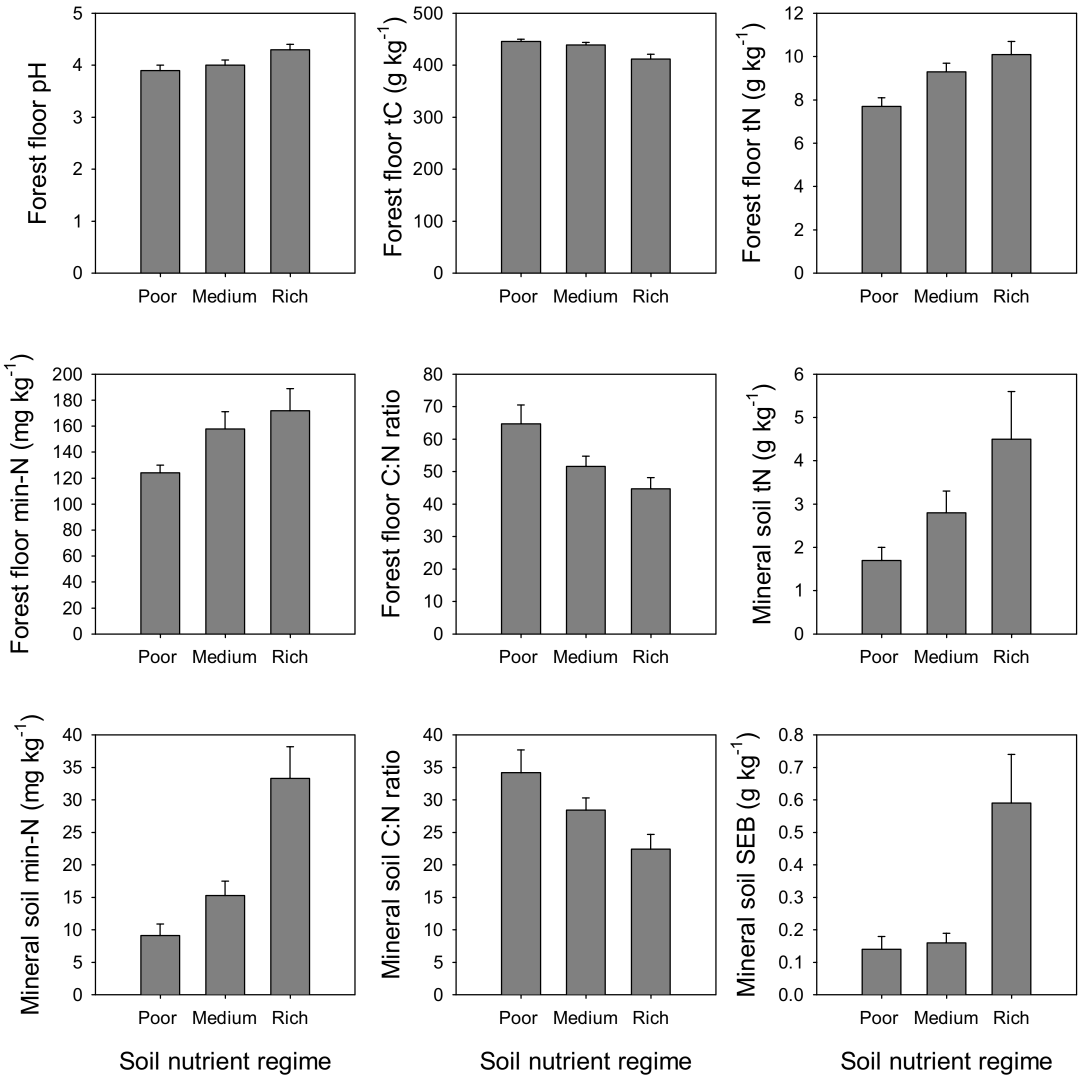

Figure 1. Direct measures of selected forest floor and mineral soil nutrient properties stratified according to field estimated soil nutrient regimes. Error bars indicate the standard errors of the mean.

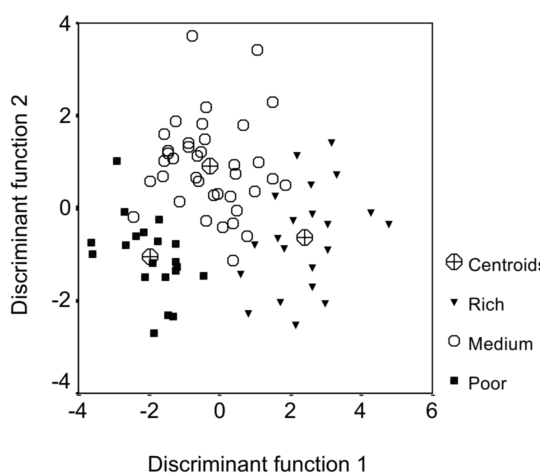

Figure 2. Ordination of samples and centroids for poor, medium, and rich soil nutrient regimes according to the first two discriminant functions (based on both forest floor and mineral soil properties) following reclassification of incorrectly assigned samples. Ninety percent of samples were correctly allocated to the soil nutrient regimes.

Table 2. Adjusted coefficients of determination (adj R^2) and standard error of estimates (SEE) for regression models of Pacific silver fir site index on elevation, soil nutrient properties, and SNRs (all represented by dummy variables). All models are significant at $p < 0.001$ (n = 42), all coefficients are significant (α=0.05).

Independent variables	Adj R^2	SEE
Elevation	0.58	4.5
Elevation, forest floor mineralizable-N	0.60	4.3
Elevation, forest floor total N	0.65	4.1
Elevation, forest floor C:N ratio	0.65	4.0
Elevation, mineral soil total N	0.62	4.2
Elevation, mineral soil C:N ratio	0.66	4.1
Elevation, SNR	0.63	4.2

Table 3. Marginal means of site index adjusted to the mean elevation of 1103 m of stands on fresh and moist sites stratified according to SNRs. SE is standard error of the mean and n is the number of samples.

SNR	Mean	SE	n
Poor	12.3	1.7	6
Medium	16.2	0.9	24
Rich	18.2	1.2	12

Discussion

The results of discriminant function analysis suggest it may be appropriate to revise the key for estimating SNRs in the field on montane and subalpine coastal sites, emphasizing the morphological properties of the mineral soil (such as acidity, the degree of leaching, and mineralogy). However, the relationships of Pacific silver fir site index to soil nutrient properties suggest that the properties which explain most of the variation in soil nutrients along the regional soil nutrient gradient (or between field-estimated SNRs) do not significantly affect site index. Of the soil properties, the quality of forest floor, mineral soil organic matter (measured as C:N ratio), and total N appear to influence Pacific silver fir height growth most strongly. These relationships are likely a reflection of the distribution of Pacific silver fir fine roots in the forest floor. Field-estimated soil nutrient regimes explain a similar portion of variation in site index as direct soil nutrient measures. Similar findings were reported for the continental subalpine forest. However, the portion of the variation in site index that can be explained by differential availability of soil nutrients is generally low on montane and subalpine sites compared to the influence exerted by climatic changes along an elevation gradient. Thus, despite the relatively weak relationship between direct soil nutrient properties and field-estimated soil nutrient regimes found in high-elevation forests of British Columbia, using existing field keys for estimating quality of forest sites in relation to tree growth seems justified.

Reference

Splechtna, B. and K. Klinka. 2000. Quantitative characterization of nutrient regimes of high-elevation forest soils in the southern coastal region of British Columbia. Accepted for publication in Geoderma 00/11/10.

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Editor: Karel Klinka (klinka@interchange.ubc.ca)
Research: Bernhard Splechtna (bsplechtna@utanet.at)
Production and design: Christine Chourmouzis (chourmou@interchange.ubc.ca)
Financial support: Forest Renewal British Columbia
For more information contact: Bernhard Splechtna (bsplechtna@utanet.at)

Copies available from:
www.forestry.ubc.ca/klinka or
K. Klinka, Forest Sciences Department,UBC,
3036-2424 Main Mall,Vancouver, BC, V6T 1Z4