QUANTITATIVE CLASSIFICATION OF SOIL NUTRIENT REGIMES OF SOME MESOTHERMAL DOUGLAS-FIR ECOSYSTEMS

by

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ABSTRACT

Previous attempts to classify nutrient regimes of forest soil have been qualitative evaluations utilizing vegetation and/or physiographic site characteristics, morphological soil properties, and parent material. The major objective of this study was to describe and classify the soil nutrient regimes (SNR) of some *Pseudotsuga menziesii* ecosystems on southern Vancouver Island, British Columbia.

The order of increasing variability for forest floor properties was pH(H_2O) <TC <TN <TS <TP <exMg <exCa <exK <exMn <minN. The order of increasing variability for mineral soil properties was pH(H_2O)=pH($CaCl_2$) <TN <TC <exP = exMg <SO_4 <minN = exK <exCa <exMn. Consistent trends in soil property variability along gradients of soil moisture or nutrient availability or between parent material lithologies were not apparent.

Multivariate analysis of understory vegetation and indicator plant analysis suggested a major trend in variation corresponding to a complex environmental gradient related to increased availability of soil moisture and nutrients. The arrangement of study plots along the gradient showed groupings which corresponded to both the calculated soil water deficit and inferred soil nutrient regime.

One multivariate axis accounted for most of the variation of soil properties between study plots. The mineral soil and forest floor plus mineral soil quantities of minN, TN, exCa and exMg significantly increased along the nutrient gradient. Ordinations of mineral soil and forest floor plus mineral soil properties arranged most plots according to the moisture-nutrient gradient.

Discriminant analysis of the soil properties selected linear combinations of properties which separated sites, parent material lithologies, soil moisture regime classes and SNR classes. Cluster analysis confirmed that minN and exMg of the forest floor plus mineral soil best separated SNR classes.

Multivariate summaries of variation in understory vegetation and foliar nutrients were highly correlated to the soil properties which best separated SNR classes. The increasing quantities of these nutrients corresponded to increases in site index for the study sites.

It was concluded that significant differences in N, Ca, and Mg availability existed between SNR classes for the study sites. These differences in nutrient availability corresponded to changes in understory vegetation, foliar nutrient status and site index for the study sites. Using forest floor plus mineral soil quantities of minN and exMg, a multivariate classification of the four SNR classes recognized in this study was proposed.

Table of Contents

List of Tables

List of Figures

List of Appendices

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1. INTRODUCTION

Within a climatic region, the supply of available soil water and nutrients strongly influences the nature and distribution of ecosystems and ecosystem productivity (Ralston, 1964; Carmean, 1975; Pritchett, 1979; Malcolm, 1981). Trophotope and hygrotope are concepts used in biogeoclimatic ecosystem classification to characterize available nutrients and moisture of the soil. Trophotope, or soil nutrient regime (SNR), is defined as the amount and balance of essential nutrients which are available to vascular plants through root uptake over an extended period of time. This period of time is in the order of several years (Courtin et al., 1985). Similarly hygrotope, or soil moisture regime (SMR), is defined as the amount of water available to vascular plants through root uptake over an extended period of time. In the biogeoclimatic system, five classes are used to characterize SNR and eight classes are used to characterize the SMR of an ecosystem.

The SNR and SMR of a particular ecosystem have been inferred subjectively from vegetation and morphological site features. The lack of an absolute scale and well defined classes has been often criticized (Kimmins, 1986). The need for a climatically independent classification with defined classes has been recognized (Nuszdorfer and Klinka, 1982) and studies to improve both classifications are continuing. An approach to SMR classification using variations in available water as it changes with the seasons in relation to climate and plant growth was tested by Giles (1983), and Giles et al. (1985). Using this approach a tentative hygrotope classification was proposed by Klinka et al. (1984b).

The development of SNR classification poses a complex problem due to the large number of nutrient forms, the many factors which influence nutrient availability, and the interactions between those factors. The study of relationships between soil nutrients, vegetation, foliar nutrients of dominant species, and productivity are important adjuncts to this purpose (Klinka et al., 1984a).

The major aim of this study was to describe and classify the SNR's of some Douglas-fir (Pseudotsuga menziesii var. menziesii [Mirb.] Franco) ecosystems. Specific objectives of this study were: 1) to determine if significant differences exist in soil properties reflecting nutrient status between field-inferred SNR classes as presently assessed by the biogeoclimatic ecosystem classification system, 2) to determine which of the measured soil properties could be chosen as differentiating characteristics, 3) to evaluate relationships between floristic composition of understory vegetation and soil properties, 4) to evaluate relationships between soil properties and foliar nutrient content of Douglas-fir, and 5) to determine relationships between site productivity (as determined by site index of Douglas-fir) and soil properties.

2. SOIL NUTRIENT REGIME

2.1 PREVIOUS APPROACHES TO CLASSIFICATION OF SOIL NUTRIENT REGIME

Although the nutrient status of a forest soil is recognized as an important characteristic for many management decisions, there are major problems to overcome in assessing nutrient status. The following limitations to soil analysis for the determination of nutrient availability have been noted (Pritchett, 1979; Mader, 1973; Armson, 1973; Tamm, 1964); 1) difficulty in securing a representative sample in forest areas due to the spatial variability of forest soils, 2) uncertainty as to what soil horizon to sample, 3) uncertainty as to what nutrient form or fraction to extract, and 4) nutrient availability may be so intertwined with other site factors that these must be taken into account at the same time, for example, moisture status and aeration for nitrogen mineralization.

Courtin *et al.* (1985) list several authors who have put forward classifications of soil nutrient regimes based on a combination of forest floor, mineral soil, physiography, parent material, and vegetation features. Several examples are discussed briefly below.

The forest land classification system developed by Hills (1952, 1961, 1976) in Ontario is based on a holistic concept of site. The site is defined as the integrated complex of land

and forest features within a prescribed area (Spurr and Barnes, 1980). Physiographic features were used as the framework for integrating and rating climate, moisture and nutrients. The eleven classes of nutrient regime were estimated in a qualitative sense by consideration of physiographic features, soil texture, soil aeration, surficial materials, and the mineralogy and weatherability of parent materials (Hills, 1976).

Bakuzis (1959) proposed a system of synecological co-ordinates, represented as axes which summarize moisture, nutrient, heat and light regimes. Pluth and Arneman (1965) found significant correlations between synecological nutrient co-ordinates and total nitrogen, available phosphorus, exchangeable potassium, and organic matter content of some mineral soil horizons. These correlations were difficult to interpret (e.g., a negative correlation with available soil phosphorus). Multivariate techniques were suggested to be more useful for determining relationships and for expressing interrelationships (Pluth and Arneman, 1965).

In British Columbia, Krajina (1969) assessed SNR by using indicator plants and selected environmental properties. Klinka et al. (1984a) noted that Krajina (1969) consistently applied the same scale relative to a regional climate. As a result, a particular SNR class could represent different soil nutrient availability in a different regional climate. While relationships between vegetation and quantified nutrient gradients were studied by Wali and Krajina (1973), the nutrient gradient was not divided into classes.

Stanek (1977) attempted to synthesize information available on the classification of SNR in relation to muskeg (organic soils) in Canada. He concluded that most workers defined oligotrophic soils as having low nutrient content, and relatively low biological activity, generally formed on base-deficient parent rocks. Sites with high nutrient content and high biological activity were defined as eutrophic. However, he did not find a precise definition of SNR classes using qualitative or quantitative characteristics. He noted that the effects of differences in nutrient status (e.g. changes in vegetation, humus form, site index) rather than differences in a nutrient related property were the characteristics used for classification.

More recently, Courtin et al. (1985) have attempted to define soil nutrient regime classes. The differentiating characteristics used were pH(H_2O) and C/N ratio of the humus form; and total soil N (kg/ha) and sum of exchangeable Ca, Mg and K (kg/ha) within the mineral soil rooting zone. These differentiating characteristics were chosen on the basis of important soil characteristics identified during a literature review, ability to be inferred from soil morphological properties and relative ease of analytical determination. Cluster and discriminant analysis distinguished several soil groups. Vegetation-soil relationships were used to assign the soil groups into five nutrient regime classes.

2.2 APPROACH TO SOIL NUTRIENT REGIME CLASSIFICATION ADOPTED IN THIS STUDY

The SNR is a function of climate, relief, soil parent materials, organisms, and time (Klinka *et al.*, 1984a). Not all of these factors could be examined in this study because of the limited resources available.

All study sites were to be located within one regional climate. Within the climatic region, two parent material lithologies with the greatest possible differences in base (Ca, Mg, K) status were to be identified. Within each parent material lithology, three moisture regimes were to be sampled. Douglas-fir would dominate the tree layer of each parent material lithology-moisture regime combination.

The justification of the above study design was as follows. Location of all study sites within one climatic region would reduce complications due to climatic differences between study sites. Parent material lithology has an important effect on soil properties and nutrient reserves, particularly Ca, Mg and K. By sampling the widest possible differences in lithology, it was assumed that differences in nutrient regime would also be present and identifiable. Moisture status is frequently a confounding factor when determining nutrient availability. Sampling the same moisture regime on the two different lithologies would allow paired comparisons without the confounding of moisture effects. The range of moisture conditions considered would be limited to those where no seepage water was present during the growing season, avoiding the complicating effects of moisture and nutrient inputs. Douglas-fir is an economically important species found over extensive areas of the Pacific Northwest, on a wide range of moisture and nutrient conditions. Uniformity in the tree strata of the vegetation would simplify interpretation of relationships between vegetation and soil nutrient regime.

Using the methods of the British Columbia Ministry of Forests described by Klinka et al. (1984a) each of the study sites were to be classified for SNR and SMR in the field. The data collected during the field portion of the study would quantitatively or qualitatively describe the environmental and vegetational properties of each study site. The methods of sampling and chemical analysis would be those commonly used by the British Columbia Ministry of Forests and other researchers in the Pacific Northwest to allow easier transfer of information and use in subsequent studies.

The soil properties to be used in quantitative analysis were those commonly used in evaluation of nutrient status of forest soils in the Pacific Northwest. Property variability would be determined to aid in evaluation of each property for classification purposes. Analysis of variance and range tests would be used to determine if there were significant differences in soil properties between study sites grouped by parent material lithologies, SMR or SNR. Multivariate statistical techniques were to be used to explore possible interactions between soil properties and to reveal any unsuspected relationships which may exist. Combinations of soil properties which distinguished between study sites and groups of study sites were to be identified. The consistency of site groupings were also to be evaluated.

Relationships between the soil properties, floristic composition of understory vegetation, foliar nutrients, and forest productivity of the study sites were to be determined to examine if differences in soil properties were reflected in vegetation properties of the study sites. If possible, a classification of the soil nutrient regimes recognized in this preliminary study was to be proposed.

3. METHODS

3.1 SITE SELECTION AND DESCRIPTION

Geological maps were used to locate areas of granitic (low Ca and Mg, higher K) and volcanic (higher Ca and Mg, lower K) parent material lithology. Field inspections were used to locate very dry, dry and fresh soil moisture regimes (Klinka et al., 1984a) within each lithology. Each parent material lithology-moisture regime combination was dominated (80% or more basal area) by Douglas-fir in the tree layer. Age of trees in sample sites was between 30 and 70 years.

Within each Douglas-fir dominated site which was as homogenous as possible in vegetation, physiography, and soil a group of four 20 m x 20 m sample plots were subjectively chosen. A total of 24 plots were sampled in the study (2 lithologies x 3 SMR's x 4 replicates = 24 plots).

For each plot a site description form was completed. The following information was recorded: aspect, slope, elevation, site position (macro and meso), site surface shape, microtopography, exposure type, soil drainage, perviousness, bedrock type and structure, coarse fragment lithology, per cent cover of decaying wood, bedrock, cobbles and stones, mineral soil, organic matter, and water. All parameters were described according to Walmsley et al. (1980). The SMR and SNR for each sample plot were assessed using the methods described by Klinka et al., (1984a).

3.2 VEGETATION SAMPLING

Methods employed for the description of vegetation were similar to those used by Brooke et al. (1970), and Kojima and Krajina (1975). Vegetation analysis included the listing of all vascular plants, bryophytes and lichens growing on the forest floor. Species growing exclusively as epiphytes, on decaying wood and/or on rocks were not included in this list. For each species an evaluation of species significance (determined by a combination of abundance and dominance) and vigor according to vegetation strata was determined. These were later identified by Dr. V.J. Krajina (Professor Emeritus, Dept. of Botany, U.B.C.), Dr. K. Klinka (Adjunct Professor, Faculty of Forestry, U.B.C.) and Mr. G. Otto. Nomenclature of vascular plants followed (with some exceptions) that of Taylor and MacBryde (1977), while Ireland et al. (1980) was followed for mosses, Stotler and Crandall-Stotler (1977) for hepatics, and Hale and Culberson (1970) for lichens. Exceptions followed Krajina et al. (1984). A complete list of plant species found on the study plots is given in Appendix A.

On each sample plot the age at breast height (1.3 m) was determined for four dominant and two codominant trees by counting the growth rings on cores extracted by an increment borer, and the height determined with a clinometer. Site index (SI) of Douglas-fir was calculated using the equations provided by Hegyi et al. (1979) and Bruce (1981). A prism sweep from the centre of each plot was used to determine basal area of tree species present.

On each plot the current year's foliage from fifteen dominant or codominant Douglas-fir trees was sampled between 23 September and 9 October 1983 following the guidelines given by Ballard and Carter (1983). Foliage samples were either oven dried at 70°C for eight hours on the same day as collected or stored at approximately 5°C until oven drying could begin. Foliar samples were never stored more than 30 hours before oven drying began.

3.3 SOIL SAMPLING

Within each sample plot, fifteen sampling locations for soils were randomly selected using a grid system and random number table. Rocks, stumps and rotting logs were not considered suitable sampling locations. If an unsuitable random sampling location was selected, the closest suitable spot was sampled or a new sampling location was randomly chosen. At each of the fifteen sampling locations, a forest floor sample was obtained by cutting around the edge of a 25 cm x 30 cm template with a sharp knife. The total forest floor was removed from the forest floor surface to the mineral soil/forest floor interface. The depths of the L, F and H horizons (if present) were recorded as the mean of the midpoint depths of the four faces of the excavation created when the forest floor sample was removed. Decaying wood which appeared unaltered in structure to the naked eye, undecomposed cones, rocky material and roots greater than 2 mm in diameter were not included in the sample. Both the humus form and each sample horizon were tentatively classified according to Klinka *et al.* (1981a). The sample was placed in a plastic bag, sealed, labelled and taken to the laboratory to begin air drying on the same day as collection.

At three of the sampling locations within each plot, a soil pit was dug down to a depth of at least 1.2 m unless parent material or a restricting layer was encountered at shallower depths. Soils were described and classified following the practices and terminology of the Canada Soil Survey Committee (CSSC, 1978). Subsamples from soil horizons were taken from the described soil pits for determination of extractable Fe and Al, as well as air-dry color. Material excavated from the described soil pits was sieved through a 11 mm x 11 mm mesh and weighed in the field using a spring balance. Coarse fragments were collected from the soil pits for determination of lithology. At the remaining 12 sampling locations, small pits were dug to a sufficient depth to allow collection of a soil sample from the upper 50 cm of the mineral soil, or less if a restricting layer was encountered. From each of the 15 sampling locations within each sample plot, a composite sample of mineral soil from the 0 to 50 cm depth (or less) was obtained for analysis. All samples were sealed in plastic bags, labelled and taken to the laboratory for air drying on the same day as collection.

Near three forest floor sampling locations in each plot, bulk density of forest floor materials was determined using the glass bead displacement method described by Nuszdorfer (1981). Near the three described soil pit sampling locations, soil bulk densities were determined by the following procedure for the 0 to 25 cm and 25 to 50 cm depths. All material excavated from a hole approximately 1.5 L in volume was retained. The hole was then lined with a thin plastic bag and water poured into the bag until the horizontal surface level was reached. The plastic bag was then removed from the hole, inspected for leaks, and the volume of water contained was determined using a graduated cylinder. Volume determinations were repeated if the plastic bags leaked. All bulk density samples began air drying in the laboratory the same day as collection.

All soil and forest floor samples were collected between 1 May 1983 and 1 August 1983.

3.4 SOIL MOISTURE ANALYSIS

Within each study site three or six sampling locations were established for soil moisture determination using a neutron probe. These were monitored between 2 June and 18 November 1983 with a Campbell Pacific Model 503 neutron probe. In addition, six sampling locations in two sites previously established and studied by Giles (1983) were monitored during the same time period for reference purposes.

Access tubing for the neutron probe sampling locations was 5.08 cm outside diameter x 0.123 cm wall thickness aluminum tubing. The bottom of the tube was closed with a schedule

40 PVC plug, sealed in place with silicone sealant. The same materials were used by Giles (1983) who noted that this method of closing the bottom of the tube showed no significant leakage after two years.

In five of the six sites of this study, the access tubes were installed by making a hole by driving a 5-cm outside-diameter, heavy-wall, open ended pipe into the ground, with several withdrawals to remove soil inside the pipe. For one study site (4) and the two reference sites the existing neutron probe sample locations established by Giles (1983) were utilized. These access tubes were installed using a 5 cm diameter bucket-type auger to make a hole as close to the access tube diameter as possible (Giles 1983). After installing the access tubes by either method, any spaces around the tube were back filled with fine soil which was lightly compacted.

To enable the quantitative evaluation of qualitatively determined SMR classes, a simple water balance analysis technique similar to that of Giles et al. (1985) was utilized.

Soil water content was measured at 15 cm intervals to the 75 cm depth and 25 cm depth intervals thereafter until a restricting layer or the rooting depth had been reached. On sites where the soils had a high coarse fragment content it was not possible to determine if the obstruction was bedrock, basal till or a large stone. Water content of the forest floor was not determined during the study.

Data for daily solar irradiance (Kd) measured as bright sunshine hours, daily maximum and minimum air temperatures, and daily precipitation (P) were used from the Cowichan Lake Research Station.

The following is a summary of the calculations used in this procedure (from Giles, 1983; and Giles et al., 1985):

$$Kd = Ket\ (0.47\ n/N + 0.295) \qquad (1)$$

where Kd is the average daily solar irradiance (megajoules m^{-2} day^{-1}), Ket is the incoming extra-terrestrial radiation (megajoules m^{-2} day^{-1}), n is the daily average bright sunshine hours, and N is the maximum average daily sunshine hours.

$$Rn = (1-a)\ Kd + L^* \qquad (2)$$

where Rn is daytime net radiation flux density (megajoules m^{-2} day^{-1}), a is the canopy albedo (assumed to be 0.12, Jarvis et al., 1976), Kd is the average daily solar irradiance corrected for slope and aspect at each site (according to the tables of Hay, 1979) (megajoules m^{-2} day^{-1}). L* is daytime net longwave irradiance (megajoules m^{-2} day^{-1}) and calculated as follows

$$L^* = [(107 - Ta)\ (0.864)]\ [0.2 + 0.8\ n/N] \qquad (3)$$

where Ta is the average daily temperature (degree Celsius).

$$E\ max = @\ s/[1\ (s + Y)]\ Rn \qquad (4)$$

where E max is the energy limited transpiration rate, @ is the evapotranspiration coefficient (assumed to be 0.8, Spittlehouse and Black, 1981), s is the slope of the saturation vapor pressure curve (kilopascals per degree Celsius), Y the psychrometric constant at 100 kPa (kilopascals per degree Celsius), and l the latent heat of vaporization of water (megajoules per kg), each evaluated at the average air temperature.

sum Emax = Emax for each day in the measurement period (mm) (5)

P = total precipitation for the measurement period (mm) (6)

AWSC = soil depth x (theta max - theta min) (mm) (7)

where AWSC is the available soil water storage capacity (mm). Soil depth is average rooting depth observed in soil pits in the study site, plus 10% of the rooting depth. The addition of 10% to the rooting depth attempts to account for moisture which moves into the rooting zone by capillary rise from lower soil depths (D. Giles, pers. comm.). If rooting depth plus 10% would be inaccurate due to the presence of a restricting layer, depth to the restricting layer was used. Theta max is the volumetric soil water content maximum measured, and theta min is calculated by the following formula (Clapp and Hornberger, 1978):

$$\frac{\text{psi d}}{\text{psi w}} = \frac{(\text{theta w})^{b}}{(\text{theta d})}$$

where psi d is soil water potential at -1500 kPa, psi w is soil water potential at -10 kPa (field capacity), theta w is volumetric soil moisture content at -10 kPa (theta max in this study), theta d is soil water potential at -1500 kPa, and b is an exponent. The value for b was determined to be 3.4 for sandy loams (sites 1 and 2) and 4.2 for loams (sites 3, 4, 5, 6). The empirical determination of b is based on data from Giles (1983) and Clapp and Hornberger (1978).

The value of the deficit for a given measurement period is equal to E max minus the sum of precipitation and the remaining available soil water storage from the previous measurement period. This deficit was computed for June, July and August. It was assumed that the entire AWSC was available at the beginning of June.

Possible sources of error in determining soil moisture content with the neutron probe are discussed by McGowan and Williams (1980), Greacen et al. (1981), Prebble et al. (1981), Williams and Sinclair (1981), and Giles (1983). Similar techniques to those of Giles (1983) were used to reduce random count errors, relocation errors, and damage to surface soil and vegetation.

The major sources of potential error most likely to apply to this study would be soil variability, and soil disturbances from creating neutron probe sampling sites. Soil disturbance may have a significant effect on probe calibration. Approximately 70 access tubes would be required to achieve a 95% confidence level with a 10% allowable error in a 20 m x 20 m sample plot (Giles, 1983). The hammering of a steel tube into the soil to create the neutron probe sampling sites may have blocked small soil pores, created air gaps or caused soil to slough. The results of these disturbances may be preferential water flow around the neutron probe sampling site and unrepresentative readings.

Maximum volumetric soil moisture content based on neutron probe readings was determined using a computer program written by D. Spittlehouse (Research Branch, British Columbia Ministry of Forests, Victoria). The program is available on the University of British Columbia computing system under the name NEUTSITE.

3.5 LABORATORY ANALYSIS

Bulk density samples were sieved in the laboratory and coarse fragments >2 mm in diameter were weighed. A specific gravity value of 2650 kg/m^3 was used to convert coarse fragment weight to volume. Forest floor bulk density samples were oven dried at 70°C for 24 hours and weighed. Roots were removed from mineral soil bulk density samples and their volume determined by water displacement in a graduated cylinder. Soil material <2 mm was oven dried at 105°C for 24 hours and weighed. Coarse fragment free bulk density was calculated using the formula given in Nuszdorfer (1981).

When air-dried, forest floor samples were ground with a Waring blender, then stored in air-tight plastic containers until chemical analysis was complete. After air-drying, all mineral soil samples were crushed with a wooden roller, passed through a 2 mm sieve to remove the coarse fraction and stored in air-tight plastic containers until chemical analysis was complete. Foliar samples were oven-dried for 8 hours at 70°C, then ground finely in a Braun model KSM2 coffee grinder. A subsample of the ground foliar sample was then oven-dried for 4 hours at 70°C and kept in a desicator until chemical analysis was complete.

To allow an assessment of property variability as well as a mean value for each plot, the following compositing procedure was used for forest floor and mineral soil samples. On one of the four plots within a site, each sample was halved and one half analyzed individually. The plots within sites chosen for variability analysis were selected by the practical consideration of having sufficient forest floor and mineral soil sample material to allow analysis of all chemical properties. In the case of forest floor samples from site 6, this was not possible and less than 15 samples were available for some chemical variability determinations (Appendix H). On all four replicate plots within a site, the fifteen samples taken within a plot were composited in groups of five samples to make a total of three composite samples per plot. Foliage samples from all fifteen trees sampled per plot were composited in the field.

Hygroscopic moisture content of the air-dried forest floor and mineral soil samples was determined by oven-drying an approximately 4 g sample weighed to the nearest .001 g overnight at 105°C, cooling in a desicator and weighing to determine moisture loss as a percentage of the air-dry weight. This information was used to correct all other property values to an oven-dry basis.

Values for forest floor pH using 4.0 g subsamples were measured in a 1:2 organic matter:distilled water suspension by use of a Radiometer Copenhagen PHM 29b standard pH meter. Mineral soil pH values were measured using 4.0 g subsamples in a 1:2 soil:distilled water suspension, and in a 1:8 soil:0.01 mol/L $CaCl_2$ suspension with the use of the same pH meter. Total carbon (TC) was estimated by use of a Leco Induction Furnace and C analyser Model No. 521 (Laboratory Equipment Corporation, St. Josephs, Michigan) to combust a 0.5 g subsample of mineral soil and a 0.05 g forest floor subsample (Bremner and Tabatabai, 1971). Due to the small sample size for forest floor material, all forest floor samples were done in duplicate, with the recorded C values representing the mean of two samples. A scoop of oven-fired quartz sand was added to forest floor samples to slow the rate of combustion (Quesnel 1980).

Mineralizeable nitrogen (minN) was determined using an anaerobic procedure modified from that of Powers (1980). One gram of air-dried mineral soil or forest floor material was combined with 12.5 mL distilled water in a 15 x 120 mm glass test tube and sealed with a rubber stopper. The test tube was shaken to sufficiently wet the sample and then incubated at 30°C for 14 days. After incubation the sample was shaken and poured into a plastic 60 mL screw cap container. The test tube was then rinsed with 12.5 mL of 2 mol/L KCl and the contents added to the 60 mL container (final solution was 25 mL 1 mol/L KCl). After shaking for two hours the sample was filtered through a Whatman #41 filter. The concentration of NH_4-N was determined using a Technicon Autoanalyzer II (Anonymous, 1974). The method for N determination is based on the Berthelot (Phenol-hypochlorite) reaction for NH_4. All mineralizeable N (min-N) incubations were done in duplicate with recorded min-N values representing the mean of two samples.

Cation exchange capacity (CEC) and exchangeable calcium (exCa), exchangeable magnesium (exMg), exchangeable potassium (exK), and exchangeable manganese (exMn) for forest floor and mineral soil samples were determined by displacement with 1.0 mol/L NaCl based on the method of Clark (1965). A 1:1 isopropyl alcohol:distilled water wash instead of a strictly isopropyl alcohol wash was used during the cation exchange capacity determination. A strictly isopropyl alcohol solution did not wash all Na from filter paper or samples of silt size quartz. Exchangeable Ca, Mg, K, Mn and Na (for CEC) were measured by atomic absorption spectrophotometry (Price, 1978) with an acetylene/air flame.

Total nitrogen (TN) for mineral soil samples was determined by digesting a 4.0 g sample with 15 mL of concentrated H_2SO_4 at 420°C for 45 minutes (Lavkulich, 1978). N was determined colorimetrically by use of the Technicon Autoanalyzer II (Anonymous, 1974). The method for total N is based on the Berthelot (phenol-hypochlorite) reaction for NH_4-N. Extractable phosphorus (exP) for a 2.0 g sample of mineral soil was determined using a modified Bray P1 (0.03 mol NH_4F and 0.025 mol HCl per L) method (Lavkulich, 1978). Measurement of P in the extracting solution was by ascorbic acid reduction of a phospho-molybdate complex as described for soil extracts by Watanabe and Olsen (1965). Color intensity was read on a Gilford Staser II at 700 nm.

Extractable sulphate S (SO_4) in 10 g samples of mineral soil was determined by ammonium acetate extraction (Bardsley and Lancaster, 1965). Sulphate S in the extracting solution was determined using turbidemetry read on a Bausch and Lomb Spectronic 20 set at 420 nm. Sodium pyrophosphate extractable Fe and Al for soil horizon samples were determined according to the procedure described by Lavkulich (1978).

For forest floor samples of 1.0 g, total nitrogen (TN), total phosphorus (TP), total calcium (TCa), total magnesium (TMg), total potassium (TK), and total manganese (TMn) were determined by a modified Parkinson and Allen (1975) procedure described in detail by Carter (1983). Total N and P were determined colorimetrically with the Technicon Autoanalyzer II. The method for total N is based on the Berthelot (phenol-hypochlorite) reaction for NH_4-N. The method for P is based on the reduction of the ammonium-molybdophosphate complex by ascorbic acid (Watanabe and Olsen, 1965). Total Ca, Mg, K and Mn were measured by use of atomic absorption spectrophotometry (Price, 1978) with an acetylene/air flame.

Total sulphur (TS) for forest floor samples and foliar samples was determined by the use of a Fisher Sulfur Analyzer Model 475 using the procedure described by Lowe and Guthrie (1984).

Foliar samples were analyzed for N, P, K, Ca, Mg, Fe, Al and Mn by the same procedure used for forest floor samples. Total K, Ca, Mg, Fe and Mn were determined with atomic absorption spectrophotometry with an acetylene/air flame, except for Al determination where a nitrous oxide flame was used.

Foliar 'active' Fe (AFe) was determined by adding 10 ml of 1 mol/L HCl to a 0.20 g foliar sample in a 60 mL plastic bottle and shaking the sample at slow speed and room temperature for 24 hours. Samples were filtered through Whatman #41 filter paper. Fe content in the filtrate was determined using atomic absorption spectrophotometry with an acetylene/air flame. This method is based on those of Oserkowsky (1933) and Zech (1970). Foliar Cu and Zn were determined using a nitric acid digest procedure. Samples of 0.7 g were digested with 10 mL of concentrated HNO_3 at 40°C for one hour and then at 140°C for two hours. Total Cu and Zn values were determined on the atomic absorption spectrophotometer with an acetylene/air flame.

Foliar B was determined by dry ashing a 0.50 g sample in a muffle furnace at 600°C for one hour. Ash contents were wetted with demineralized water and 10 mL of 0.36 mol/L H_2SO_4, let stand one hour and filtered through Whatman #41 filter paper. Determination of the B content of the filtrate was done using the azomethine-H method similar to that of Wolf (1974).

Except where otherwise noted, all analyses for forest floor and mineral soil samples were done only once. Some replication was performed to check on the precision of results, and where individual samples had values which varied widely from values of similar samples. This approach was utilized to reduce the time and expense of analyzing such a large number of samples in duplicate or triplicate. All foliar analyses were done in duplicate and the values reported represent the mean of two samples.

Nutrient data were expressed as concentrations and on an areal (kg/ha) basis. Statistical analyses were conducted with data expressed on an areal basis. Expression of nutrient data on a kg/ha basis permits the integration of soil chemical data with soil physical data (Lewis, 1976) to obtain a better estimate of the nutrient content of the soil. The formulas used for converison of chemical data to kg/ha are given in Appendix G. The bulk density values used for conversion are given in Appendix E. The coarse fragment free bulk density values used for mineral soil and forest floor samples were the means of the three bulk density samples taken within each plot. The L horizon sampled as forest floor in site 6 was too thin to be measured. A bulk density value of 100 kg/m^3 was used for this stand, based on the average forest floor bulk densities measured in other study sites.

3.6 DATA SUMMARY AND STATISTICAL ANALYSIS

3.6.1 Vegetation

Because Douglas-fir dominated the tree strata of all study sites it was decided to use only species present in the shrub, herb and moss strata for vegetation analysis. As well, species which appeared in only one plot were deleted from the vegetation data set. Removal of species which occur in 5% or less of the sample plots from a vegetation data set generally improves the interpretability of the results without a significant loss in information (Gauch, 1982).

Tabular analysis and indicator species analysis (EISG) of the edited data set were conducted using VTAB (Emanuel, 1984a). Multivariate analysis of vegetation was conducted using the principal components analysis (PCA) subroutine in the MIDAS statistical package (Fox and Guire, 1976); reciprocal averaging (RA) using the ORDIFLEX (Release B) program (Gauch, 1977); and detrended correspondence analysis (DCA) using the DECORANA program of Hill (1979).

3.6.2 Foliar Nutrient Analysis

Analysis of foliar nutrient status for the study stands was performed with the FNA program written by J. Emanuel (1984b) which is based on the research and programs of Dr. T.M. Ballard (Department of Soil Science, and Faculty of Forestry, U.B.C.). The program is available on the University of British Columbia computing system as F203:FNA.

3.6.3 Soil Properties

Soil properties were analyzed to determine the number of samples necessary to obtain the mean value of a property with a specified allowable error and confidence level. The calculations were performed by use of an equation presented in

Husch et al. (1972).

$$n = \frac{t^2 \ (n-1) \quad (CV)^2}{(AE)^2}$$

where n is the number of sampling units needed to estimate the mean with a specified allowable error and probability, t (n-1) is the value of Student's T distribution with n-1 degrees of freedom; CV is the coefficient of variation; and AE is the allowable sampling error in percent. The equation was solved for n by an iterative method using a computer program developed and written by P. Courtin (Forester, Research Section, Vancouver Region, B.C. Ministry of Forests).

This type of analysis has been applied to mineral soil data by Grier and McColl (1971), Lewis (1976), Slavinski (1977), and Courtin et al. (1983); and to forest floor data by Quesnel (1980), and Carter (1983). The data were analyzed for two allowable errors (10% and 20%) and at three levels of confidence (80%, 90%, and 95%).

The concentration data for the variability plot was multiplied by a constant to allow expression on an areal basis (kg/ha). Since the values were multiplied by a constant, the CV's and sample size analysis would be comparable to those for chemical data or elemental concentrations of other studies.

Three data sets: forest floor properties, mineral soil properties, and forest floor plus mineral soil properties, were used to distinguish between groups of study sites. The forest floor variables used were pH(H_2O), TC, TN, minN, TP, TS, exCa, exMg, exK, and exMn. The mineral soil variables used were $pH(H_2O)$, $pH(CaCl_2)$, TC, TN, minN, exP, SO_4, exCa, exMg, exK, and exMn. The nutrient quantities were expressed on a kg/ha basis, which better represents nutrient availability by integrating chemical and physical data. A third data set was created by summing the forest floor and mineral soil values (kg/ha) for TC, TN, minN, exCa, exMg, exK, and exMn for each plot.

All soil analytical values were expressed on an areal basis by multiplying the chemical concentration by a conversion factor (Appendix G). The conversion factor for forest floor included depth and bulk density. The plot area occupied by trees was subtracted from the total area, which decreased forest floor kg/ha values by <1%. For mineral soil calculation, coarse fragment free bulk density and the sampling depth of 50 cm were used to determine the conversion factor. Where soil depth was less than 50 cm, the conversion factor was decreased.

No variables used in the statistical analyses were derived by calculating ratios. The statistical disadvantages of using ratios are discussed by Sokal and Rolf (1973), and Green (1979), who noted the inaccuracies which may result particularly when the variables used in the numerator and denominator err in opposite directions. Considering the variability of forest soil properties and the relatively small sample size of this study, any ratios which were derived may not be representative or may not have wider applicability.

During the statistical analyses, several groupings of the study sites were utilized to explore possible relationships. The six sites were analyzed as separate entities, or as groupings according to parent material lithology, SMR, or SNR.

The variables were tested for homogeneity of variance between study sites. A log + 1 transformation was used to improve homogeneity of variance for all mineral soil properties except pH(H_2O) and pH($CaCl_2$), and all forest floor plus mineral soil properties.

Analysis of variance (ANOVA) was used to determine if significant differences were present between groups of study sites using UBC ANOVAR (Greig and Osterlin, 1978). Both two-way ANOVA with lithology of parent material and SMR as factors and one-way ANOVA with SNR as the factor were performed. The Student-Newman-Keuls (SNK) range test was applied when significance at the .05 level was determined.

The two-way ANOVA was designed as follows:

Source	Degrees of Freedom
Sites	5
SMR	2
Parent material lithology	1
Interaction	2
Plot within sites	18
Composite samples within plots	48
Total	71

The differences between the six sites were assessed using the 'plot within sites' term. The 'composite samples within plots' term was used to assess within site versus between site variability (J. Petkau, Associate Professor, U.B.C. Statistics Dept., pers. comm.).

Multivariate analysis techniques were utilized to determine: 1) the relative contribution of variables to the total variation between study sites (partitioning the sum of squares, and specific variance using multivariate sample size analysis, MSS), 2) underlying or unknown relationships between the variables (principal components analysis, PCA), 3) which variables in combination would best distinguish the potential groupings of the study sites (stepwise discriminant analysis, DA), and 4) the consistency of stand groupings using combinations of variables judged to be important from previous analyses (cluster analysis, CA).

Ranking each property by sum of squares and specific variance was conducted using Multivariate Sample Size Analysis (MSS) software (Emanuel, 1984c). The program is available as F405:MSS on the University of British Columbia computing system. MSS is a technique for assessing which variables (properties) in a multivariate study are likely to be most useful. A partial correlation technique is used to rank the variables according to the information each contains about the data set, and then uses multivariate analysis of covariance to remove each variable in turn and determine the remaining information. The ranked dispersion and specific variance of each property were determined from a correlation matrix, which standardizes the values of each property in the data set (Emanuel, 1984c). Further discussion and an illustration of the procedure are provided in Scagel _et al._ (1985).

Principal components analysis (PCA) was conducted using the PCA subroutine in MIDAS (Fox and Guire, 1976). PCA was used to examine the relationships between the study sites. All PCA's were conducted using a correlation matrix, which causes all variables to be scaled equally, in standard deviation units (Pimental, 1979). A random variable introduces an eigenvalue equal to 1 if a correlation matrix is used for the PCA (Legendre and Legendre, 1983). A PCA axis with an eigenvalue less than or equal to 1 was not interpreted as it may be describing random variation.

The objective of discriminant analysis (DA) in this study was to determine the optimal 'separation' of groups of plots based on linear transformation of the properties and to identify the features by which they were separated. Stepwise jacknifed discriminant analysis was performed using the 7M subroutine of BMDP (Dixon, 1983). The jacknifed classification method is preferrable to non-jacknifed methods because it results in a classification with less bias (Dixon, 1983). The jacknifed classification matrix is created by classifying each case (plot) with a series of classification functions computed from all the data except for the case being classified.

Three important assumptions of DA are: 1) dispersions are equal, 2) prior probabilities are identifiable, and 3) means and dispersions are estimated accurately and precisely (Williams, 1983). The variance-covariance matrices of the study stands did not have equality when tested using Box's statistic (Fox and Guire, 1976). The lack of equality is common in ecological data (Green, 1979; Williams, 1983). As the numbers of variables increases the likelihood of inequality of covariance matrices increases rapidly (Green, 1979). When assumptions are clearly violated, DA, like any other mathematical technique, should be regarded as a data-exploratory procedure (Williams, 1983).

Average distance cluster analysis (CA) was performed using UBC CGROUP (Lai, 1982). CA assesses whether natural groups occur in a population of samples, based on variables measured. In this study the interest was in the extent to which clusters produced by the CA corresponded to the grouping of study plots suggested by previous analyses.

The results of the cluster analysis include a dendrogram of the study plots and the error value for each step. The error values at each step is calculated from the formula given in Lai (1982).

$$\text{Error value} = \frac{\text{sum of the squared differences between corresponding scores in the properties}}{\text{number of items in the potential group}}$$

The first grouping is made by combining the two plots (cases) with the minimum error value. After grouping, the error values which reflect potential error for combination with this new group are modified. The next grouping is made by determining the grouping which yields the smallest error value. This is continued until only one group remains.

3.6.4 Relationships Between Soil Properties and Vegetation

Relationships between understory vegetation and soil properties and foliar nutrients and soil properties were explored using the canonical correlation analysis subroutine of SAS (SAS Institute Inc., 1982). Canonical correlation analysis (CCA) is a multivariate technique which operates on both sets of variables simultaneously (Gittins, 1979).

Due to the small number of sample plots (24) relative to the number of variables it was necessary to summarize and reduce the number of variables. The vegetation data was summarized with DCA axes and the soil properties summarized with PCA axes. The DCA and PCA axes scores can be used as new variables which are continuous and linear. Correlations between the original soil properties, PCA axes, DCA axes and canonical variates were used to interpret the results of the CCA. Redundancy, and variance extracted by each canonical variate as described by Gittins (1979) were also used to interpret the results of CCA.

4. CHARACTERIZATION AND CLASSIFICATION OF STUDY STANDS

In the following chapter the climate, bedrock geology, management history, surficial materials, and soils of the study sites will be described. The soil properties of the study sites will be compared to values found in the literature. The soil moisture regimes of the study sites will be analyzed and classified. The field-assessed classification of soil nutrient regimes for two study sites will be described as an example of the method and factors considered. Multivariate analysis and tabular classification of the understory vegetation will be used to identify major environmental trends among the study sites. The foliar nutrient status of the study sites will be described.

4.1 LOCATION AND MANAGEMENT HISTORY

Study sites were located on south central Vancouver Island around Cowichan Lake and in the Robertson River Valley (Fig. 1) at elevations below 700 m. The study area was thus confined to the East Vancouver Island Variant of the Drier Maritime Coastal Western Hemlock subzone (CWHa1) (Klinka _et al._, 1984a). All study sites were within a 25 km radius of the Cowichan Lake Research Station of the British Columbia Ministry of Forests.

All study stands were dominated by second-growth Douglas-fir in the tree layer, established after logging and fire, ranging in age between 33 and 68 years. The original study

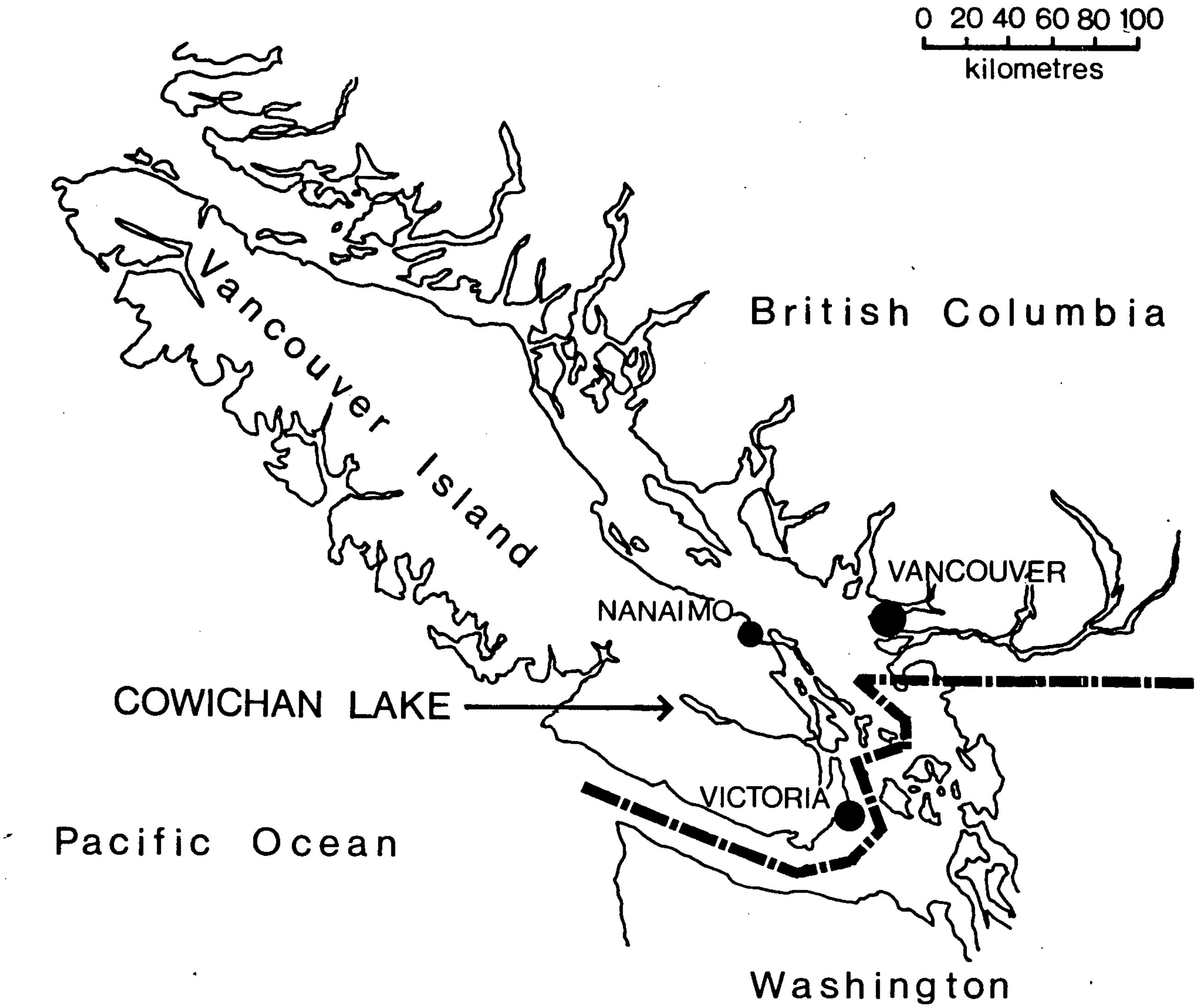

Figure 1. Location of the study area

design called for all study sites selected to be free from forest management treatments such as fertilization and thinning. This would have avoided consideration of nutrient inputs by fertilizer, and the effect of management practices on nutrient concentrations. Due to the restricted nature of parent materials derived from granitic lithology, it was necessary to locate two of the study sites within areas which had been fertilized and thinned. Study site 2 had been fertilized with urea in 1968 and 1976, study site 3 had been fertilized with urea in 1968 and 1979. All fertilizations had been conducted from fixed wing aircraft, with rates of application of 200 kg N per ha (Ken Hart, Forester, CIP Forest Industries, pers. comm.). The amount of fertilizer applied to any one 20 m x 20 m study plot was probably quite variable, and could not be assessed during this study. Study site 3 had also been precommercially thinned to approximately 700 stems per ha in 1979.

To aid in interpretation of results, each site was given an identifying name based on parent material lithology and SMR. Each replicate plot within the site was numbered from 1 to 4. The field assessments of parent material lithology and SMR were to be confirmed by later analyses. Study sites 1 to 3 represented the SMR gradient on the granitic lithology. Site 1 being the granitic lithology, very dry SMR combination, GVD. Similarly site 2 will be referred to as GD (granitic, dry) and site 3 as GF (granitic, fresh). The same procedure was used to name sites 4 (VVD), 5 (VD) and 6 (VF) which represent the SMR

Table 1. Selected characteristics of study sites

Site No.	Site code	Parent material lithology	Soil moisture regime	Soil nutrient regime	Site age (yrs)
1	GVD	granitic/ volcanic	very dry	poor	34
2*	GD	granitic	dry	medium	35
3**	GF	granitic/ volcanic	fresh	rich	33
4	VVD	volcanic	very dry	medium	68
5	VD	volcanic	dry	rich	61
6	VF	volcanic	fresh	very rich	67

* Fertilized with 200 kg N/ha, 1968 and 1976.

** Fertilized with 200 kg N/ha, 1968 and 1979; and thinned to 700 stems/ha 1979.

sequence on the volcanic lithology. For example, the third replicate plot in the GD site was referred to as GD3.

Selected characteristics of the study sites are summarized in Table 1.

4.2 CLIMATE

The climate of the CWHa1 variant had been described as Cfb (humid, cool mesothermal) according to the system of Koppen/Trewartha (Trewartha, 1968) by Klinka et al. (1979). Selected climatic data for the CHWa1 variant is presented in Table 2.

Table 2. Selected climatic data for the East Vancouver Island Variant of the Drier Maritime Coastal Western Hemlock subzone (data from Klinka et al., 1979)

Climatic variables	
Mean annual precipitation (mm)	2060
Mean precipitation April-September (mm)	404
Mean precipitation driest month (mm)	36
Mean precipitation wetest month (mm)	347
Mean annual temperature (°C)	8.7
Mean temperature warmest month (°C)	16.8
Mean temperature coldest month (°C)	0.9
Months with mean temperature > 10°C	5.0
Months with mean temperature < 10°C	0.0

4.3 BEDROCK GEOLOGY AND LITHOLOGY OF PARENT MATERIALS

Within the study area the bedrock is mainly of volcanic origin (Muller, 1977; Korelus and Lewis, 1976). The north side of Lake Cowichan is underlain by rock of the Sicker Group which includes both metamorphosed volcanic (mainly basaltic to rhyolitic lava flows) and volcanic derived metamorphosed sedimentary (mainly metagreywacke and argillite) deposits. The eastern end of the Lake is underlain by theoleiitic volcanic (mainly basalt) deposits of the Karmutsen Formation. The southern and western ends of the Lake are underlain by volcanic (basalts and rhyolites with andesites and dacites) deposits of the Bonanza Group. Within the study area there is a limited occurrence of granitic rocks (quartz diorite to granite) of the Island Intrusions.

Identification of coarse fragments and samples of bedrock is summarized in Table 3. Average chemical content of rock types, similar to the identified samples is given in Table 4. The parent material lithologies of study sites 1, 2 and 3 were dominated or co-dominated by rock types with low Ca and Mg status (Island Intrusions or rhyolite and rhyodacite). In contrast, the parent material lithologies of study sites 4, 5 and 6 were dominated by rock types with greater Ca and Mg status (Sicker Group or Karmutsen). On the basis of these differences in parent material lithology the field assessment of parent material lithology was considered confirmed. The granitic parent material lithology (low Ca and Mg, higher K status)

Table 3. Approximate percent of coarse fragment and bedrock samples* from study sites arranged by local geological unit and lithology

		Locality								
		Site 1		Site 2		Site 3	Site 4		Site 5	Site 6
		Bedrock	Coarse fragments	Bedrock	Coarse fragments	Coarse fragments	Bedrock	Coarse fragments	Coarse fragments	Coarse fragments
Local geological unit	Lithology	Number of samples								
		24	35	9	26	28	12	31	31	52
Island Intrusions	Quartz monzonite				15				20	
	Grano-diorite	75			23			6		
	Quartz diorite		29	100	15	45				
	Quartz diorite to diorite				8					
Bonanza Group	Rhyolite		29			2				
	Rhyodacite	25			12			13		
	Dacite		26		12	28				
	Andesite		16		15	25				
Karmutsen	Tholeiitic basalt						100	7		
Sicker Group	Andesite							39	22	44
	Andesite (serpentinitic)							16	25	25
	Basaltic andesite							3	33	30
	Greywacke siltstone (andesitic)							16		1

* Samples identified by J. Getsinger, U.B.C. Dept. Geology.

Table 4. Average chemical compositions (per cent of weight) of lithologies similar to those of the study area (from Hyndman, 1972; and MacDonald, 1972)

Chemical	Rock types						
	Grano-diorite	Quartz Diorite	Rhyolite	Rhyoda-cite	Dacite	Andesite	Tholeiitic basalt
SiO_2	66.9	66.2	73.6	66.3	63.6	54.2	50.8
TiO_2	0.6	0.6	0.2	0.7	0.6	1.3	2.0
Al_2O_3	15.7	15.6	13.4	15.4	16.7	17.2	14.1
Fe_2O_3	1.3	1.4	1.2	2.1	2.2	3.5	2.9
FeO	2.6	3.4	0.8	2.2	3.0	5.5	9.1
MnO	0.1	0.1	0.3	0.1	0.1	0.1	0.2
MgO	1.6	1.9	0.3	1.6	2.1	4.4	6.3
CaO	3.6	4.7	1.1	3.7	5.5	7.9	10.4
Na_2O	3.8	3.9	3.0	4.1	4.0	3.7	2.2
K_2O	3.1	1.4	5.4	3.0	1.4	1.1	0.8
P_2O_5	0.2	0.2	0.1	0.2	0.2	0.3	0.2
H_2O	0.7	0.7	0.8	0.7	0.6	0.9	0.9

consisted of sites 1, 2 and 3 (GVD, GD, GF). The volcanic parent material lithology (higher Ca and Mg, lower K status) consisted of sites 4, 5 and 6 (VVD, VD, VF).

4.4 SURFICIAL MATERIALS AND SOILS

Maps showing the distribution and type of surficial materials in the study area have been produced by the E.L.U.C. Secretariat (1975a and 1975b) and Korelus and Lewis (1976). These were used along with on site observations to determine the surficial materials present for each study site. The soil materials of GVD, GD and VVD sites (1, 2, 4) were derived from glacial till. The soil materials of the VD site (5) were derived from a mixture of colluvial and possibly alluvial parent materials. The soil materials of the GF and VF sites (3, 6) were glaciofluvial and alluvial materials, respectively.

Korelus and Lewis (1976) noted that soil texture and coarse fragment content were somewhat related to the type of bedrock from which the till was derived; the coarsest tills (very stony, gravelly, loamy sands) were derived from the igneous intrusions (Island Intrusions), intermediate textured tills (stony, sandy loams) were derived from the Sicker Group and the Karmutsen Formation, and the finest textured tills (sandy loam to loam, low stone and gravel content) were derived from the "soft" volcanics of the Bonanza Group.

The soils of the GVD, GD, GF, VVD and VD sites (1, 2, 3, 4, 5) were classified as Orthic Humo-Ferric Podzols. The soils of the VF site (6) were classified as Orthic Cumulic Regosols. Soil descriptions of representative soils of the study sites are given in Appendix F. Rooting depth, coarse fragment content, bulk density and other soil information are given in Appendix E.

Soil properties of the study sites arranged by sampling scheme are given in Appendix I for forest floor properties, and Appendix J for mineral soil properties. The values for each sample of the forest floor and mineral soil properties are given in Appendix H.

Forest floor properties were compared to values for Douglas-fir stands found in Carter (1983), Grier and McColl (1971), Heilman (1979), Lewis (1976), Lowe and Klinka (1981), Klinka _et al_. (1981a), Roy (1984), Youngberg (1966), and Youngberg (1979). The values for pH(H_2O), TC, TN, minN, TP, TS, exCa, exMg and exK were within the range of values found in the references cited above, allowing for differences in analytical methods, presentation of results and sampling.

Although TCa values were comparable to those in the literature, TCa values were sometimes less than those for exCa (eg., sites VVD and VD). In general there is a poor recovery of Ca using an acetylene/air flame with the atomic absorption spectrophotometer due to inhibition effects by other elements (Dean, 1960). In the GF site the exK values for the composite samples in the variability plot were greater than the TK values (25.53 vs 24.04 kg/ha). It was decided to delete TCa, TMg and TK from further statistical analyses, because of analytical problems (TCa and possibly TK), and the assumption that the exchangeable forms of Ca, Mg and K were more available to plants.

The TMn values were much higher than those of Carter (1983). The high values were believed to be due to analytical problems, in particular with the standards used for the atomic absorption spectrophotometer. The forest floor TMn values were not used in further statistical analyses.

The CEC values for the forest floor were less than those of Quesnel (1980) who used a similar analytical technique (Na displacement), but studied older and deeper forest floors developed under Tsuga heterophylla, Abies amabilis, Thuja plicata and Chamaecyparis nootkatensis stands in the CWHb biogeoclimatic subzone on northern Vancouver Island. Problems with determining CEC using the Na displacement method with isopropyl alcohol were previously noted. It was decided not to use forest floor CEC values in further statistical analyses because they could not be confidently considered as representative.

Mineral soil chemical properties were compared to values found in Binkley (1983), Courtin et al. (1983), Heilman (1979), Klinka et al. (1981b), Lewis (1976), Roy (1984), and Slavinski (1977). The mineral soil values of this study were within the range of those cited above for pH(H_2O), pH($CaCl_2$), TC, TN, minN, exP, SO_4, exCa, exMg, exK, exMn and CEC, allowing for differences in analytical technique, presentation of results and sampling.

The CEC values for mineral soil were similar to those reported by Lewis (1976) using the Na displacement method. However, as noted previously for forest floor CEC values, they were not utilized in further statistical analyses because of a lack of confidence that the values were representative of mineral soil conditions.

4.5 FIELD-ASSESSED SMR AND SNR OF STUDY SITES

A combination of site characteristics (App. E) and indicator plant species were used to assess SMR and SNR of study sites during the period of field work. The assessments of two study sites are given below as examples. A similar assessment and synthesis were applied to the other study sites.

Site 1 was on a upper slope with a southwest aspect. A thin Mor overlay a well developed Ae horizon. The Ae horizon was not always present, but this was probably due to soil disturbance during logging. Mineral soil texture of the upper horizons was loamy sand to sandy loam with a high coarse fragment content. Depth of mineral soil averaged approximately 55 cm and ranged from <10 cm to 100 cm. Coarse fragment lithology was volcanic and granitic and the underlying bedrock was granitic. Understory vegetation was strongly dominated by *Gaultheria shallon*. A variety of lichen species were present on very shallow soils. Other species present included *Boschniakia hookeri*, *Hylocomium splendens*, and *Rhytidiopsis robusta*. Based on a synthesis of the environmental and vegetation characteristics described above, this site was classified as being SMR 1 (very dry) and SNR B (nutrient poor).

Site 4 was on an upper slope with a northern aspect. A Mor overlay a weakly developed, discontinuous Ae horizon. Mineral soil was a loam to sandy loam texture with a moderate coarse fragment content. Soil depth averaged approximately 45 cm and ranged from 10 to 70 cm. Coarse fragment lithology was dominantly andesitic and the underlying bedrock was basaltic. While Gaultheria shallon was an important part of the understory vegetation, there was also significant cover of Mahonia nervosa, Hylocomium splendens, Kindbergia oregana plus Achlys triphylla and Polystichum munitum. Based on a synthesis of the environmental and vegetation characteristics described above, this site was assessed as being SMR 1 (very dry) and SNR C (nutrient medium).

A similar synthesis and assessment was applied to classify the SMR and SNR to the other study sites. While every attempt was made to have study sites as homogeneous as possible, in two sites within-site variability was evident. Depth to bedrock in study site 1 was variable, and so the tree canopy was not completely closed in two of the four plots. Study site 2 was restricted to a small area which had not been thinned. As a result it was necessary to have two plots on the gentler lower slope and two plots further upslope with a steeper slope angle. Variation between plots within a site was judged to be less than variation between sites. Therefore all plots within a site were given the same provisional SMR and SNR rating.

4.6 MEASUREMENTS OF SOIL MOISTURE

The attempt to quantify the field-assessed SMR's of the study sites should be interpreted cautiously, considering the limited nature of the sampling, the assumptions of the calculations used, and the problem of soil variability.

The cumulative growing season moisture deficits for the study sites and reference sites are given in Table 5. During 1983, only the GVD and VVD sites had a growing season moisture deficit. The 9 mm growing season moisture deficit for the VVD site during 1983 was well below the 114 mm average deficit calculated for the same site for the 1964 to 1982 period (Giles et al., 1985). In 1983, June and the first half of July were above average in precipitation and below average in sunshine hours in the study area.

Theta max, theta min, delta theta, soil depth, and AWSC are listed in Table 6 for the study sites and reference sites. The GVD site had both a greater AWSC and a greater growing season soil moisture deficit than the VVD site (Table 6, and 5). The slope (10-15%) and southwest aspect of the GVD site result in greater net radiation and greater E_{max} (potential evapotranspiration) for the GVD site compared to the VVD site (slope 30-40%, northwest aspect). On the basis of growing season soil moisture deficit the GVD and VVD sites have similar actual SMR's, although the GVD site may experience slightly greater soil moisture deficits.

Table 5. Cumulative growing season soil water deficits for each site between 2 June and 31 August, 1983

Site	Cumulative growing season soil water deficits (mm)	
	1983	1964-1981 average[1]
GVD	21	
VVD[2]	9	114
GD	0	
VD	0	
Reference dry SMR[2]	0	52
GF	0	
VF	0	
Reference fresh SMR[2]	0	(NA)

[1] From Giles, 1983; and Giles et al., 1985.
[2] Also studied by Giles, 1983.
(NA) not available.

Table 6. Comparison of theta max, theta min, theta max minus theta min (delta theta), soil depth, and available water storage capacity (AWSC) for study sites and reference soil moisture regime sites

Site	Theta max (m^3/m^3)	Theta min (m^3/m^3)	Delta theta (m^3/m^3)	Soil depth (m)	AWSC (mm)
GVD	.195	.044	.151	.60	91
VVD	.248	.075	.173	.43	74
GD	.253	.058	.195	.96	187
VD	.242	.073	.169	.98	166
Reference dry SMR	.237	.072	.165	1.00	165
GF	.249	.075	.174	1.03	179
VF	.238	.072	.166	1.07	178
Reference fresh SMR	.235	.074	.161	1.13	182

The GD site had a greater AWSC than the VD site (187 mm vs 166 mm). The slope (30-40%), and northeast aspect of the GD site would further increase E_{max} differences with the VD site which had a southern aspect. The somewhat higher AWSC for the GD site compared to the reference site (187 mm vs 165 mm) suggests that either the inference of potential SMR was inaccurate, or that the AWSC calculations were not accurate. In particular, the calculation of theta min which involved empirical relationships and a general classification of soil texture, could be responsible for the difference in AWSC between the GD and VD sites. Based on AWSC and E_{max} values, the GD site would appear to be more similar to the GF and VF sites than the VD site.

The GF and VF sites would have very similar E_{max} values since slope is relatively slight (<5%) in both sites, which would minimize the effects of aspect and slope on net radiation. The AWSC values for the GF, VF and reference F sites are very similar (Table 5). On the basis of AWSC the GF and VF sites have similar actual soil moisture regimes.

Keeping in mind the limitations of the moisture measurements, the growing season soil moisture deficits and AWSC for the study sites were in the same order as the relative rankings of SMR with the possible exception of the GD site. This agrees with Giles (1983) who also found that growing season soil moisture deficits were in the same order as the relative rankings of SMR's.

4.7 VEGETATION ANALYSIS AND CLASSIFICATION

The spectra for nitrophytic and oxylophytic indicator species for the study sites are given in Figure 2. Oxylophytic species were defined as those adapted to, or preferably growing on, acid substrates with pH approximately <4.5 (Courtin et al., 1985). Nitrophytic species were defined as those adapted to, or preferably growing on, substrates with a relatively high supply of available N, primarily in the form of nitrate. From the GVD site to the VF site, there was a decrease in oxylophytic spectra and a corresponding increase in nitrophytic spectra (Fig. 2).

Nitrogen fertilization of forest sites would be expected to increase temporarily the abundance and vigor of those species which would respond to increased N availability (Pritchett, 1979). Fertilizer effects on understory vegetation are likely to be less important in the GD site, where fertilization had occurred seven growing seasons before the study, compared to the GF site which had been fertilized three growing seasons prior to the study.

For the GD site, as the effects of fertilization decrease over time, it would be reasonable to assume a decrease in the nitrophytic spectrum and an increase in the oxylophytic spectrum. This would probably result in the nitrophytic and oxylophytic indicator spectra of the GD and VVD sites becoming more similar. The more recently fertilized GF site could be expected to have a decrease in the nitrophytic spectrum. Over

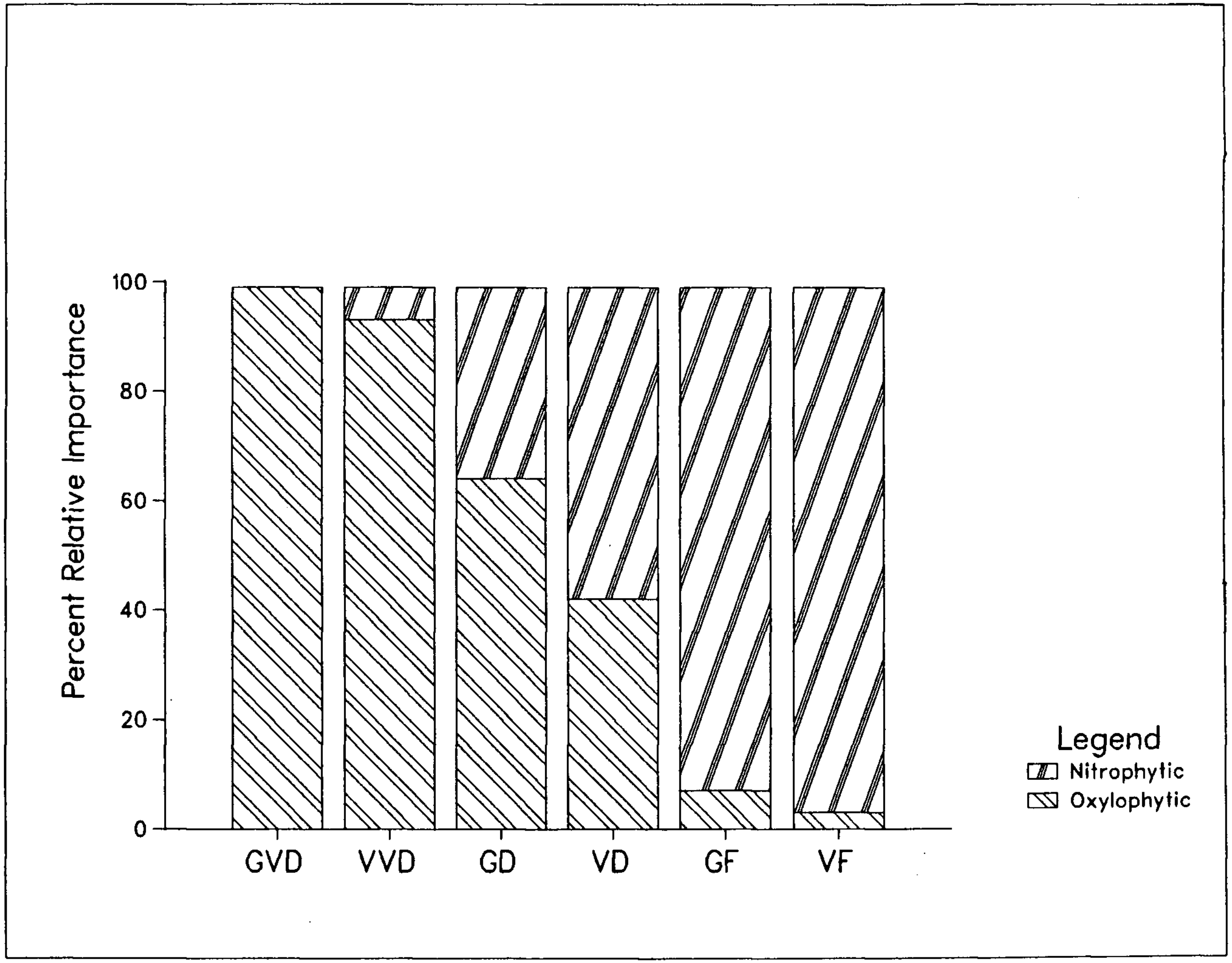

Figure 2. Nitrophytic and oxylophytic indicator spectra for the study sites

time the nitrophytic and oxylophytic spectrum of the GF site would then more closely resemble the VD site.

Three major trends were noted with the SMR spectra (Fig. 3). From the GVD site to the VF site there was an increase in the fresh to moist and moist to wet spectra. The dry to fresh spectrum increased from the VVD site, peaked in the GD site, and decreased to the VF site. The dry to moist spectrum was at a minimum in the GD site with larger values at sites GVD and VF. The presence of very dry to dry spectrum on the VVD site would suggest that it is slightly drier than the GVD site. This is in contrast to the results of the soil moisture analysis. However, the overall differences in moisture regime between the GVD and VVD sites suggested by the two analyses were relatively small.

Ordination graphs for all three combinations of axes (i.e. axes 1 and 2, 1 and 3, 2 and 3) were examined for the PCA, RA and DCA ordinations of the understory vegetation. Plot and species scores for the PCA, RA and DCA ordinations are in Appendix C.

A consistent pattern was displayed by all three multivariate techniques. The plots within each study site formed an identifiable cluster. Study sites GVD and VF were always at opposite ends of axis 1. Along axis 1 the usual ordering of the study sites was GVD, VVD, GD, VD, GF and VF. This arrangement was interpreted as reflecting a combined moisture-nutrient gradient, with the GVD site representing the drier nutrient-poorer extreme, and the VF site the wetter

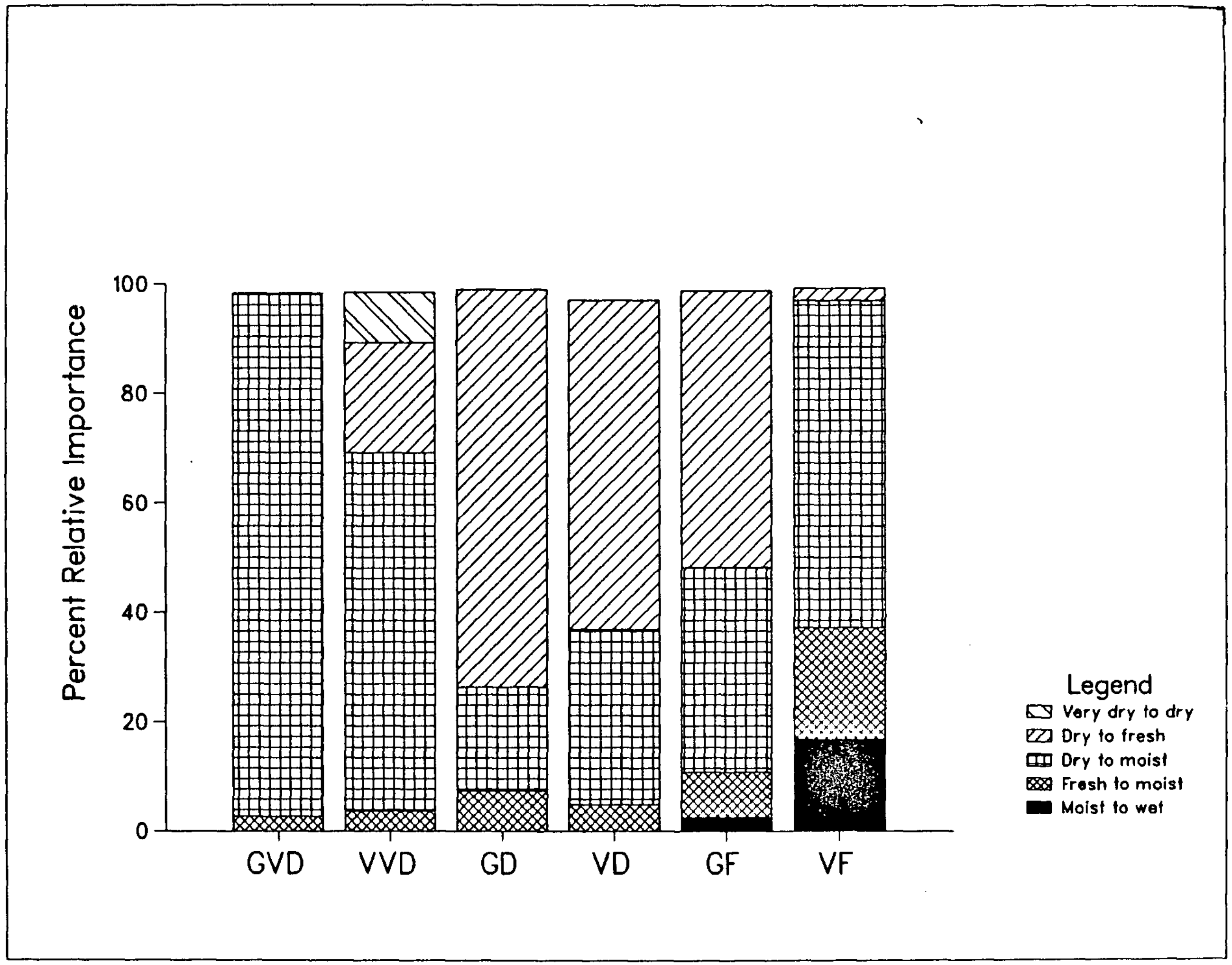

Figure 3. Soil moisture regime indicator spectra for the study sites

nutrient-richer extreme. This is illustrated in the ordination of DCA axes 1 and 2 (Fig. 4). The VVD and GD sites were distinctly separated along axis 2 of the DCA ordination (Fig. 4). This was mostly due to the high eigenvector loadings of Holodiscus discolor and Chimaphila menziesii (App. E).

A study plot by species matrix arranged by RA axis 1 scores is displayed in Table 7. A shortened species name which consists of the first four letters of the genus name and the first three of the species name is used. If one main gradient is inherent in the data, the arranged matrix will have a concentration of larger values along the matrix diagonal (Gauch, 1982). The matrix diagonal observed in Table 7 further supports the interpretation of a combined moisture-nutrient gradient.

Each multivariate analysis of the understory vegetation pattern of the study sites consistently displayed an arrangement which was interpreted as being a combined moisture-nutrient gradient. Arrangement of the study sites along the gradient was GVD, VVD, GD, VD, GF, and VF. This arrangement was similar to the field assessment of SMR and SNR, in that the two sites of equal SMR class were always adjacent (e.g. GVD, VVD) and pairs of sites with the same SNR class were also always adjacent (e.g. VVD, GD).

The classification of the study plots was done after consideration of the results of indicator plant and multivariate analyses of the vegetation data. A synopsis and diagnosis of the distinguished vegetation units are given in Tables 8 and 9, respectively.

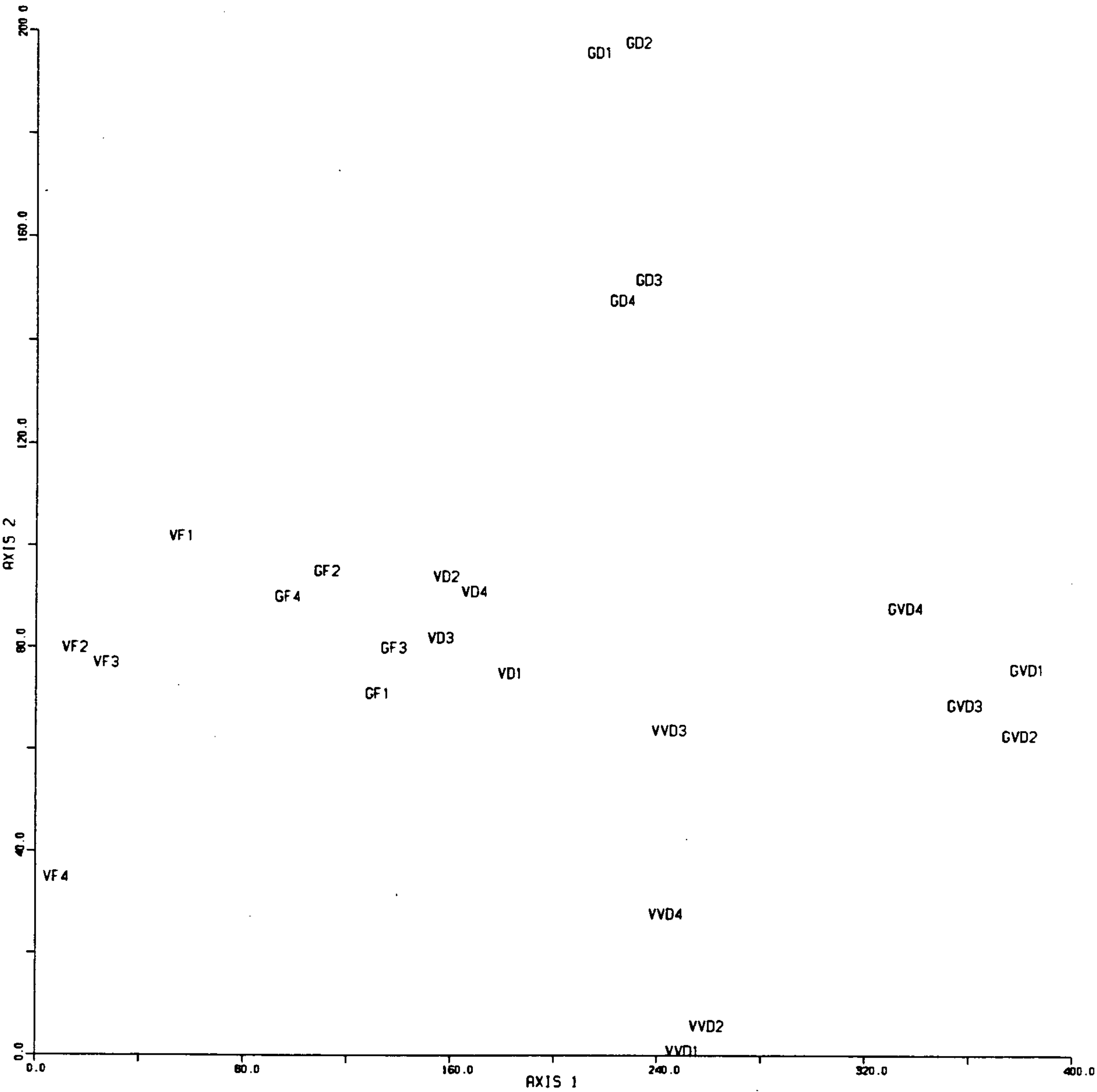

Figure 4. Ordination graph for axis 1 and axis 2 of the DCA ordination of understory vegetation data

Table 7. Arranged species by plots matrix for the study plots vegetation data. Species and plots are arranged according to axis 1 order in the RA ordination

Species	Plot
	GGGGVVVV
	VVVVVVVVGGGGVVVVGGGGVVVV
	DDDDDDDDDDDDDDDDFFFFFFFF
	123421343241142331241324
DICRFUS	43----------------------
CLADMUL	422---------------------
CLADGRA	222---------------------
TRACMEG	6553--------------------
POLYCOM	5444--------------------
BOSCHOO	2222--1-----------------
LISTCOR	-253---11---2-----------
DICRSCO	432-333-----------------
PSEUMEN	6566----3543------------
HIERALB	1-2----------------1----
RHYTROB	6-535525----------------
FESTOCC	1----2------------------
PELTLEU	122-2-2-----2-----------
PINUMON	--24--------------2-----
GAULSHA	99999989534-2---544-----
THUJPLI	665675445664----4--44---
HYLOSPL	35446668---14545--------
HOLODIS	----66-6----------------
LINNBOR	-3-2434-----7--1-4------
ROSAGYM	----6445--------4-------
GOODOBL	-----2------1-----------
RHYTLOR	--3-4-43----334-1-------
CHIMMEN	------2-13-21-----------
MAHONER	113-56666354768722------
TSUGHET	5-45335544334454-22-54--
SYMPMOL	----44-3----42-3---1----
SALISIT	2--------3-3----3-3-----
ELYMGLA	-2----------2333--------
VACCPAR	4333544432343455433-4444
KINDORE	-----6793867999989894---
PTERAQU	------2-21215233314-----
RUBUURS	----3-23--2-23553443--1-
BROMVUL	----4433--------323--2-4
DISPSMI	-------------33---------
VIOLSEM	-----3----------323-----
ACHLTRI	---234643442869775644668
TRIELAT	----1322-----34331-223-2
POLYMUN	--3354434443676676779999
STREAMP	----------------22------
MAIADIL	------------21112433----
DISPHOO	------------2-----22----
TRAUCAR	----------------4-42----
TRILOVA	--------21122---3343323-
RANUOCC	----------------2122----
GALITRI	------------33344454434-
MYCEMUR	------------33234334334-
ADENBIC	-------2----1---3143-23-
LEUCMEN	----2-----------344--43-
CAMPSCO	-----1------------11--11
RHYTTRI	----------------23-22--3
TIARTRI	------------3-43----6868
DICEFOR	----------------1------2
PLAGINS	------------------436766
ACERMAC	---------------1-------3
ATHYFIL	-------------------24333
RUBUSPE	------------------2-3354
DRYOASS	--------------------443-
TIARLAC	--------------------3444
CAREHEN	--------------------2434
MONTSIB	---------------------114

Table 8. Synopsis of seral vegetation units recognized in the study area

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Order

    Alliance

        Association

            Subassociation

Gaultherio-Pseudotsugetalia

- Gaultherio-Pseudotsugion
    - Gaultherio-Pseudotsugetum
        - $Gaultherio-Pseudotsugetum trachybryetosum
        - $Gaultherio-Pseudotsugetum mahonietosum

Polysticho-Thujetalia

- Mahonio-Thujion
    - $Mahonio-Pseudotsugetum
    - $Achlydo-Pseudotsugetum
- Tiarello-Thujion
    - $Tiarello-Pseudotsugetum

Table 9. Diagnostic combinations of species (1) for the seral vegetation units recognized in the study area based on the analysis of understory vegetation.

Order	G-P (2)			P-T		
Alliance	G-P			M-T		T-T
Association	G-P		M-P		A-P	T-P
Subassociation	G-Pt	G-Pm				
Site code	GVD	VVD	GD	VD	GF	VF
Site number	1	4	2	5	3	6
Number of plots	4	4	4	4	4	4
Species	Presence class and mean species significance (3)					
Gaultherio-Pseudotsugetalia, Gaultherio-Pseudotsugion, Gaultherio-Pseudotsugetom (all GP)						
Dicranum scoparium (d) (4)	4 2.4	4 2.1				
Rhytidiopsus robusta (d,c)	4 4.3	5 4.1				
Peltigera leucophlebia (d)	4 1.1	3 1.0		2 +.3		
Gaultheria shallon (dd,c)	5 9.5	5 8.2	4 3.3	2 +.3	4 3.5	
Hylocomium splendens (d,cd)	5 3.6	5 5.9	2 +.0	5 4.1		
Linnaea borealis (ic)	3 1.3	4 3.0		3 4.4	2 1.8	
$Gaultherio-Pseudotsugetum trachybryetosum (G-Pt)						
Cladonia multiformis (d)	4 2.1					
Cladonia gracilis (d)	4 1.2					
Trachybryum megaptilum (d,c)	5 4.7					
Polytrichum commune (d,c)	5 3.8					
Boschniakia hookeri (d,c)	5 1.5	2 +.0				
Listera cordata (d)	4 3.0	2 +.0	2 +.0	2 +.3		
$Gaultherio-Pseudotsugetom mahonietosum (G-Pm)						
Holodiscus discolor (d)		4 5.1				
Rosa gymnocarpa (d,c)		5 4.6			2 1.8	
Rhytidiadelphus loreus (d)	2 1.1	4 3.0		4 2.6	2 +.0	
Mahonia nervosa (dd,c)	4 1.3	5 5.3	5 4.5	5 6.5	3 1.0	
Symphoricarpos mollis (d)		4 3.0		4 2.4	2 +.0	
Kindbergia oregana (d)		4 6.2	5 5.8	5 9.5	5 8.0	2 1.8
Rubus ursinus (d)		4 1.9	2 +.3	5 3.7	5 3.1	2 +.0
Bromus vulgaris (d,c)		5 3.1			4 1.9	3 2.0
Trientalis latifolia (d)		4 1.4		4 2.6	4 1.4	3 1.3
Achlys triphylla (d,c)	2 +.3	5 4.3	5 3.0	5 7.2	5 5.2	5 5.6
Polystichum munitum (d,c)	3 1.7	5 3.6	5 3.3	5 5.6	5 6.1	5 9.2
Polysticho-Thujetalia (P-T)						
Achlys triphylla (dd,c)	2 +.3	5 4.3	5 3.0	5 7.2	5 5.2	5 5.6
Polystichum munitum (dd,c)	3 1.7	5 3.6	5 3.3	5 5.6	5 6.1	5 9.2
Trillium ovatum (d)			5 1.1	2 +.3	5 2.9	4 1.9
Mahonio-Thujion (M-T)						
Mahonia nervosa (d)	4 1.3	5 5.3	5 4.5	5 6.5	3 1.0	
Gaultheria shallon (d)	5 9.5	5 8.2	4 3.3	2 +.3	4 3.5	
Kindbergia oregana (d,cd)		4 6.2	5 5.8	5 9.5	5 8.0	2 1.8
Pteridium aquilinum (d)		2 +.3	5 1.1	5 3.2	4 2.3	
$Mahonio-Pseudotsugetum (M-P)						
Chimaphila menziesii (d)		2 +.3	4 1.4	2 +.0		
$Achlydo-Pseudotsugetum (A-P)						
Kindbergia oregana (d,cd)		4 6.2	5 5.8	5 9.5	5 8.0	2 1.8
Trientalis latifolia (d)		4 1.4		4 2.6	4 1.4	3 1.3
Achlys triphylla (dd)	2 +.3	5 4.3	5 3.0	5 7.2	5 5.2	5 5.6
Polystichum munitum (dd)	3 1.7	5 3.6	5 3.3	5 5.6	5 6.1	5 9.2
Maianthemum dilatatum (d)				5 1.0	5 2.7	
Galium triflorum (d)				5 2.9	5 3.8	4 3.0
Mycelis muralis (d)				5 2.3	5 3.1	4 2.6
Rubus ursinus (d,c)		4 1.9	2 +.3	5 3.7	5 3.1	2 +.0
Tiarello-Thujion (T-T), $Tiarello-Pseudotsugetum (T-P)						
Tiarella trifoliata (dd,c)				4 2.6		5 6.5
Athyrium filix-femina (d)					2 +.3	5 2.9
Plagiomnium insigne (d,cd)					3 2.2	5 5.6
Dryopteris expansa (d)						4 3.0
Polystichum munitum (dd,c)	3 1.7	5 3.6	5 3.3	5 5.6	5 6.1	5 9.2
Rubus spectabilis (d,c)					2 +.3	5 3.5
Tiarella laciniata (d,c)						5 3.3
Carex hendersonii (d,c)						5 3.0
Montia sibirica (d)						4 2.0

(1) The source for nomenclature is given in Barkman et al. 1976.

(2) Full name of vegetation units are given in Table 8.

(3) Species presence classes as % of frequency 1 = 1-20, 2 = 21-40, 3 = 41 - 60, 4 = 61 - 80, and 5 = 81 - 100. Species significance for the individual plots is based on the the ten-class abundance and dominance scale of Domin and Krajina (Mueller-Dombois and Ellenberg, 1974).

(4) Diagnostic values for plant species areas follows: c, constant; cd, constant dominant; d, differential; dd, dominant differential; ic, important companion; (from Pojar et al., 1985)

Classification results showed that with one exception the lithology-moisture sampling units were floristically distinguishable. In Table 9, the Dicranum scoparium and Achlys triphylla species groups (referred to by the name of the first species in a group) separated the plots into two major groups. Within the first group (Gaultherio-Pseudotsugetum association), GVD plots were clearly separated from all other plots as well GVD from VVD plots. However, VVD plots showed floristic affinities to other, wetter and presumably nutrient-richer plots.

Within the second group (Polysticho-Thujetalia order), two subgroups were recognized: GD, VD, and GF plots (Mahonio-Thujion alliance) amd VF plots (Tiarello-Thujion alliance). GD plots were separated from VD and GF plots rather by the absence of the species included into the Kindbergia oregana species group. Of the six lithology-moisture regime sampling sites, the VD and GF were the only sites grouped into a single vegetation unit despite different lithology and moisture regime. The fertilization, thinning, and successional stage of the GF site may have contributed to the floristic grouping of this site with the VD site. Differences in soil moisture regime between the VD and GF sites suggested by indicator plant analysis and soil moisture analysis were not reflected in the tabular classification. Differentiation by the Tiarella trifoliata species group set the VF plots distinctly apart from all others.

The Douglas-fir ecosystems of the study were in two distinct age categories, early-immature (approximately 35 years old GVD, GD, GF) and late-immature (approximately 65 years old VVD, VD, VF). Possible differences due to the different successional stages of the study sites did not mask the similarities which were recognized in the multivariate analysis and classification.

The GF site had been thinned to approximately 700 stems/ ha which would increase light availability in the site. However, distribution of thinning debris created microsites which varied in the amount of light penetrating to the forest floor. This source of variability may have contributed to the lack of floristic separation between the GF and VD sites.

In spite of differences in stand age and management practices (fertilization and thinning), the understory vegetation plant communities display a consistent arrangement, which reflected a combined moisture-nutrient gradient. The position of the study sites along this inferred gradient was very similar for each technique, and corresponded to the field-assessed SNR and analysis of SMR for each site.

4.8 FOLIAR NUTRIENT STATUS

The foliar nutrient data for each study plot are given in Appendix D. For all plots, K was the macronutrient in least supply. The foliar K concentration was in the very severe deficiency range for all plots, although the K/Ca ratio suggested only a possible K deficiency. Ca or Mg status of all study plots was adequate.

N was very severely deficient in the VVD and VD plots, and slightly to moderately deficient in the VF plots. The N fertilized GD and GF plots were slightly to moderately deficient. Increasing nutrient availability assumed by the SNR classification corresponded to decreasing severity of N deficiency for the unfertilized sites.

The anticipated differences in Ca, Mg and K status due to differences in parent material lithology were not reflected in the nutrient status. As well, all SNR classes had adequate Ca and Mg and were deficient in K.

No micronutrients were indicated as being deficient in the VVD and VD plots. The Fe and AFe status of the GVD plots indicated a likely Fe deficiency. No other micronutrient was indicated as being deficient in the GVD plots.

GD plots were likely deficient in B. The GD4 plot had a slight possibility of Cu deficiency. The GD3 plot has a slight possibility of both Zn and Cu deficiency. The GF plots were all likely deficient in Fe and Zn. B was severely deficient in GF3, likely deficient in GF1 and GF4; and possibly deficient in GF2. There was a slight possibility of Cu deficiency in GF1 and GF3.

The VF1, VF2 and VF3 plots were possibly deficient in B. The VF3 plot was likely deficient in Fe. There was a slight possibility of Zn deficiency in the VF1, VF2 and VF4 plots.

The management effects of fertilization (GD, GF) and thinning (GF) may have induced B and/or Zn deficiencies in the GD and GF sites. To a lesser extent the VF site may also be affected by B and/or Zn deficiencies.

5. RESULTS AND DISCUSSION

The variability of the soil properties will be examined to aid in analyzing patterns of variability between the study sites. Univariate and multivariate analyses will be used to analyze the patterns of variation in the soil properties. Of particular interest will be determination of which properties, if any, differ between groups of study sites. In addition, the properties which best differentiate between the groups of study sites will be determined.

Relationships between understory vegetation, foliar nutrient status and productivity of Douglas-fir and the soil properties will be examined to determine if the differences in nutrient status correspond to other site characteristics. Finally, a tentative classification of the nutrient regimes of the study sites will be proposed. This classification will be compared to a recent proposal for the objective classification of soil nutrient regimes by Courtin et al. (1985).

5.1 VARIABILITY OF SOIL PROPERTIES

The variability plots for each site were chosen by the practical consideration of ensuring that there was enough sample material to complete the laboratory analyses. Because the variability plots were not chosen randomly, they should not be regarded as representing the entire site (J. Petkau, Associate Professor, Statistics Dept., U.B.C., pers. comm.).

For the purposes of comparing the coefficients of variation (CV) and sample size requirements, it was decided to consider the variability plots as representative of the sites, while realizing that the statistical assumption of random selection was violated.

5.1.1 Potential Sources of Variability Not Determined in this Study

Analytical and subsampling error were not determined during this study. However, for the forest floor properties of pH($CaCl_2$), TC, TN, TP, exCa, exMg and exK, the mean CV was <3.7% in the study of Quesnel (1980). For the mineral soil properties of pH(H_2O), pH($CaCl_2$), TN, exP, exCa, exMg and exK studied by Slavinski (1977), the mean CV was <7.4%. For both forest floor and mineral soil properties, pH values had the lowest mean CV, exchangeable bases the greatest, and TC and TN were intermediate.

Soil sampling was conducted between 1 May and 1 August during this study. Seasonal variability of properties could also be contributing to the observed variation between sites. Mineral soils were sampled during May, July and September by Slavinski (1977) to evaluate seasonal variability of chemical properties. He concluded that for the properties studied, under the climate of coastal southwestern British Columbia any seasonal variation within the main growing season was small and subordinate to spatial variation. MinN as defined in this study would include both extractable NH_4-N present at the time of sampling and the N mineralized during the incubation period. It is possible that seasonal effects on decomposition and uptake of NH_4-N could have contributed to the total variation of the minN values between the study sites.

The CV's and sample size requirements of the study site forest floors (App. I, Table 10) compare favorably with those of Quesnel (1980) and Carter (1983). For all study sites the overall order of increasing CV for forest floor properties would be as follows:

$pH(H_2O) < TC < TN < TS < TP < exMg < exCa < exK < exMn < minN.$

This is similar to both Quesnel (1980) and Carter (1983), who noted that pH, TC and TN were among the least variable properties and that Ca, Mg and K were among the most variable.

The CV's and sample size requirements of the mineral soil samples of the study sites (App. J, Table 11) were similar to or slightly lower than the same properties studied by Courtin *et al.* (1983). The slightly higher CV and sample size requirements of Courtin *et al.* (1983) could probably be attributed to the 0-30 cm sampling depth versus the 0-50 cm sampling depth of this study. Both Lewis (1976) and Slavinski (1977) noted that variability of mineral soil properties at a given depth decreased with ever increasing depth of sampling.

For all study sites the overall order of increasing CV for mineral soil properties would be as follows:

$pH(H_2O)=pH(CaCl_2) < TN < TC < exP=exMg < SO_4 < minN=exK < exMn.$

This compares to the CWHa low productivity plot of Courtin *et*

Table 10. Forest floor sample size requirement arranged by site, level of precision and allowable error

		Forest floor property									
Site	Level of precision	pH (H_2O)	TC	TN	minN	TP	TS	exCa	exMg	exK	exMn
	20%@.80	1	1	1	3	3	2	2	4	4	4
	20%@.90	1	1	2	5	5	2	4	6	7	6
GVD	20%@.95	1	2	2	7	7	3	6	8	9	9
	10%@.80	1	1	2	9	9	4	7	12	14	12
	10%@.90	2	2	4	15	15	6	12	19	22	20
	10%@.95	2	3	5	22	21	9	17	27	31	28
	20%@.80	1	1	1	6	1	1	3	2	3	2
	20%@.90	1	2	1	10	2	2	5	4	4	4
GD	20%@.95	2	2	3	14	2	2	6	5	6	6
	10%@.80	1	2	3	21	3	3	8	7	7	7
	10%@.90	2	3	5	34	4	5	13	11	12	12
	10%@.95	3	5	6	48	6	7	19	16	17	16
	20%@.80	1	1	2	10	1	1	3	2	7	7
	20%@.90	1	2	2	16	2	2	5	4	11	12
GF	20%@.95	2	3	3	22	2	3	7	5	15	17
	10%@.80	2	3	4	35	3	3	10	7	24	26
	10%@.90	3	5	6	58	4	5	16	11	39	43
	10%@.95	4	7	9	81	6	8	23	15	55	60
	20%@.80	1	1	1	3	2	2	2	2	3	2
	20%@.90	1	2	2	5	3	2	3	4	4	4
VVD	20%@.95	1	2	3	7	5	3	4	5	6	5
	10%@.80	1	2	3	10	6	4	5	7	8	7
	10%@.90	2	4	5	16	10	6	8	11	13	11
	10%@.95	2	5	7	22	13	9	11	16	18	16
	20%@.80	1	1	1	3	2	2	2	2	3	4
	20%@.90	1	1	2	5	3	3	4	3	5	6
VD	20%@.95	1	2	2	7	4	4	5	4	6	8
	10%@.80	2	3	2	10	6	4	7	6	8	12
	10%@.90	3	4	4	16	9	7	11	9	13	19
	10%@.95	3	6	5	22	13	10	15	13	19	27
	20%@.80	4	1	2	10	1	8	10	9	12	10
	20%@.90	7	1	3	16	1	13	16	15	20	17
VF	20%@.95	10	1	4	23	3	18	22	21	28	24
	10%@.80	14	1	4	36	3	29	35	34	46	38
	10%@.90	23	1	7	60	5	47	57	56	75	61
	10%@.95	32	1	10	84	6	67	80	79	106	87

Table 11. Mineral soil sample size requirement arranged by site, level of precision and allowable error

		Mineral soil property											
Site	Level of precision	pH (H_2O)	pH ($CaCl_2$)	TC	TN	minN	exP	SO_4	exCa	exMg	exK	exMn
	20%@.80	1	1	6	5	20	15	4	65	12	7	40
	20%@.90	1	1	10	8	33	24	7	106	19	12	66
GVD	20%@.95	1	1	14	11	46	34	10	151	27	16	93
	10%@.80	1	1	22	17	76	55	14	256	44	25	158
	10%@.90	1	1	36	28	125	91	23	424	72	42	262
	10%@.95	1	2	50	39	179	129	32	604	102	59	373
	20%@.80	1	1	9	6	9	4	8	17	13	9	12
	20%@.90	1	1	14	10	14	6	13	28	21	14	20
GD	20%@.95	1	1	19	13	20	9	19	40	29	20	28
	10%@.80	1	1	30	20	32	13	29	66	47	31	45
	10%@.90	1	2	50	33	53	21	48	108	78	51	74
	10%@.95	2	2	70	47	74	29	68	154	110	73	105
	20%@.80	1	1	5	4	6	10	11	7	7	8	11
	20%@.90	1	1	8	6	9	16	18	12	12	14	19
GF	20%@.95	1	1	11	8	13	23	25	17	16	19	26
	10%@.80	1	1	16	11	20	36	40	26	26	30	42
	10%@.90	1	1	26	18	33	60	66	43	42	49	69
	10%@.95	1	2	36	26	46	85	93	60	59	70	97
	20%@.80	1	1	7	7	27	17	11	19	13	9	27
	20%@.90	1	1	12	12	45	28	18	31	22	14	45
VVD	20%@.95	1	1	16	16	63	40	25	43	31	20	63
	10%@.80	1	1	26	25	106	65	41	72	50	31	105
	10%@.90	1	1	42	41	175	107	67	118	82	50	174
	10%@.95	1	1	59	58	250	153	94	168	117	71	248
	20%@.80	1	1	4	3	7	6	12	14	9	10	17
	20%@.90	1	1	7	5	11	9	20	23	15	17	27
VD	20%@.95	1	1	9	7	16	13	28	32	21	24	39
	10%@.80	1	1	14	10	24	20	46	52	33	38	63
	10%@.90	1	1	22	17	40	33	75	86	54	62	104
	10%@.95	2	2	31	24	56	47	106	122	76	88	148
	20%@.80	1	1	3	3	6	8	8	6	7	20	5
	20%@.90	1	1	5	6	10	14	13	10	11	33	7
VF	20%@.95	1	1	7	8	14	19	19	13	16	46	10
	10%@.80	1	1	9	11	21	30	30	20	24	76	15
	10%@.90	2	2	15	18	35	49	49	33	40	126	24
	10%@.95	2	2	21	25	49	70	69	47	56	179	34

al. (1983) where:

$pH(H_2O)=pH(CaCl_2) < TC=TN=exK < minN < SO_4 < exMg < exP < exCa$

and for the high productivity plot where:

$pH(H_2O) < pH(CaCl_2) < TN < TC < minN=SO_4 < exK < exMg < exP < exCa$.

Similar patterns of variability were noted by Lewis (1976) for podzolic B horizons in the CWH zone on Vancouver Island where $pH < TN = TC < exK = exCa$, and Slavinski (1977) for the 0-20 cm mineral layer in the CDFb subzone near Vancouver where $pH < TN = TC < exK < exMg < exCa$.

The pattern of variability in the above examples is quite similar in that pH has the lowest variability and exchangeable bases the greatest. Compared to the other studies the variability of exP and exMg was lower than that of exK, and minN was among the most variable properties in this study.

5.1.2 Trends in Variability

For forest floor properties, both Quesnel (1980) and Carter (1983) noted that the least variable horizon was an LF, while the most variable was an H/Ah. In general LF horizons were less variable than H/Ah horizons. For the sites in this study, the predominant forest floor horizons would be LF for the GVD and GD sites, H for the VVD, GF and VF sites, and Ah for the VF site. The Ah horizon was sampled as part of the mineral soil in this study, and only the L horizon plus any dead wood which had been visibly altered was sampled as part of the forest floor in the VF site. At the 95% confidence level with 10% allowable error, the VF site had the most variable forest floor for all properties (Table 10). This probably reflects sampling methodology, rather than inherent variability of the L horizon.

When the sites were ranked according to the maximum number of forest floor samples required to achieve the 95% confidence level with a 10% allowable error for all properties, they were ranked as VVD <VD <GVD <GD <GF <VF. This arangement could be interpreted as reflecting a number of factors. Time from last disturbance could explain the VVD site being less variable than the younger GVD, GD and GF sites. The increasing activity of soil organisms in Moders versus Mors could explain the VVD being less variable than VF and GVD, and GD being less variable than GF. In addition, the disturbance of recent fertilization and thinning could contribute to the higher variability of forest floor properties for the GF site. When forest floor minN variability was compared for the study sites, the highest minN CV's were for the recently fertilized GD and GF sites, supporting the above hypothesis.

The GVD and VVD sites had the highest sample size requirement for all mineral soil properties at the 95% confidence level with a 10% total allowable error (Table 11). The ranking in terms of increasing sample size requirement was GF <VD <GD <VF <VVD <GVD. The CWHa 'low productivity' sites of Courtin et al. (1983) which may be equivalent to the VVD and GVD sites of this study, required greater sampling intensity than the 'high productivity' plots for minN, exCa, exK, exMg, exP and SO_4. In this study, greater sampling intensity would

only be required for minN, exCa and ExP in the GVD and VVD sites. The GVD sites would require the least sampling for SO_4 and exK. A possible explanation for the increased variability of SO_4 in sites with better moisture status (VF and GF) is a more suitable leaching environment for the mobile sulfate anion.

Within-plot CV was compared to among-plot CV for the study sites for forest floor properties (App. I), and mineral soil (App. J). Similar to Courtin et al. (1983), consistent trends were not found. For mineral soil properties in the CWHa subzone Courtin et al. (1983) noted that, in general, there was a greater among-plot variability for the high productivity plots, attributing this at least partly to parent material homogeneity. They noted that variability among plots on glaciofluvial parent materials was generally less than that among plots on morainal parent materials which was less than that among alluvial parent materials. The GF site on glaciofluvial parent material was the overall least variable site in this study. However, some sites on morainal parent materials (GVD and VVD) were more variable than the alluvial (VF) and colluvial (VD) sites in this study.

All forest floor properties expressed as concentrations could only be described at the 80% confidence level, with a 20% allowable error in this study (Table 10). For mineral soil properties expressed as concentrations, in all sites only $pH(H_2O)$, TC, TN, SO_4 and exMg, could be described and only at the 80% confidence level, with a 20% allowable error. Of the mineral soil properties studied by Courtin et al. (1983) only TN and SO_4 quantities (kg/ha) tended to be more variable than their respective concentrations, but consistent differences were not found for minN, exP, exK, exMg and exCa. It is likely that mineral soil and forest floor properties expressed quantitatively in this study are generally at or below the 80% confidence level with a 20% allowable error.

In summary, variability of forest floor and mineral soil properties in this study were similar to those of other studies. Lowest variability was found with properties such as pH, TC and TN, while exCa and exMn were the most variable. Compared to the ranking of properties in other studies exP and exMg had relatively lower variability.

Consistent trends in variability were not apparent. Although for mineral soil properties of minN, exCa and exP the GVD and VVD sites were the most variable. Contributing factors to the observed variability probably include parent materials, parent material lithology, time since last disturbance and possibly moisture regime.

5.2 SELECTION OF DIFFERENTIATING CHARACTERISTICS

5.2.1 Univariate Analysis

5.2.1.1 Forest Floor Bulk Densities and Conversion Factors

The results of the ANOVA for the forest floor bulk densities and conversion factors for parent material lithology and SMR are given in Table 12. The significant interaction

Table 12. The F-values for two-way ANOVA with interaction for bulk density and conversion factor of forest floor arranged by parent material lithology (PML) and soil moisture regime (SMR)

Property	PML	SMR	PML x SMR
Forest floor bulk density	6.76**	2.45	10.20**
Forest floor conversion factor	1.54	32.82**	14.72**

** Significant at the .01 level.

between parent material lithology and SMR for forest floor bulk densities and conversion factors does not allow independent consideration of either factor (Sokal and Rolf, 1973). The results of the SNK range test for forest floor bulk densities and conversion factors on a standard basis are given in Table 13. The forest floors of the study sites display a gradient of bulk density reflecting humus form. The L horizon of the VF site had the lowest bulk density, with increasing bulk density for the Mors and the GVD and GD sites, the Moders of the GF and VD sites and the greatest bulk density in the Mor of the VVD site. The variability of both depth and bulk density of the forest floors was reflected in the lack of separation between the thin Mors (GVD, GD) and Moders (GF, VD).

5.2.1.2 Forest Floor Properties

For each forest floor property there was significant within site variation (Table 14). There was also a significant interaction between the SMR and parent material lithology for all forest floor properties except pH(H_2O). The significant interaction term indicates that the two factors should not be interpreted independently. The significant interaction also indicates that the grouping of sites by parent material and SMR did not identify the main sources of variation for most forest floor properties. Analysis of the conversion factor for the forest floors also indicates that the arrangement of SMR classes did not show a relationship to nutrient quantities of forest floors. The significant differences between forest

Table 13. The results of Student-Newman-Keuls range test (1) for forest floor bulk density and conversion factor for each study site

Property	Sites and Value					
	VF	GVD	GD	GF	VD	VVD
Forest floor bulk density (g/cc)	.100	.104	.111	.123	.136	.156
	———	———	———	———		
			———	———	———	
					———	———
	VF	GF	GVD	GD	VD	VVD
Forest floor conversion factor ($x10^4$)	1.14	2.78	3.71	3.84	4.19	6.14
		———	———	———	———	

(1) Underlined values are not significantly different at the .05 level.

Table 14. The F-values for two-way ANOVA with interaction for parent material lithology (PML) and soil moisture regime (SMR) for forest floor properties

Property	PML	SMR	PML x SMR	Plot
TC	0.41	43.73**	17.75**	20.13**
TN	1.18	19.62**	19.95**	19.42**
minN	15.48**	1.15	20.94**	7.38**
TP	12.73**	54.09**	31.66**	7.05**
TS	0.43	37.57**	29.63**	16.34**
exCa	1.84	18.23**	27.36**	8.55**
exMg	0.13	12.67**	11.28**	10.32**
exK	1.76	45.20**	10.78**	4.49**
exMn	6.82*	250.04**	67.24**	4.47**
pH(H_2O)	0.11	48.61**	3.17	1.83*

* Significant at the .05 level.

** Significant at the .01 level.

floor pH of SMR classes are explained by changes in humus form which correspond to SMR (Table 15). The VVD and GVD sites in this study both had Mors, the GD and VD sites a Mor and Moder, respectively and the GF and VF sites a Moder and a Mull, respectively.

Most forest floor nutrients had an arrangement of plot means very similar to that of TC presented in Table 16. The lowest values were for plots in the VF site, intermediate values were for the thin Mors and Moders of the GVD, GD, GF and VD sites, while the greatest values were for plots in the VVD site. As was noted for the conversion factor, this arrangement reflects differences in depth and bulk density of the forest floor materials. The variability of the chemical properties, depth of forest floor, and bulk density of forest floor would all contribute to the within site variability noted for each forest floor property. The arrangement of study sites using forest floor properties did not correspond to either SNR or the moisture-nutrient gradient of the multivariate vegetation analysis.

5.2.1.3 Mineral Soil Bulk Density and Conversion Factors

The results of the ANOVA for mineral soil bulk density and conversion factor for parent material lithology and SMR are given in Table 17. The interaction between parent material lithology and SMR was not significant. SMR classes were significantly different while parent material lithologies were not. A general tendency for granitic tills to be coarser

Table 15. Study sites, most common humus form in the study sites arranged by soil moisture regime (SMR) and soil moisture regime mean forest floor pH(H_2O)

SMR	Site	Most common humus form within study site	Mean pH(H_2O)
Very dry	GVD, VVD	Mor, Mor	4.1 a
Dry	GD, VD	Mor, Moder	4.2 a
Fresh	GF, VF	Moder, Mull	4.8 b

a-b: Values in the same column with the same letter are not significantly different at the .05 level.

Table 16. The results of Student-Newman-Keuls range test for forest floor TC values for each study plot

VF3, VF1[1,2]
VF4, VF2
GF4, GF2
GF2, GD3, GF1, GD4
GD4, GVD2, GD2, VD1
GVD2, GD2, VD1, GF3
GF3, GVD4, VD4
GVD4, VD4, VD2, GVD3
VD2, GVD3, GVD1
GVD3, GVD1, VD3
GVD1, VD3, GD1
GD1, VVD2
VVD2, VVD4
VVD1, VVD3

[1] There is no significant difference between plots in the same row.

[2] Values are arranged with lowest in the top and greatest in the bottom, within each row values increase from left to right.

Table 17. The F-values for two-way ANOVA with interaction for bulk density and conversion factor for mineral soil arranged by parent material lithology (PML) and soil moisture regime (SMR)

Property	PM	SMR	PML x SMR
Mineral soil bulk density	1.25	17.11**	0.72
Mineral soil conversion factor	0.33	15.13**	0.83

** Significant at the .01 level.

Table 18. The results of Student-Newman-Keuls range test for mineral soil bulk density and conversion factor for each soil moisture regime (SMR)

SMR	Sites	Bulk density (g/cc)	Conversion factor ($x10^6$)
Very dry	GVD, VVD	.622 a	2.81 a
Dry	GD, VD	.515 b	2.57 a
Fresh	GF, VF	.767 c	3.85 b

a-c: Values in the same column with the same letter are not significantly different at the .05 level.

textured and to have a greater coarse fragment content than volcanic tills in the Cowichan Lake area was noted by Korelus and Lewis (1976). The small number of study sites including a variety of surficial materials and the variability of mineral soil bulk density would explain the non-significant differences between parent material bulk densities in this study.

The results of the SNK range test for mineral soil bulk densities and conversion factors are included in Table 18. The very dry and dry SMR classes were not consistently separate in conversion factor values because the GVD and VVD sites included plots with less than 50 cm mineral soil, which would decrease the value of the conversion factor. The fresh SMR sites were clearly different, due to the greater value for bulk density. When the mineral soil bulk density and conversion factors were compared between sites (Table 19), the VD site was consistently the lowest, while the VF site was consistently the highest. The low coarse fragment-free bulk density of the VD site was due to the high coarse fragment content (App. E). While the trend between sites was clear, the great variability of bulk density values shows that significant differences between the sites were few.

5.2.1.4 Mineral Soil Properties

For each mineral soil property except minN and pH($CaCl_2$) there was a significant within site variability (Table 20). There was also a significant interaction between parent material lithology and SMR for all properties except TC, TN and

Table 19. The results of Student-Newman-Keuls range test (1) for mineral soil bulk density and conversion factor for each study site

Property	Site					
	VD	GD	GVD	VVD	GF	VF
Mineral soil bulk density (g/cc)	.508	.521	.602	.642	.721	.813
	VD	GD	VVD	GVD	GF	VF
Mineral soil conversion factor ($x10^6$)	2.54	2.61	2.78	2.85	3.61	4.09

(1) Underlined values are not significantly different at the .05 level.

Table 20. The F-values for two-way ANOVA with interaction for parent material lithology (PML) and soil moisture regime (SMR) for mineral soil properties

Property	PML	SMR	PML x SMR	Plot
TC	0.63	12.41**	3.21	3.09**
TN	20.51**	87.80**	1.92	3.64**
minN	54.35**	131.07**	0.89	1.38
exP	58.23**	4.52*	7.16**	8.80**
SO_4	3.51	9.12**	4.24*	3.16**
exCa	54.75**	94.67**	3.97*	3.96**
exMg	79.20**	130.38**	30.36**	3.16**
exK	0.01	4.49*	4.69*	4.00**
exMn	13.65**	5.93*	12.96**	2.94**
pH(H_2O)	56.84**	19.25	20.14**	3.17**
pH($CaCl_2$)	49.33*	74.19**	66.08**	1.47

* Significant at the .05 level.

** Significant at the .01 level.

minN. The significant interaction indicates that the grouping of sites by parent material and SMR did not identify the main sources of variation for most mineral soil properties.

The SNK range test results for comparing the SMR class means for TC, TN and minN have been included in Table 21. The fresh SMR includes sites with Moder and in particular Mull humus forms, which would incorporate greater amounts of organic material into the mineral soil, resulting in greater quantities of C and N. The trends for TC and TN also reflect the confounding of the SMR gradient with mineral soil bulk density. The values for minN are distinct for each SMR, and the observed minN increases parallel the soil moisture increase along the SMR gradient. The increase in N availability (using minN as an index of N availability) could be due to an improvement in soil moisture conditions which enhances mineralization of organic matter and the rate of N cycling. A similar increase in the amount of available soil N with increasing soil moisture content was found during a greenhouse study by Brockley (1981). The covariation of both available N and site moisture status formed a complex gradient in the forest communities studied by Pastor et al. (1982).

Mineral soil TN was significantly greater in the volcanic lithology compared to the granitic lithology (3755 kg/ha vs 2860 kg/ha). The improved Ca and Mg status of the volcanic lithology may have improved nutrient availability, and soil structure (resulting in better moisture holding capacity and aeration), which resulted in better conditions for organic

Table 21. Study sites arranged by soil moisture regime (SMR) and soil moisture regime mean values for mineral soil TC, TN, and minN

SMR	Sites	TC	TN	minN
		kg/ha		
Very dry	GVD, VVD	84,795 a	2,332 a	16 a
Dry	GD, VD	79,538 a	2,632 a	59 b
Fresh	GF, VF	115,381 b	5,738 b	156 c

a-c: Values in the same column with the same letter are not significantly different at the .05 level.

matter decomposition and enhanced N cycling. During the time since the last glaciation, this may have resulted in greater total N in the upper mineral soil of the volcanic lithology sites. The high mineral soil TN of the VF site (approx. 7000 kg/ha) would also raise the overall average of the volcanic lithology. There was insufficient information to assess the degree to which the fertilization of the GD and GF sites affected the differences in mineral soil TN between the two lithologies.

The greater minN values for the volcanic parent material compared to the granitic parent material (82 kg/ha vs 35 kg/ha) suggested an overall increased N availability. This can be attributed to a combination of factors, including: greater TN, better Ca and Mg status which improve conditions for N mineralization by soil organisms, and some upward bias of the mean by the much greater minN values for the VF site compared to all other sites (Appendix H).

The SNK range test results for mineral soil properties arranged by plot mean display several trends depending on the property. For pH(H_2O), TC, SO_4, exK and exMn there were very few study plots which were significantly different. The few significant differences between plots and the great within site variability was illustrated by the arrangement of plots for mineral soil TC (Table 22). The very low TC quantity for plot VD4 can be attributed to the low bulk density (.346 g/cc, App. E) and the resulting decrease of the conversion factor. The TC in the mineral soil was within the range for other VD

Table 22. The results of Student-Newman-Keuls range test for mineral soil TC values for each study plot

VD4, GD1, GVD1, GD4, VD3, GD3, VVD3, VD1, VVD4, VVD2, VVD1, GVD2, GVD4[1,2]

GD1, GVD1, GD4, VD3, GD3, VVD3, VD1, VVD4, VVD2, VVD1, GVD2, GVD4, GF3, VD2, GF4, GD3, VF3, GF2

GVD1, GD4, VD3, GD3, VVD3, VD1, VVD4, VVD2, VVD1, GVD2, GVD4, GF3, VD2, GF4, GD3, VF3, GF2, GF1, GD2

VVD2, VVD1, GVD2, GVD4, GF3, VD2, GF4, GD3, VF3, GF2, GF1, GD2, VF2

VF3, GF2, GF1, GD2, VF2, VF1, VF4

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1 There is no significant difference between plots in the same row.

2 Values are arranged with lowest in the top row and greatest in the bottom, within each row values increase from left to right.

plots (App. H). The high TC quantity for GD2 was attributed to disturbance during logging which mixed organic material with the mineral soil (App. F). While some individual plot values may be explained by unique factors, the overall impression for TC and the above-mentioned properties with similar patterns was that the within site variability was high, few if any sites were distinct, and even general trends were not discernable with a SNK range test.

The SNK range test results for mineral soil minN (Table 23) display a within site variability that was much less than that for mineral soil TC. Where the plot means of two different sites were 'mixed' (e.g. the GD and VVD sites), the sites were assessed as having the same SNR class (Section 4.5). The arrangement of sites was also similar to that for the combined moisture-nutrient gradient of the vegetation analysis (Section 4.7).

The SNK range test results for exP (not shown) seemed to reflect differences in parent material lithology. Most volcanic lithology plots had greater quantities of exP (13.0-51.5 kg/ha) than the granitic lithology plots (3.0-11.5 kg/ha). Only the VVD2 plot (6.6 kg/ha) was separate from the other volcanic lithology plots. The trends for exMg and exCa (not shown) also reflected the influence of parent material lithology. Greater exCa and exMg quantities were generally present in the volcanic lithology except for the GF site. This could be explained by the mixed lithology of the GF site and high mineral soil bulk density. Between site variability

Table 23. The results of Student-Newman-Keuls range test for mineral soil minN values for each study plot

GVD1, GVD4, GVD2[1,2]
GVD4, GVD2, GVD3, VVD1
GVD2, GVD3, VVD1, VVD3, GD1
GVD3, VVD1, VVD3, GD1, VVD2, VVD4, GD3, GD4
VVD3, GD1, VVD2, VVD4, GD3, GD4, GD2, VD4
VVD2, VVD4, GD3, GD4, GD2, VD4, VD1, GF4, VD3, VD2, GF3
GD3, GD4, GD2, VD4, VD1, GF4, VD3, VD2, GF3, GF1
GD4, GD2, VD4, VD1, GF4, VD3, VD2, GF3, GF1, GF2
VD1, GF4, VD3, VD2, GF3, GF1, GF2, VF3, VF2
GF1, GF2, VF3, VF2, VF1, VF4

[1] There is no significant difference between plots in the same row.

[2] Values are arranged with lowest in the top row and greatest in the bottom, within each row values increase from left to right.

for mineral soil exP, exCa and exMg was quite high. This emphasized the variability due to a combination of property variability and bulk density.

5.2.1.5 Forest Floor Plus Mineral Soil Properties

For each forest floor plus mineral soil property there was significant within site variation at the .05 level (Table 24). There were significant interactions between SMR and parent material lithology only for exMg and exMn.

The SNK range test results for comparing the SMR class means of TC, TN, minN, exCa and exK have been included in Table 25).

The SNK range test results for the SMR class means for TC, TN and minN have the same arrangement for those of the mineral soil SNK range test. The relatively thin forest floors of this study did not change the relationship of SMR classes noted for mineral soil. The same explanations of the relationships between SMR and TC, TN and minN for mineral soil would apply to forest floor plus mineral soil. The very large exCa difference which separate the fresh SMR from the others can be attributed to the greater mineral soil bulk densities of the VF and GF sites, the very high exCa values for the VF site, and the mix of lithologies in the GF site parent material.

The relationship between SMR classes for exK reflects parent material lithology in spite of the lack of significance of the lithology factor (Table 24). In spite of relatively lower bulk densities, the plots in the GVD site had large

Table 24. The F-values for two-way ANOVA with interaction for parent material lithology (PML) and soil moisture regime (SMR) for forest floor plus mineral soil properties

Property	PML	SMR	PML x SMR	Plot
TC	1.66	7.82**	1.99	2.97**
TN	30.29**	89.18**	3.03	3.07**
minN	94.99**	143.98**	2.55	2.94**
exCa	73.52**	138.52**	2.53	3.92**
exMg	96.56**	120.66**	28.04**	3.23**
exK	0.01	3.61*	2.66	3.44**
exMn	23.30**	30.83**	10.32**	3.53**

* Significant at the .05 level.

** Significant at the .01 level.

Table 25. Study sites arranged by soil moisture regime (SMR) and soil moisture regime mean values for forest floor plus mineral soil TC, TN, minN, exCa, and exK

		TC	TN	minN	exCa	exK
SMR	Sites	kg/ha				
Very dry	GVD, VVD	105,134 a	2837 a	31 a	658 a	183 ab
Dry	GD, VD	94,645 a	3080 a	74 b	705 a	148 a
Fresh	GF, VF	124,118 a	6020 b	171 c	3293 b	195 b

a-c: Values in the same column with the same letter are not significantly different at the .05 level.

quantities of exK. As a result the very dry SMR exK quantities were not significantly different from those of the fresh SMR. Parent material lithology alone does not appear as a significant factor because of the confounding effects of bulk density and possibly leaching. The fresh SMR had much greater bulk density than the other two SMR classes. The fresh SMR would have a greater soil moisture content for longer periods than the other SMR classes in this study. These would be conditions suitable for movement of relatively mobile K ions below the 50 cm soil depth sampled in this study.

The SNK range test results for forest floor plus mineral soil TN, minN and exMg arranged by study plots are given in Tables 26, 27 and 28. The results for TN display a pattern of the GVD plots at the poorest extreme with plot mean quantities progressively increasing the GD, VVD, GF and VF plots. The plots of the VD site were quite scattered. Plot VD4 had particularly low TN values. The within site variability of the other sites was less than that of the VD site. The lower mineral soil bulk density of the VF3 plot (App. E) would account for the significantly lower TN values compared to the other plots in the VF site. The separation of the GD2 plot can be attributed to the churning of organic material into the upper mineral soil during logging.

For forest floor plus mineral soil minN values (Table 27) the GVD and VF sites were quite distinct at the extremes, while plots from the GD and VVD sites and the GF and VD sites were mixed. The GD and VVD sites were both assessed as medium SNR,

Table 26. The results of Student-Newman-Keuls range test for forest floor plus mineral soil TN values for each study plot

GVD1, GVD2 GVD4, GVD3, GD1, VD4[1,2]
GVD2, GVD4, GVD3, GD1, VD4, GD3, GD4
GVD3, GD1, VD4, GD3, GD4, VVD2, VD1, VD3, VVD1, VVD4, GD2
GD3, GD4, VVD2, VD1, VD3, VVD1, VVD4, GD2, VVD3, VD2
VVD2, VD1, VD3, VVD1, VVD4, GD2, VVD3, VD2, GF3
GF3, GF4, GF2, VF3, GF1
VF2, VF4, VF1

[1] There is no significant difference between plots in the same row.

[2] Values are arranged with lowest in the top row and greatest in the bottom row, within each row values increase from left to right.

Table 27. The results of Student-Newman-Keuls range test for forest floor plus mineral soil minN values for each study plot

GVD2, GVD4, GVD1, GVD3[1,2]
GD1, VVD1, VVD3, VVD2, GD3, GD4, VVD4
VVD1, VVD3, VVD2, GD3, GD4, VVD4, GD2
VVD4, GD2, VD1, VD4, GF4
GD2, VD1, VD4, GF4, VD2, GF3, VD3
VD1, VD4, GF4, VD2, GF3, VD3, GF1, GF2
VD2, GF3, VD3, GF1, GF2, VF3
VF3, VF2
VF2, VF1, VF4

[1] There is no significant difference between plots in the same row.

[2] Values are arranged with lowest in the top row and greatest in the bottom row, within each row values increase from left to right.

Table 28. The results of Student-Newman-Keuls range test for forest floor plus mineral soil exMg values for each study plot

GDl, GD4, GVD2, VVD2, GVDl, VVD2, GVD2, GVD4, GVD3, VVDl, VVD4, GD3[1,2]
VVD2, GVDl, VVD2, GVD2, GVD4, GVD3, VVDl, VVD4, GD3, VDl, GF4,
VDl, GF4, VD4, GF3, GFl, GF2, VD2
VD4, GF3, GFl, GF2, VD2, VD3
VF3, VF2
VFl, VF4

[1] There is no significant difference between plots in the same row.

[2] Values are arranged with lowest in the top row and greatest in the bottom row, within each row values increase from left to right.

and the GF and VD sites were both assessed as rich SNR. The observed within site variability would support the similar nutrient availability (SNR) assessment for these sites. When minN and TN are compared, the scatter of the VD plots was less for minN. The SNR classes corresponded more closely to minN rather than TN for the study sites.

The forest floor and mineral soil exMg values (Table 28) did not have as many signficant differences between plots as the GVD, GD and VVD sites. Except for plots VD1 and GF4, the VD and GF plots were separated from each other, and the VF plot was distinct. Based on forest floor plus mineral soil nutrient quantities, there was not be much difference between the poor (GVD site) and medium (GD, VVD sites) SNR classes, while the rich (GF, VD sites) and very rich (VF site) SNR classes were distinct.

5.2.1.6 Univariate Analysis of Field-Assessed SNR

A one-way ANOVA with field-assessed SNR as the factor was performed on all forest floor and mineral soil properties of this study. There were significant differences between SNR classes at the .05 level for all properties except forest floor plus mineral soil exMn (Table 29). The results of the SNK range test are included in Tables 30, 31 and 32 for the forest floor, mineral soil and forest floor plus mineral soil properties, respectively.

The forest floor properties did not clearly separate or reflect the SNR classes. In general the lowest quantities were

Table 29. The F-values for one-way ANOVA for forest floor, mineral soil, and forest floor plus mineral soil properties of study sites grouped by soil nutrient regime

Forest floor		Mineral soil		Forest floor plus mineral soil	
Property	F-values	Property	F-values	Property	F-values
TC	8.23**	TC	7.33**	TC	4.78*
TN	8.36**	TN	25.13**	TN	24.96**
minN	5.28**	minN	98.20**	minN	133.03**
TP	6.29**	exP	6.46**	exCa	37.95**
TS	9.59**	SO_4	7.69**	exMg	149.49**
exCa	11.34**	exCa	34.94**	exK	4.17*
exMg	6.84**	exMg	154.32**	exMn	1.14
exK	9.06**	exK	6.27**		
exMn	5.39**	exMn	3.53**		
pH(H_2O)	12.18**	pH(H_2O)	10.60**		
		pH($CaCl_2$)	12.65**		

* Significant at .05 level.

** Significant at .01 level.

Table 30. The results of Student-Newman-Keuls range test for forest floor properties of study sites grouped by soil nutrient regime (SNR)

Property	SNR[1,2]
TC	E D B C
TN	E B D C
minN	B E D C
TP	E B D C
TS	E B D C
exCa	E B D C
exMg	E B D C
exK	E D C B
exMn	E D B C
pH(H_2O)	C B D E

[1] Mean values increase from left to right.

[2] Underlined values do not differ significantly at .05 level.

Table 31. The results of Student-Newman-Keuls range test for mineral soil properties of study sites grouped by soil nutrient regime (SNR)

Property	SRN[1,2]
TC	C B D E
TN	B C D E
minN	B C D E
exP	C B D E
SO_4	E D B C
exCa	B C D E
exMg	C B D E
exK	C D B E
exMn	C D E B
pH(H_2O)	B C E D
pH($CaCl_2$)	B C E D

[1] Mean values increase from left to right.

[2] Underlined values do not differ significantly at .05 level.

Table 32. The results of Student-Newman-Keuls range test for forest floor plus mineral soil properties of study sites grouped by soil nutrient regime (SNR)

Property	SNR[1,2]
TC	D B C E
TN	B C D E
minN	B C D E
exCa	B C D E
exMg	C B D E
exK	C D B E
exMn	NS

[1] Mean values increase from left to right.

[2] Underlined values do not differ significantly at .05 level.

NS: Factor of one way ANOVA not significant at .05 level.

for the very rich (E) class, and medium (C) the greatest (Table 30). This arrangement of SNR classes for forest floor nutrients reflected depth and bulk density relationships as described previously for the two-way ANOVA. The pH of the forest floor was the only property which was similar to the SNR assessment of the study sites. However, only the very rich (E) SNR class was significantly different.

The mineral soil nutrient properties which clearly reflected the SNR assessment were TN and minN (Table 31). To a lesser extent exCa and exMg reflected SNR but there were no significant differences between the poor (B) and medium (C) classes. The pH(H_2O) of the mineral soil also reflected SNR to some extent, but there was not a significant difference between the very rich (E) and rich (D) classes.

The forest floor plus mineral soil nutrient quantities displayed a pattern very similar to mineral soil for SNR. There was a very clear separation of SNR classes in the expected order for TN and minN, and to a lesser extent with exMg and exCa (Table 32).

5.2.2 Multivariate Analysis

The results of univariate analyses and examination of soil N quantities (App. H) did not suggest that N fertilization of the GD and GF sites had increased soil N quantities sufficiently to prevent comparison with the unfertilized sites. The TN and minN soil properties were therefore included in all multivariate analyses.

5.2.2.1 Multivariate Sample Size Analysis

The results of the multivariate sample size analysis are summarized in two complementary tables. The first table shows the sum of squares for each variable across the correlation matrix in descending order. Variables with the highest sum of squares (dispersion) are considered the best candidates for variable selection. The second table shows the specific variance and redundancy of each variable and is sorted in ascending order of redundancy. Variables with high measures of redundancy can be eliminated. However, a single variable with both a high redundancy and a high sum of squares would be the most economical variable in terms of sampling effort.

The results of the MSS analysis on forest floor property plot means are included in Table 33. One variable, TS, accounted for almost 83% of the variation, and is also the most redundant variable. The variation between plots would include all types of variation, both within-site and between-site variation. The specific variance of each property was less than the common variance. This is evidence that the forest floor properties were all very highly interrelated. The humus forms of the GVD, GD and VVD sites were Mors and in the VF site only the L horizon was sampled as forest floor. The predominant litter input in all sites would be tree foliage, which would not be disturbed or mixed with mineral soil in Mors or L horizons. The nutrient content of both litter and forest floors would reflect the complex interrelationships between moisture and nutrient availability and physiological aspects of the tree nutrition.

Table 33. Multivariate sample size analysis of forest floor properties

A. Variables Ranked by Dispersion Criterion

Rank	Property	Sum squares	% of total
1	TS	8.2567	82.567
2	minN	0.6942	6.942
3	exMn	0.3901	3.901
4	pH(H_2O)	0.3141	3.141
5	exCa	0.1650	1.650
6	exK	0.0838	0.838
7	exMg	0.0437	0.437
8	TP	0.0324	0.324
9	TN	0.0112	0.112
10	TC	0.0088	0.088

B. Redundancy of Variables and Specific Variance

Rank	Property	Variance	Specific	Common	R-squared	Redundancy
1	pH(H_2O)	1.0000	0.0907	0.9093	0.9093004	90.930
2	minN	1.0000	0.0654	0.9346	0.9346109	93.461
3	exK	1.0000	0.0407	0.9593	0.9593081	95.931
4	exCa	1.0000	0.0344	0.9656	0.9655772	96.558
5	TP	1.0000	0.0308	0.9692	0.9692404	96.924
6	exMn	1.0000	0.0302	0.9698	0.9697605	96.976
7	exMg	1.0000	0.0222	0.9778	0.9777670	97.777
8	TN	1.0000	0.0112	0.9888	0.9888054	98.881
9	TC	1.0000	0.0088	0.9912	0.9911592	99.116
10	TS	1.0000	0.0068	0.9932	0.9931928	99.319
		10.0000				965.872

The results of the MSS analysis on mineral soil property plot means are included in Table 34. One variable, exCa, accounts for almost 56% of the variation and is also the most redundant variable. The mineral soil variables are also highly interrelated. The high redundancy of the mineral soil variables may reflect the effect of bulk density on the nutrient content of the study sites. As was noted in the univariate analysis, the GF and VF sites generally had higher quantities of most nutrients.

The results of the MSS analysis of forest floor plus mineral soil properties are included in Table 35. One variable, TN, accounted for over 58% of the variation between sites and was also the most redundant. The forest floor plus mineral soil properties were less highly interrelated than the forest floor or mineral soil data sets. A unique pattern of variation between the sites was contributed by exMn, and exK also had a lower redundancy than most of the other variables. The redundancy of exMg, minN, exCa and TN suggests that these properties have a similar relationship in all the study sites. The univariate analysis of SNR suggested that these variables had the best relationship to SNR. While exMn was redundant for mineral soil, it was the least redundant of the 11 mineral soil properties. This suggests that exMn may be contributing unique variability between the study sites.

5.2.2.2 Principal Components Analysis

The correlation matrix of a PCA conducted on forest floor properties is given in Appendix K. The first PCA axis

Table 34. Multivariate sample size analysis of mineral soil properties

A. Variables Ranked by Dispersion Criterion

Rank	Property	Sum squares	% of total
1	exCa	6.1465	55.877
2	exK	1.4159	12.872
3	exMn	1.0703	9.730
4	SO_4	0.9258	8.416
5	TC	0.6694	6.085
6	exP	0.3876	3.524
7	minN	0.1941	1.764
8	pH($CaCl_2$)	0.1154	1.059
9	pH(H_2O)	0.0337	0.306
10	exMg	0.0283	0.257
11	TN	0.0131	0.119
		11.0000	100.000

B. Redundancy of Variables and Specific Variance

Rank	Property	Variance	Specific	Common	R-squared	Redundancy
1	exMn	1.0000	0.2016	0.7984	0.7984432	79.844
2	exP	1.0000	0.1873	0.8127	0.8127174	81.272
3	exK	1.0000	0.0777	0.9223	0.9223317	92.233
4	SO_4	1.0000	0.0708	0.9292	0.9291790	92.918
5	TC	1.0000	0.0593	0.9407	0.9407279	94.073
6	minN	1.0000	0.0459	0.9531	0.9530702	95.307
7	pH($CaCl_2$)	1.0000	0.0356	0.9644	0.9643556	96.436
8	exMg	1.0000	0.0202	0.9798	0.9797548	97.975
9	pH(H_2O)	1.0000	0.0176	0.9824	0.9824269	98.243
10	TN	1.0000	0.0131	0.9869	0.9869055	98.691
11	exCa	1.0000	0.0074	0.9926	0.9926068	99.261
		11.0000				1026.252

Table 35. Multivariate sample size analysis of forest floor plus mineral soil properties

A. Variables Ranked by Dispersion Criterion

Rank	Property	Sum squares	% of total
1	TN	4.0804	58.291
2	exMn	1.2131	17.330
3	exK	0.8484	12.120
4	TC	0.3955	5.650
5	exMg	0.3158	4.511
6	minN	0.0862	1.231
7	exCa	0.0607	0.867
		7.0000	100.000

B. Redundancy of Variables and Specific Variance

Rank	Property	Variance	Specific	Common	R-squared	Redundancy
1	exMn	1.0000	0.5762	0.4238	0.4238370	42.384
2	exK	1.0000	0.4597	0.5403	0.5403381	54.034
3	TC	1.0000	0.1516	0.8484	0.8484447	84.844
4	exMg	1.0000	0.0895	0.9105	0.9105024	91.050
5	minN	1.0000	0.0824	0.9176	0.9176357	91.764
6	exCa	1.0000	0.0607	0.9393	0.9393333	93.933
7	TN	1.0000	0.0369	0.9631	0.9630799	96.308
		7.0000				554.317

accounted for nearly 84% of the variation and was the only interpreted axis. The variables which were most highly correlated with the first PCA axis (in descending order) were TS, TC, TN, exMg, exCa, exK, exMn, (negative) pH(H_2O) and minN. All variables were significantly correlated with the first PCA axis at the .01 level. This suggests that there was one major trend for the forest floor properties, that of increasing nutrient quantities and decreasing pH.

The PCA was an overall summary of the univariate forest floor analyses where the sites were arranged from the low nutrient quantities but high pH of the Mull (L horizon only), to the intermediate values of the thin young Mors and thin Moders, and the greatest nutrient quantities with the well developed Mor of the VVD site. All forest floor properties were significantly correlated with one PCA axis which supports the interrelatedness of all properties suggested by the MSS analysis.

The correlation matrix of a PCA conducted on mineral soil properties is included in Appendix K. The first three PCA axes were interpretable. The first axis (57.8% of the variation) was significantly correlated (in descending order) with exCa, exMg, minN, TN, exP, pH(H_2O), TC, pH($CaCl_2$), (negatively) SO_4, exK, and exMn at the .05 level. The second axis (16% of the variation) was significantly correlated (in descending order) with exK, (negatively) pH($CaCl_2$), (negatively) pH(H_2O) and TC at the .05 level. The third mineral soil PCA axis (10.5% of the variation) was significantly correlated with (negatively) exMn and (negatively) exP at the .05 level.

The first mineral soil PCA axis suggested that there was a major trend of increasing soil nutrient quantities and increasing pH among the study sites. The only exception was a negative correlation with SO_4. This property had its greatest quantities in the VVD and GVD sites (App. H). The first mineral soil PCA axis was very highly correlated with exCa, exMg, TN and minN in particular. The second PCA axis summarized the largest remaining trend among the study sites as increasing exK values, and decreasing pH. The univariate analysis indicated that there was no clear arrangement of plot mean values for exK. The small amount of variation explained by the seecond PCA axis would support this interpretation. The correlation of exMn with both the first and third PCA axes suggested that mineral soil exMn quantities were not easily summarized as a linear function. To a lesser extent this would apply to exP as well. The relatively low redundancy for mineral soil exMn in the MSS analysis supports the interpretation of a complex non-linear pattern of variation among the study sites for exMn.

The ordination of sample plots using the mineral soil PCA axis scores is given in Fig. 5. With the exceptions of plots GD1 and VD4, the plots within sites formed identifiable clusters. Along axis 1 the GVD and GD plots were mixed, followed by the VVD plot, a mix of the VD and GF plots and the VF plot. The major separation of the GVD site from the GD site along the second axis could be attributed to lower pH values and greater exK quantities in the GVD site. The 'arched'

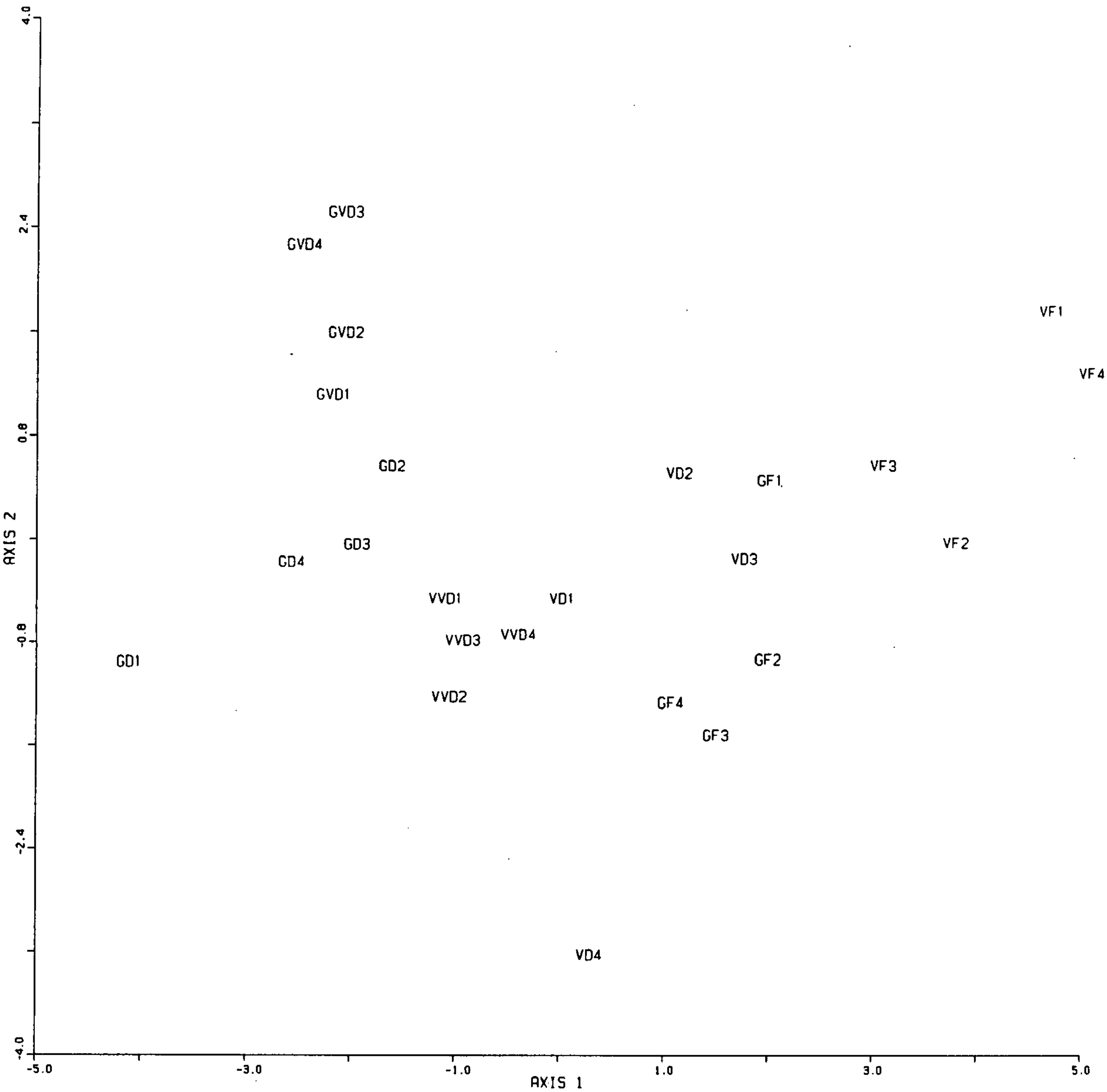

Figure 5. Ordination graph for axis 1 and axis 2 of the PCA ordination of mineral soil properties

arrangement of the study sites was similar to that of the sites along the combined moisture-nutrient gradient of the multivariate vegetation analysis (Section 4.7), GVD, GD, VVD, VD/GF, VF. The 'arched' array of stands in Fig. 5 was also the same as for SNR assessment. The properties most highly correlated with axis 1 were exCa, exMg, TN, and minN which were also the variables which corresponded best to SNR class (see Section 5.2.1.6). The lack of separation between poor and medium SNR classes with exCa and exMg (see Section 5.2.1.6) was also supported by the overlap of the GVD (poor) and GD sites (medium) (Fig. 5).

The correlation matrix for the sum of forest floor plus mineral soil properties is included in Appendix K. The first two axes were interpretable. The first PCA axis (62.3% of the variation) was highly correlated (in descending order) with TN, exCa, exMg, minN, TC, and exK at the .05 level of significance. The first axis suggested a trend of overall nutrient quantity increase among the study sites except for exK and exMn. The moderate correlation of exK with the first two PCA axes suggested that exK was not well summarized by the linear PCA functions. The negative correlation of exMn with the second mineral soil PCA axis supported the unique variation for exMn quantities among the study sites suggested by the MSS analysis.

5.2.2.3 Discriminant Analysis

Ten variables (TC, TN, minN, TP, TS, exCa, exMg, exK, exMn, pH(H_2O)) were used throughout the forest floor discriminant analyses. Five properties were used to maximize the separation of study sites. The properties and the order in which they were utilized were exMn, pH(H_2O), exCa, TP, and TN. Mineralizeable N was entered at the third step but deleted at the sixth step. All plots were correctly classified.

Three forest floor properties were used to maximize the separation of parent material lithologies. The properties and the order in which they were utilized were minN, exCa, and TP. Plots GD3 and GD4 were misclassified for parent material lithology.

Three forest floor properties were used to maximize the separation of SMR classes. The properties and the order in which they were utilized were pH(H_2O), exMn and minN. All plots were correctly classified for SMR.

Four forest floor properties were used to maximize the separation of SNR classes. The properties and the order in which they were utilized were pH(H_2O), exCa, TN, and exK. Five plots were misclassified for SNR, GVD4, GD2, GD3, VD1, and VD2.

Eleven variables (TC, TN, minN, exP, SO_4, exCa, exMg, exK, exMn, pH(H_2O), pH($CaCl_2$)) were used for the mineral soil DA. Seven mineral soil properties were used to maximize the separation of study sites. The properties and the order in which they were utilized were exMg, pH(H_2O), exMn, minN, TN, exP, and TC. All plots were correctly classified.

Four mineral soil properties were used to maximize the separation of SMR classes. The properties and the order in which they were utilized were TN, minN, exCa, and exP. All plots were correctly classified.

Six mineral soil properties were used to maximize the separation of SNR classes. The properties and the order in which they were utilized were exMg, minN, TC, TN, pH($CaCl_2$), and exCa. All plots were correctly classified.

Seven properties (TC, TN, minN, exCa, exMg, exK, exMn) were used for the forest floor plus mineral soil DA. Six properties were used to maximize the separation of study sites. The properties and the order in which they were utilized were exMg, minN, exMn, exCa, TN, and TC. All plots were correctly classified.

Three properties were used to maximize the separation of parent material lithologies. The properties and the order in which they were utilized were minN, exMn and TN. Four plots were misclassified. Plots GVD3, GF1 and GF2 were classified as volcanic lithology and VF2 was classified as granitic lithology.

Four properties were used to maximize the separation of SMR classes. The properties and the order in which they were utilized were TN, minN, exMn, and exCa. All plots were correctly classified.

Three properties were used to maximize the separation of SNR classes. The properties and the order in which they were utilized were exMg, minN and TC. All plots were correctly classified.

Two additional DA's were conducted to separate plots on the basis of SNR. Using the forest floor plus mineral soil variables with the addition of pH(H_2O) of the forest floor, and mineral soil pH(H_2O) and pH($CaCl_2$) as a data set of ten properties, only exMg, minN and TC were utilized to correctly classify all plots. Similarly with the forest floor plus mineral soil variables of exMg, minN, and exMn, plus pH(H_2O) of the forest floor as the data set, only exMg and minN were utilized to correctly classify all plots.

The addition or deletion of variables from a discriminant analysis might change the results, making a segregation better or worse (Pimental, 1979). As a result, no two groups can be proven identical with this technique. However, for the plots of this study exMg and minN quantities for forest floor plus mineral soil were consistently the best properties for separating SNR classes.

The results of all DA's are summarized in Table 36.

5.2.2.4 Cluster Analysis

A summary table which ranks important properties for distinguishing SNR classes selected by the different statistical techniques used in this study are given in Table 37. The properties chosen using results of the sample size requirement were ranked according to variability. Highly variable properties were considered of less value in characterizing an area. ANOVA and SNK range test results were ranked according to how well the increases in property means

Table 36. Summary of properties selected for separation of study plots grouped by site, parent material lithology (PML), soil moisture regime (SMR), and soil nutrient regime (SNR), using stepwise discriminant analysis

Data source	Group	Property[1]	Correct classification (%)
Forest floor	Site	exMn, pH(H_2O), exCa, TP, TN	95.8
	PML	minN, exCa, TP	91.7
	SMR	pH(H_2O), exMn, minN	100
	SNR	pH(H_2O), exCa, TN, exK	79.2
Mineral soil	Site	exMg, pH($CaCl_2$), exMn, minN, TN, exP, TC	100
	PML	exP	95.8
	SMR	TN, minN, exCa, exP	100
	SNR	exMg, minN, TC, TN, pH($CaCl_2$), exCa	100
Forest floor plus mineral soil	Site	exMg, minN, exMn, exCa, TN, TC	100
	PML	minN, exMn, TN	83.3
	SMR	TN, minN, exMn, exCa	100
	SNR	exMg, minN, TC	100

[1] Order of variable selection was left to right.

Table 37. Summary of ranking of important properties for distinguishing soil nutrient regime selected by different statistical techniques

Data source	Statistical technique	Property[1]
Forest floor	Sample size requirement	pH(H_2O), TC, TN, TS, TP, exMg
	ANOVA and SNK range test	TC, TN, pH(H_2O), exMn
	MSS	TS, TC, TN, exMg, exMn, TP
	PCA	TS, TC, TN, TP, exMg, exCa
	DA	pH(H_2O), exCa, TN, exK
Mineral soil	Sample size requirement	pH(H_2O), pH($CaCl_2$), TN, TC, exMg, exP
	ANOVA and SNK range test	TN, minN, exMg, exCa, pH(H_2O)
	MSS	exCa, TN, pH(H_2O), exMg, pH($CaCl_2$), minN
	PCA	exCa, exMg, TN, minN, exP, pH(H_2O)
	DA	exMg, minN, TC, TN, pH($CaCl_2$), exCa
Forest floor plus mineral soil	ANOVA and SNK range test	minN, TN, exCa, exMg
	MSS	TN, exCa, minN, exMg
	PCA	TN, exMg, exCa, minN, TC
	DA	exMg, minN, TC

[1] Properties are ranked in order of decreasing importance from left to right.

corresponded to the assumed increases in nutrient availability of the SNR classes. MSS properties were selected after consideration of both dispersion and redundancy. The properties selected using PCA were ranked by the degree of correlation with the first PCA axis. The DA properties were ranked in the order selected by the discriminant function.

The properties which were consistently identified as being important for distinguishing between SNR classes were TC, TN, TS, and pH(H_2O) of the forest floor; and minN, TN, exMg, and exCa for mineral soil and forest floor plus mineral soil (Table 37). The above named properties were used in Cluster Analysis (CA) as an independent test of the stability of plots grouped according to SNR.

The results of the CA using all forest floor properties is given in Fig. 6. Three broad groups can be distinguished; 1) plots VVD1, VVD3 and VVD4 which were all plots with thick Mors, 2) the VF plots which were all L horizons from Mull, and 3) all the remaining plots which were a combination of thin young Mors and Moders except for VVD2.

A similar arrangement of plots was found using TC, TN, TS, and pH(H_2O) (Fig. 7). The first large increase in error came after reducing the number of groups from three to two. The VF plots were again distinct, and the majority of thin young Mors and Moders were again grouped. Three plots, VVD2, GD1 and VD3, which had been in the large Mor plus Moder group when all variables were used, were grouped with the VVD1, VVD3 and VVD4 plots. When only TC and TN (Fig. 8) were used, there was no

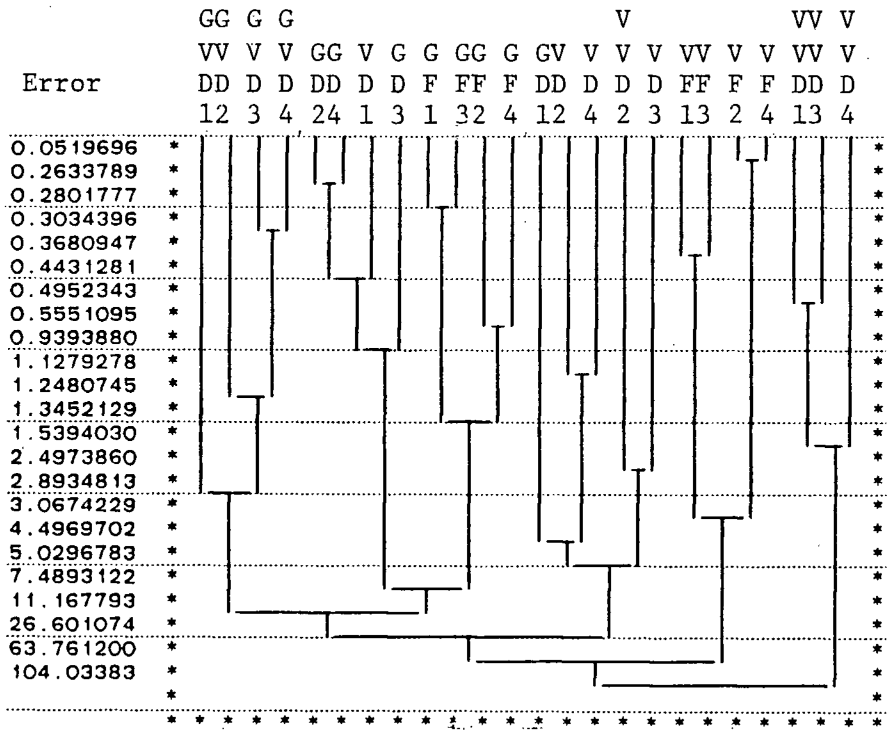

Figure 6. Cluster analysis of study plots using all forest floor properties

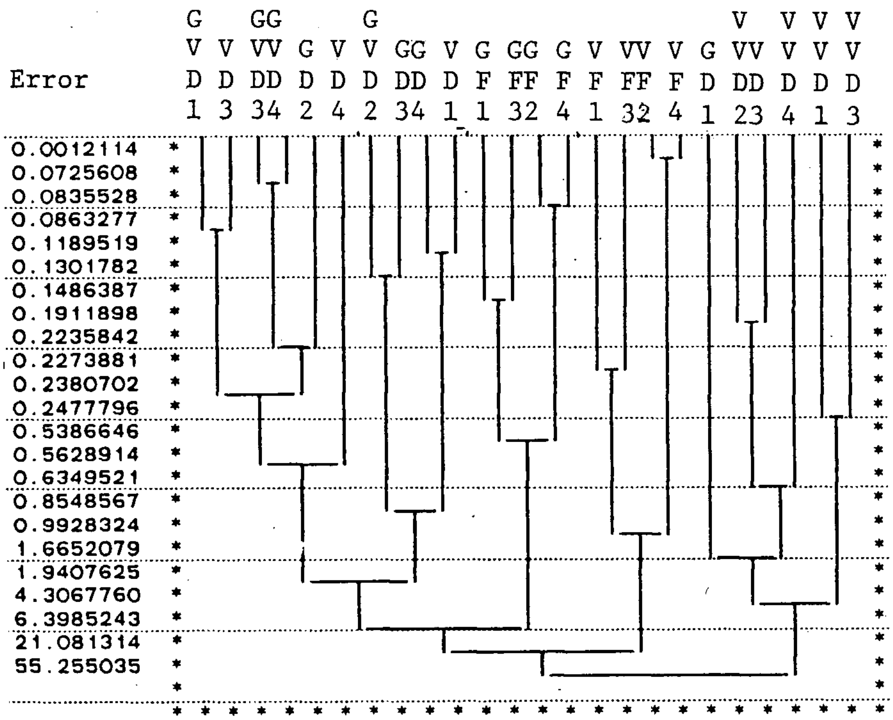

Figure 7. Cluster analysis of study plots using TC, TN, TS and $pH(H_2O)$ of forest floor

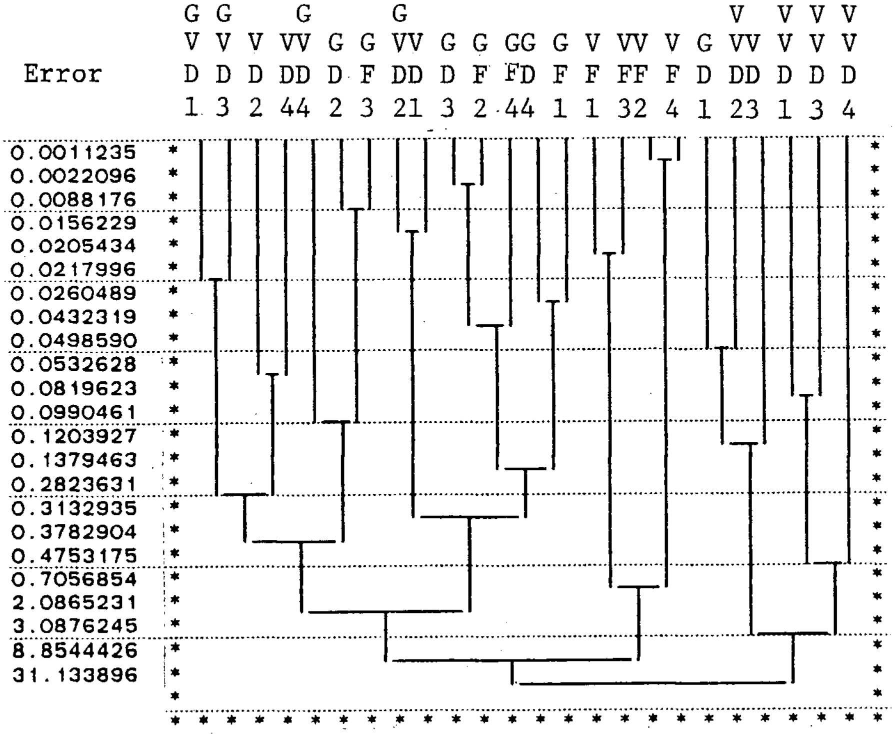

Figure 8. Cluster analysis of study plots using TC and TN of forest floor

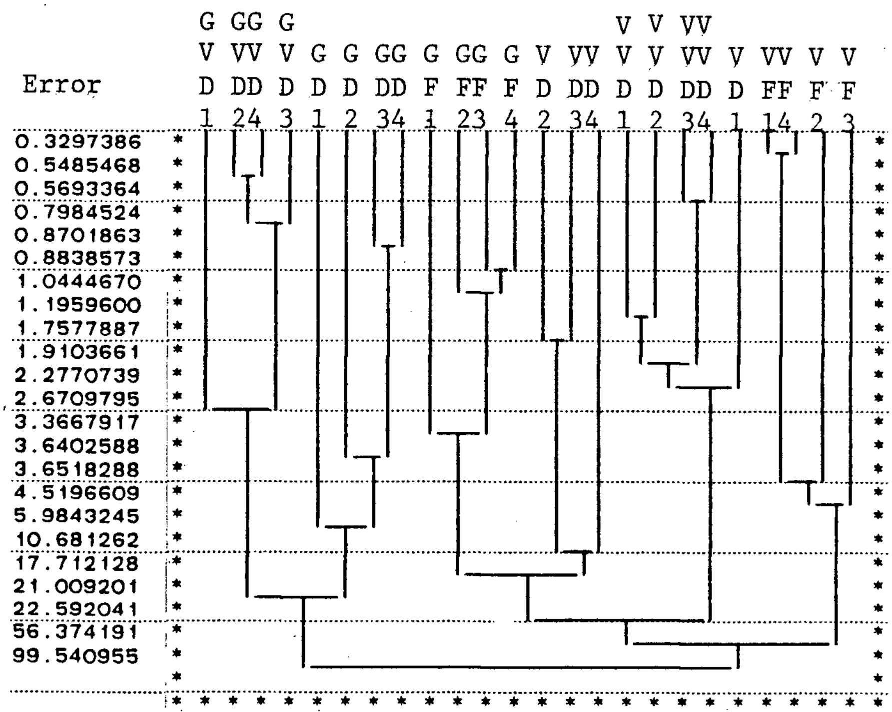

Figure 9. Cluster analysis of study plots using all mineral soil properties

change in the plots within the three main groups. This suggested that humus form differences were consistent for a broad grouping of the study plots. The GD1 plot was a Mor which included some residual areas of thicker Mor which survived disturbances and fire after logging. The VD3 plot was a Moder but had greater quantities of C and N than the other plots in the same site (App. H).

The results of the CA using all mineral soil properties is given in Fig. 9. Except for VD1 which was with the VVD plots, the grouping of plots was according to site. The VD1 plot had a lower coarse fragment-free bulk density (App. E) which would explain why all nutrient properties were more similar to the VVD plots. There was a large increase in error after reducing the number of groups from three to two. The three groups were: 1) the VF plots, 2) the GVD and GD plots, and 3) the GF, VD and VVD plots. The overall arrangement of plots suggest a nutrient gradient which emphasized exCa and exMg content.

The results of the CA using mineral soil TC, minN and exMg are given in Fig. 10. Except for the GD2 and VD4 plots, the grouping of plots was according to SNR class. Disturbance during logging incorporated organic material into the mineral soil of the GD2 plot. This resulted in greater TC and minN values, compared to other medium SNR plots (App. H). The VD4 plot had lower mineral soil TC and minN values than other rich SNR plots (App. H).

The results of the CA using all forest floor plus mineral soil properties is given in Fig. 11. The plots were grouped

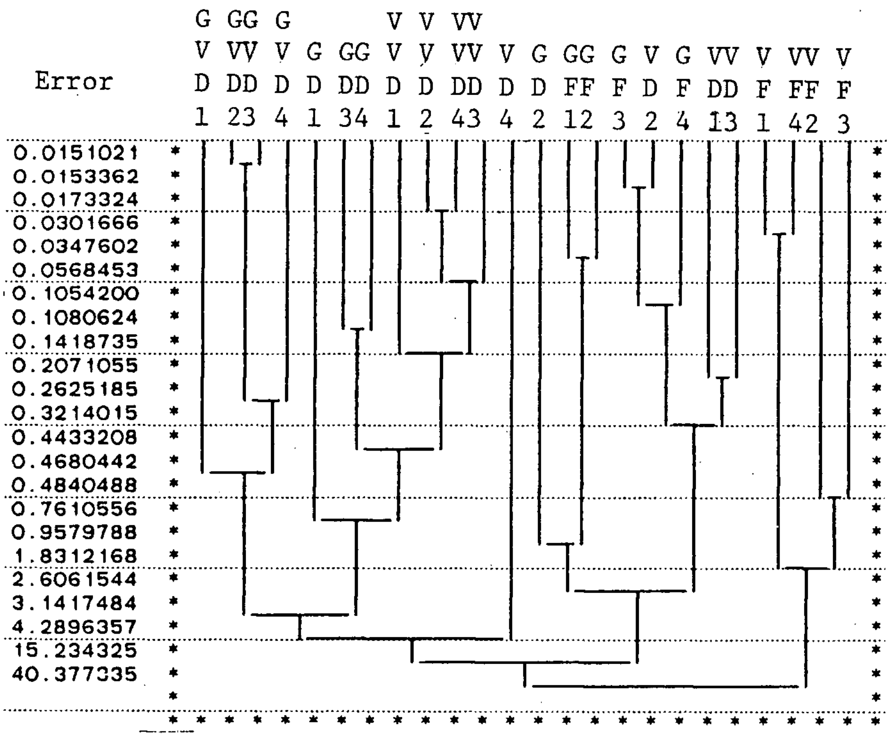

Figure 10. Cluster analysis of study plots using TC, minN, and exMg of mineral soil

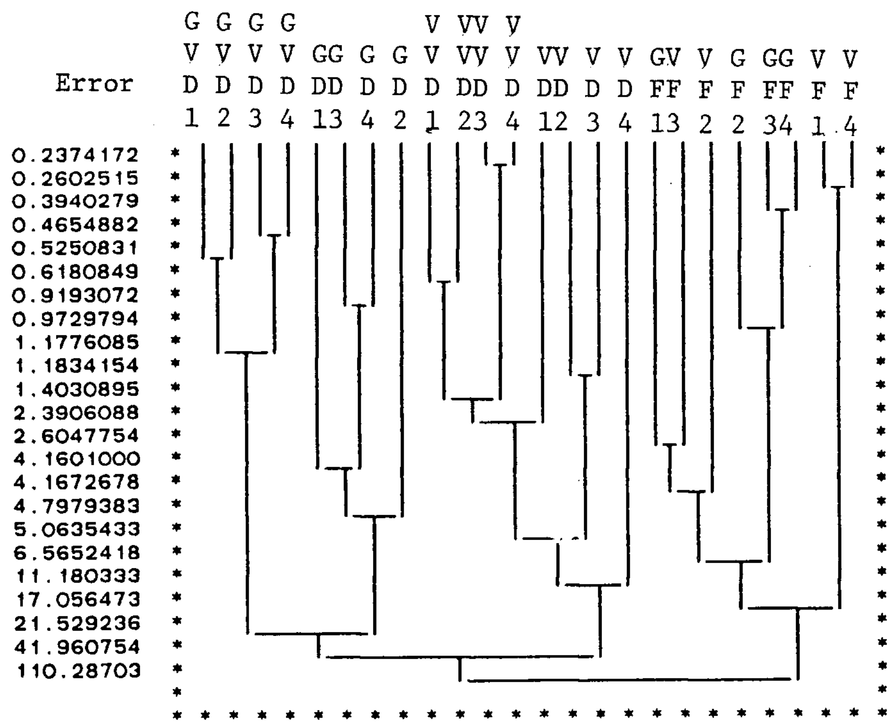

Figure 11. Cluster analysis of study plots using all forest floor plus mineral soil properties

according to study site except for the mixing of plots from the GF and VF sites. The three major groups could be attributed to parent material for the GVD, GD, VVD, and VD sites and the greater nutrient quantities of the GF and VF sites.

When only minN and exMg were used as properties the CA arranged the plots according to SNR (Fig. 12). The GVD (poor) and VF (very rich) sites were distinct, while the plots of the GD and VVD sites (medium) and the GF and VD sites (rich) were mixed. The first major increase in error value was after reducing the number of groups from four to three. The reduction to three groups was achieved by amalgamating plots which were in the poor and medium SNR classes. The non-significant differences between the poor and medium SNR classes for exMg were noted in the univariate analyses.

The results of the CA using minN and exMg of forest floor plus mineral soil and pH(H_2O) of forest floor are given in Fig. 13. Except for the VD1 plot, which was grouped with the VVD and GD plots, the arrangement of plots also reflects SNR. The pH(H_2O) of the forest floor of the VVD plot was 4.0, which was closer to the 4.1 average of the medium SNR plots than the 4.4 average of the rich SNR plots (App. H).

5.3 RELATIONSHIPS BETWEEN SOIL PROPERTIES AND VEGETATION

5.3.1 Understory Vegetation and Soil Properties

The results of canonical correlation analysis (CCA) between vegetation and soil variables are summarized in Tables

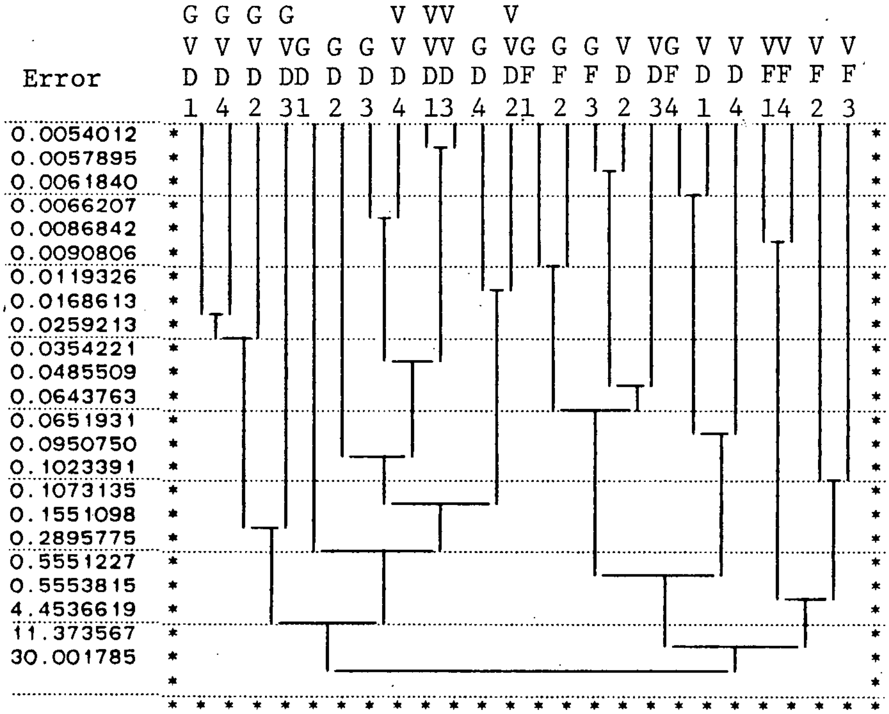

Figure 12. Cluster analysis of study plots using minN and exMg of forest floor plus mineral soil

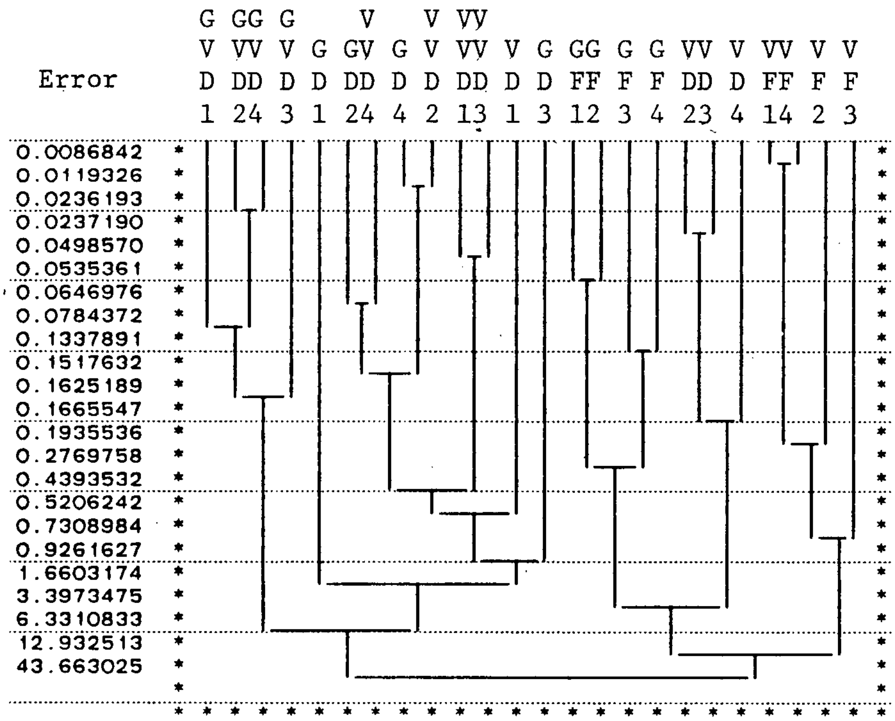

Figure 13. Cluster analysis of study plots using minN and exMg of forest floor plus mineral soil and pH(H_2O) of forest floor

38, 39 and 40. There were high canonical correlation coefficients which indicated strong linear relationships between the mineral soil properties and vegetation (r=.969), forest floor plus mineral soil properties and vegetation (r=.968) and to a lesser extent between forest floor properties and vegetation (r=.619). However, the canonical correlation coefficient is a highly unreliable index of the relationship between two data sets. As noted by Gittins (1979), it can be shown that the magnitude of at least one canonical correlation must exceed the absolute magnitude of the largest observed simple correlation between variables of different data sets.

The majority of the variation for each data set could be summarized by one axis. Only the first canonical correlation coefficient was significant at the .05 level for the vegetation-forest floor CCA, and the vegetation-forest floor plus mineral soil CCA. The second correlation coefficient of the mineral soil versus vegetation CCA was significant at the .05 level (r=.663).

The first vegetation canonical variate was most highly correlated with the forest floor properties of exMn, exK and TC (App. L). The mineral soil properties most highly correlated with the first vegetation canonical variate were minN, TC, exCa, and exMg (App. L). The forest floor plus mineral soil properties most highly correlated with the first vegetation canonical variate were minN, exCa, TN, and exMg (App. L).

Mineral soil exMn was the only property significantly correlated with both the vegetation and mineral soil second

Table 38. Correlations between forest floor PCA axis, vegetation DCA axes and canonical variates

	Canonical Variates			
Variables	FflCan1	h^2w	VegCan1	h^2b
FflPCA1	1.000	1.000	.619	.383
Variance extracted	1.000	1.000	.619	
Redundancy	.383	.383	.619	.383

	Canonical Variates			
Variables	VegCan1	h^2w	FflCan1	h^2b
VegDCA1	.877	.769	.543	.295
VegDCA2	-.486	.236	-.301	.091
VegDCA3	-.152	.023	-.094	.009
Variance extracted	.343	.343	.131	.131
Redundancy	.131	.131	.131	.131

h^2w is the communality between the variables of one data set and the canonical variates of that data set (intraset communality).

h^2b is the communality between the variables of one data set and the canonical variates of the other data set (interset communality).

Table 39. Correlations between mineral soil PCA axes, vegetation DCA axes and canonical variates

	Canonical Variates					
Variables	MinCan1	MinCan2	h^2w	VegCan1	VegCan2	h^2b
MinPCA1	-.952	-.176	.937	-.922	-.117	.881
MinPCA2	.254	.005	.065	.246	.003	.061
MinPCA3	.172	.984	.998	.166	.652	.453
Variance extracted	.333	.333	.667	.313	.146	.459
Redundancy	.313	.146	.459	.313	.146	.459

	Canonical Variates					
Variables	VegCan1	VegCan2	h^2w	MinCan1	MinCan2	h^2b
VegDCA1	.981	-.193	1.000	.951	-.128	.016
VegDCA2	.167	.950	.930	.162	.630	.397
VegDCA3	.168	.476	.255	.163	.315	.099
Variance extracted	.339	.389	.728	.319	.171	.490
Redundancy	.318	.171	.489	.319	.171	.490

h^2w is the communality between the variables of one data set and the canonical variates of that data set (intraset communality).

h^2b is the communality between the variables of one data set and the canonical variates of the other data set (interset communality).

Table 40. Correlations between forest floor plus mineral soil PCA axes, vegetation DCA axes and canonical variates

Variables	FminCanl	h^2w	VegCanl	h^2b
	Canonical Variates			
FminPCA1	-.969	.939	-.937	.878
FminPCA2	.248	.062	.240	.058
Variance extracted	.500	.500	.468	.468
Redundancy	.467	.467	.468	.468

Variables	VegCanl	h^2w	FminCanl	h^2b
	Canonical Variates			
VegDCA1	.968	.937	.936	.876
VegDCA2	.215	.046	.208	.043
VegDCA3	.217	.047	.210	.044
Variance extracted	.346	.346	.321	.321
Redundancy	.321	.321	.321	.321

h^2w is the communality between the variables of one data set and the canonical variates of that data set (intraset communality).

h^2b is the communality between the variables of one data set and the canonical variates of the other data set (interset communality).

canonical variates. This was similar to previous analyses which noted that mineral soil exMn did not follow the pattern of most other mineral soil properties.

The proportion of the total variation of a data set which is associated with a canonical variate is referred to as the variance extracted by the canonical variate (Gittins, 1979). The number of PCA axes used as variables in the canonical correlation analysis results in the variance extracted of 1.000 for the forest floor properties (one PCA axis), .500 for forest floor plus mineral soil (two PCA axes), and .333 for mineral soil (three PCA axes).

Of greater value and interest in this study is the examination of redundancy. Interset redundancy expresses the explanatory power of a canonical variate from one data set with respect to the observed variables of the other data set (Gittins, 1979). The interset redundancy for the first forest floor canonical variate was .131 (Table 38). For the first mineral soil canonical variate interset redundancy was .319 (Table 39). For the first forest floor plus mineral soil canonical variate interset redundancy was .321 (Table 40). The interset redundancy of the vegetation canonical variate was .619 for the forest floor properties, .468 for forest floor plus mineral soil properties, and .313 for mineral soil properties. The vegetation canonical variate accounted for more forest floor property variation than vice versa. The first canonical variates of the vegetation-forest floor plus mineral soil CCA had greater interset redundancy than any other vegetation-soil CCA.

The ordination of the first variates of the vegetation-forest floor CCA is given in Fig. 14. Three groups of study plots can be recognized: 1) the VF plots, 2) a mix of the GD, GF and VD plots, and 3) a diffuse group consisting of the GVD and VVD plots. The arrangement of plots along the first forest floor canonical variate was very similar to the cluster analysis of all forest floor properties, and to univariate analysis of forest floor properties. The VF plots formed one distinct group, due to the thin L horizon sampled as forest floor in this study; thick Mors of the VVD1, VVD3 and VVD4 plots were in another distinct group, and the remaining plots formed an intermediate group. The first vegetation canonical variate also distinguished three groups, 1) the VF plots, 2) the GF, VD and GD plots, and 3) the VVD and GVD plots. This arrangement of plots was similar to the tabular analysis of understory vegetation.

The ordinations of the first variates of the vegetation-mineral soil and the vegetation-forest floor plus mineral soil CCA is given in Figs. 15 and 16. The arrangement of study plots was similar in both ordinations. The plots within a site formed a fairly cohesive group. The study sites were ordered as GVD, GD, VVD, VD, GF, VF which was very similar to the GVD, VVD, GD, VD, GF, VF pattern of the combined moisture-nutrient gradient of the multivariate vegetation analyses. The CCA supports the interpretation of nutrient gradient correlated with a major trend in the vegetation. Although the first multivariate axis only accounted for approximately 25-28% (PCA

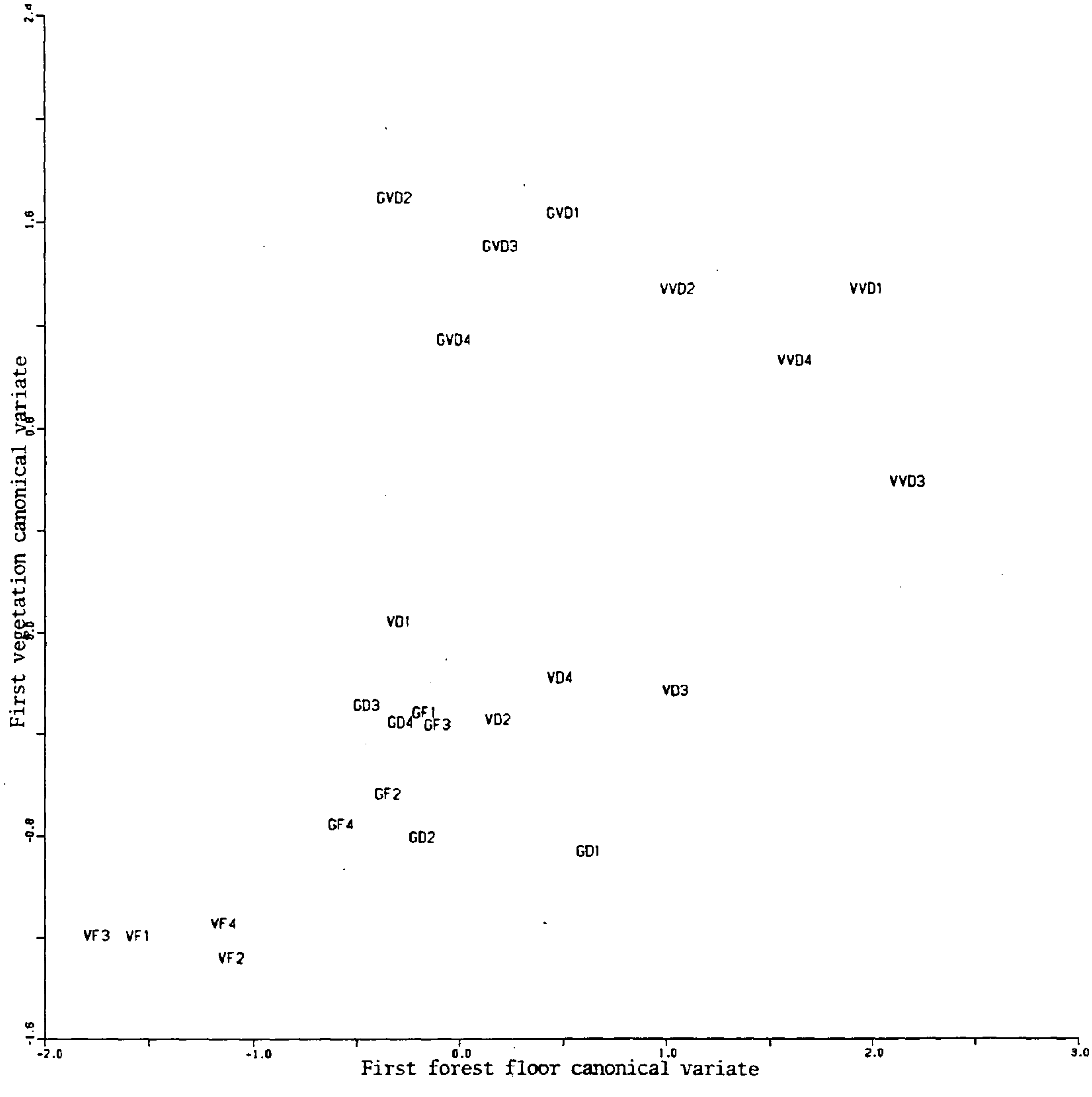

Figure 14. Relationship between forest floor properties and understory vegetation in the study sites using the first canonical variates

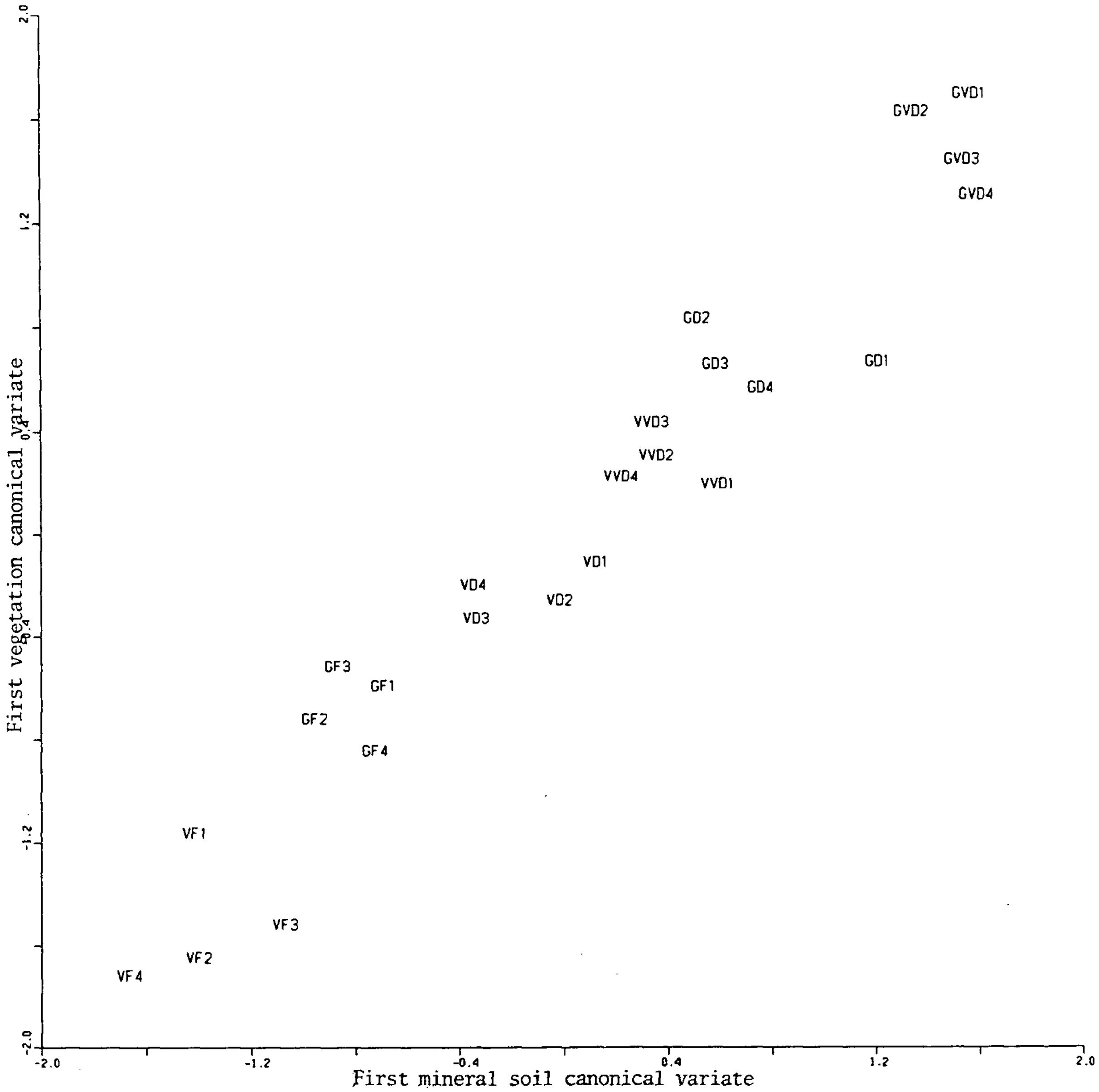

Figure 15. Relationship between mineral soil properties and understory vegetation in the study sites using the first canonical variates

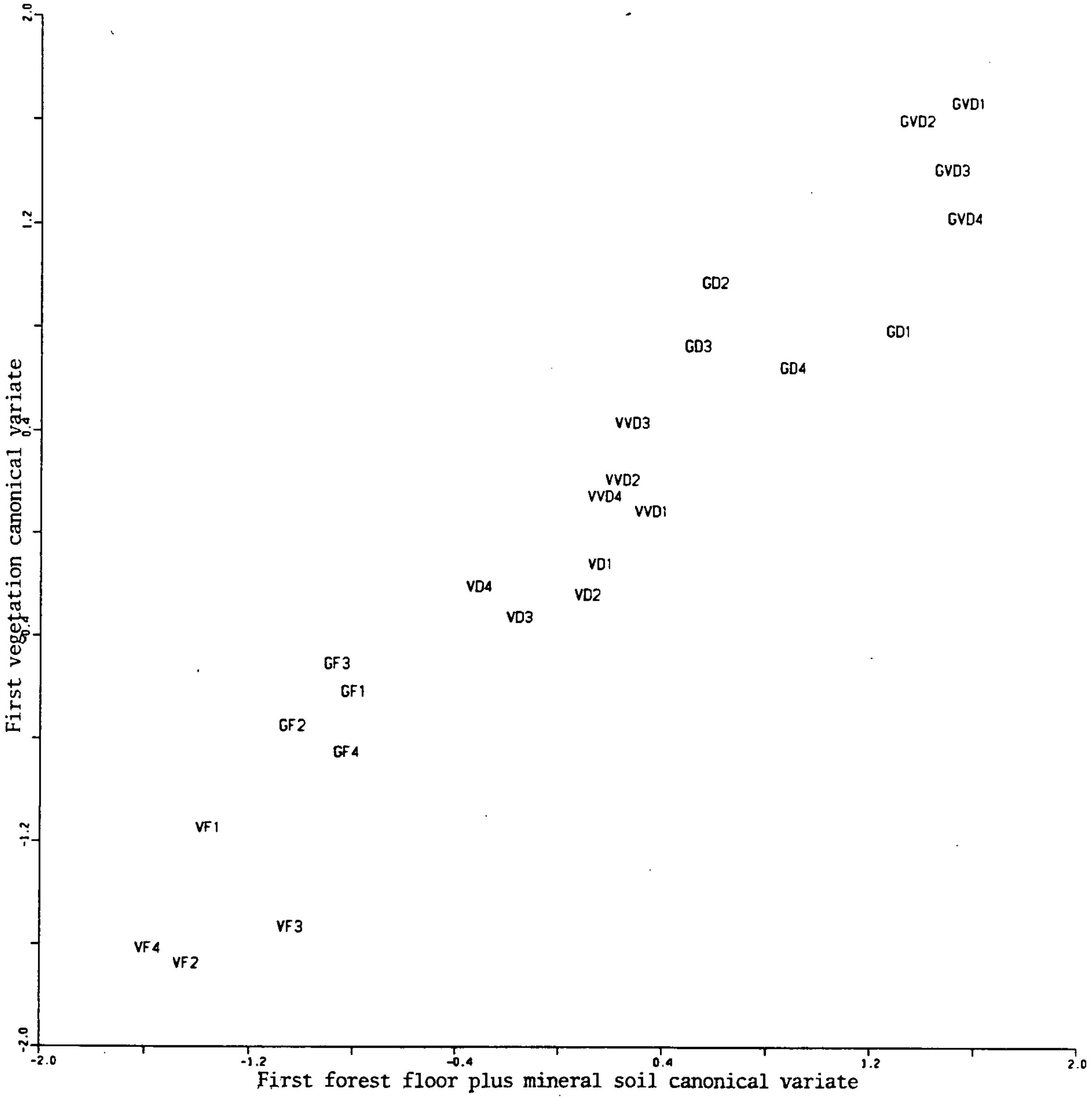

Figure 16. Relationship between forest floor plus mineral soil properties and understory vegetation in the study sites using the first canonical variates

or RA axis 1) of the total variation, it was the most important trend in variation and was consistent for each method.

The arrangement of sites in the ordinations was the same as the assessment of SNR. The sites assessed as poor (GVD) and very rich (VF) were at opposite ends of the gradient and the medium (GD, VVD) and rich (GF, VD) classes were adjacent and in the order assumed by the SNR assessment.

5.3.2 Foliar Nutrients and Soil Properties

The results of CCA between foliar nutrients expressed as concentrations and soil properties are summarized in Tables 41, 42 and 43. The canonical correlation coefficient for the first foliar canonical variate and the first canonical variates for the forest floor properties was r=.733, for mineral soil properties, r=.971, and for forest floor plus mineral soil properties, r=.966.

Only the first canonical correlation coefficient was significant at the .05 level for the foliar-forest floor CCA, and the foliar-forest floor plus mineral soil CCA. The second canonical correlation coefficient was significant for the foliar-mineral soil CCA (r=.718).

Foliar nutrients which had the highest correlations with the first forest floor canonical variate were Mn, B, Ca, and Zn (App. M). Foliar Al, N, Cu, and Mn had the highest correlations with the first mineral soil canonical variate (App. M). Foliar Al, N, Cu, and Mn had the highest correlations with the first forest floor plus mineral soil canonical variate (App. M).

Table 41. Correlations between forest floor PCA axis, foliar nutrient concentration PCA axes and canonical variates

	Canonical Variates			
Variables	FflCanl	h^2w	FolCanl	h^2b
FflPCAl	1.000	1.000	.733	.537
Variance extracted	1.000	1.000	.537	.537
Redundancy	.537	.537	.537	.537

	Canonical Variates			
Variables	FolCanl	h^2w	FflCanl	h^2b
FolPCAl	.964	.929	.706	.498
FolPCA2	.226	.051	.165	.027
FolPCA3	-.139	.019	-.102	.010
Variance extracted	.333	.333	.177	.177
Redundancy	.179	.179	.177	.177

h^2w is the communality between the variables of one data set and the canonical variates of that data set (intraset communality).

h^2b is the communality between the variables of one data set and the canonical variates of the other data set (interset communality).

Table 42. Correlations between mineral soil PCA axes, foliar nutrient concentration PCA axes and canonical variates

	Canonical Variates					
Variables	MinCan1	MinCan2	h^2w	FolCan1	FolCan2	h^2b
MinPCA1	-.930	-.118	.879	-.903	-.084	.822
MinPCA2	.343	.073	.123	.333	.052	.114
MinPCA3	-.136	.990	.999	-.132	.711	.523
Variance extracted	.333	.333	.667	.315	.172	.487
Redundancy	.314	.172	.486	.315	.172	.487

	Canonical Variates					
Variables	FolCan1	FolCan2	h^2w	MinCan1	MinCan2	h^2b
FolPCA1	.780	-.588	.954	.757	-.422	.751
FolPCA2	-.403	-.209	.206	-.392	-.150	.176
FolPCA3	.479	.781	.839	.465	.561	.531
Variance extracted	.333	.333	.667	.314	.172	.486
Redundancy	.314	.172	.486	.314	.172	.486

h^2w is the communality between the variables of one data set and the canonical variates of that data set (intraset communality).

h^2b is the communality between the variables of one data set and the canonical variates of the other data set (interset communality).

Table 43. Correlations between forest floor plus mineral soil PCA axes, foliar concentration PCA axes and canonical variates

	Canonical Variates			
Variables	FminCanl	h^2w	FolCanl	h^2b
FminPCA1	-.948	.899	-.916	.839
FminPCA2	.319	.102	.308	.095
Variance extracted	.500	.500	.467	.467
Redundancy	.467	.467	.467	.467

	Canonical Variates			
Variables	FolCanl	h^2w	FminCanl	h^2b
FolPCA1	.788	.621	.761	.579
FolPCA1	-.366	.134	-.353	.125
FolPCA3	.495	.245	.478	.228
Variance extracted	.333	.333	.311	.311
Redundancy	.311	.311	.311	.311

h^2w is the communality between the variables of one data set and the canonical variates of that data set (intraset communality).

h^2b is the communality between the variables of one data set and the canonical variates of the other data set (interset communality).

The forest floor properties most highly correlated with the first foliar canonical variate were exMn, TC, exK, and TP (App. M). The mineral soil properties most highly correlated with the first foliar canonical variate were minN, exCa, TN, and exMg (App. M). The forest floor plus mineral soil properties most highly correlated with the first foliar canonical variate were minN, exCa, TN, and exMg (App. M).

The foliar nutrients significantly correlated with both the foliar and mineral soil second canonical variates were N, P, B, and Mn (App. M). The mineral soil properties significantly correlated with both foliar and mineral soil second canonical variates were exP and exMn (App. M). This suggests that the P and Mn relationships of the study plots did not follow the pattern of most other properties.

The interset redundancy of the first foliar canonical variate was .537 for forest floor properties, .467 for forest floor plus mineral soil properties, and .315 for mineral soil properties (Tables 41, 42, 43). As with vegetation-soil CCA, the forest floor properties were the data set with the greatest variance explained by the first canonical variate of the other data set. This could be attributed to the interrelatedness of the forest floor properties which were well summarized by one linear function. For the foliar-forest floor CCA it was likely that the forest floor properties were closely related to the litter inputs which were predominantly foliage. The intermediate interset redundancy of the forest floor plus mineral soil data can be attributed to the inclusion of forest floor nutrient quantities in the properties.

The ordination of the first canonical variate of the foliar-forest floor CCA is given in Fig. 17. The pattern of study sites was similar to previous analyses with the VF and VVD plots at opposite ends of the ordination with the remaining plots forming a large intermediate group. The plots within sites formed more cohesive groups than in the vegetation-forest floor CCA ordination. For most sites the greatest dispersion of plots was along the forest floor canonical variate. This suggests that the foliar nutrient properties of most study sites were less variable than forest floor properties.

The ordinations of the first canonical variates for the foliar-mineral soil CCA and foliar-forest floor plus mineral soil CCA are given in Figs. 18 and 19. The arrangement of plots in both ordinations were very similar. Except for the GF site, plots within a site formed a recognizeable group. The arrangement of study sites was the same as for the SNR assessment (GVD, GD, VVD, VD, GF, VF). The fertilization (GD, GF) and thinning (GF) of some sites did not seem to affect the overall arrangement of the study sites, although the greater dispersion of the GF plots may be due to their more recent thinning and fertilization.

The results of CCA between foliar nutrients expressed in milligrams per 100 needles (mg/100 needles) and soil variables are summarized in Tables 44, 45 and 46. The canonical correlation coefficients for the first foliar canonical variate and the first canonical variate for forest floor properties was

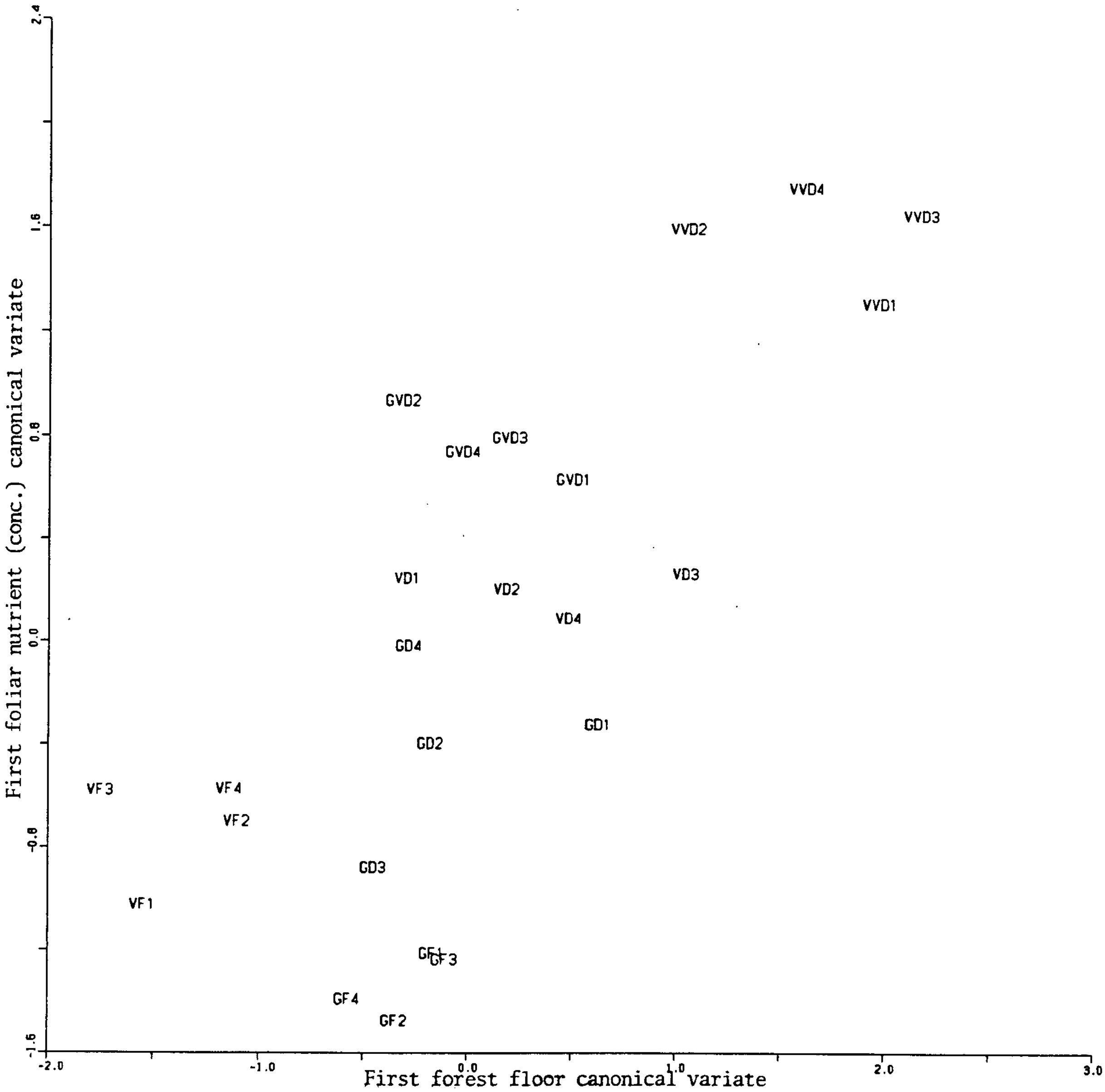

Figure 17. Relationship between forest floor properties and foliar nutrients (concentration) in the study sites using the first canonical variates

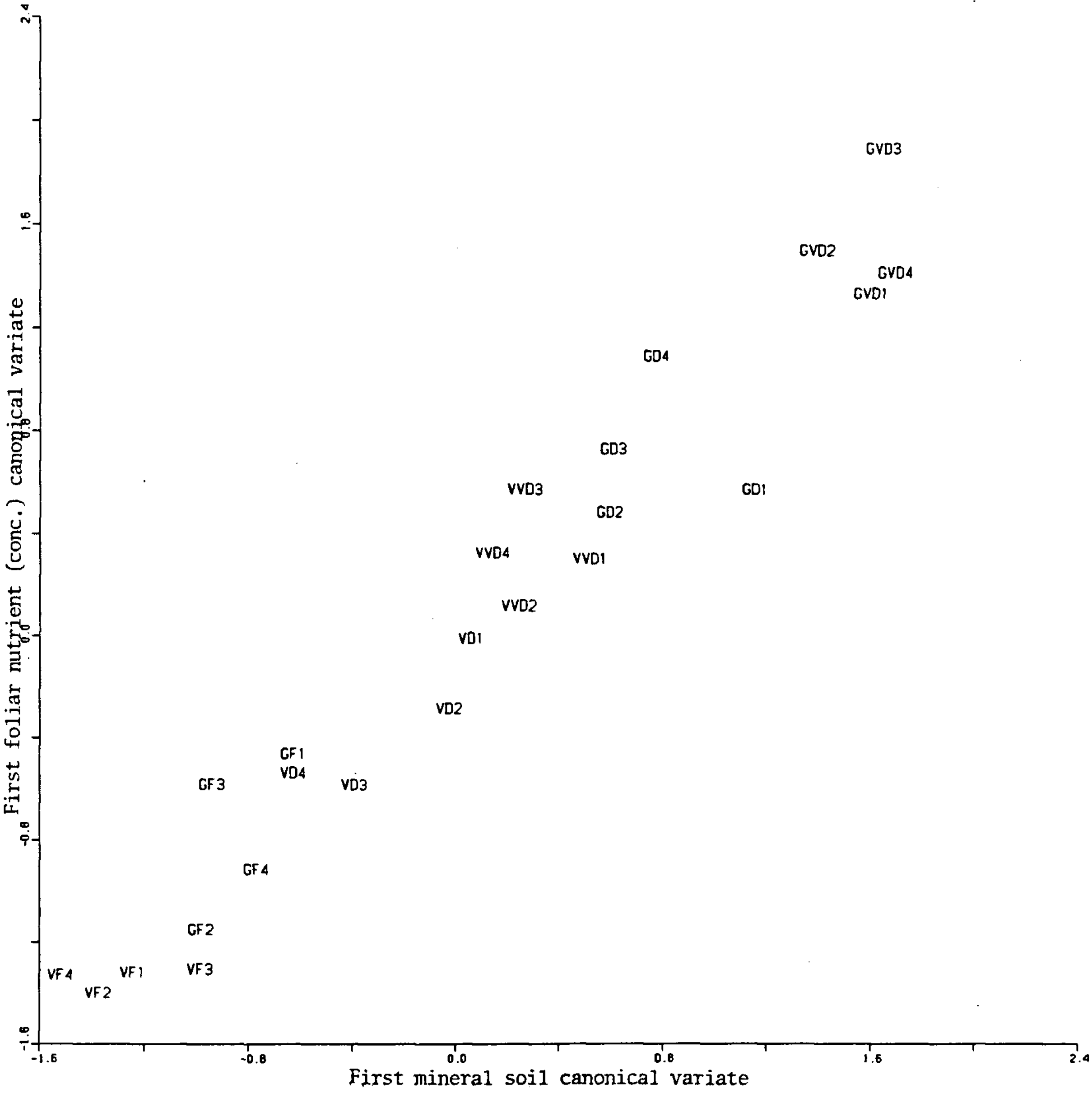

Figure 18. Relationship between mineral soil properties and foliar nutrients (concentration) in the study sites using the first canonical variates

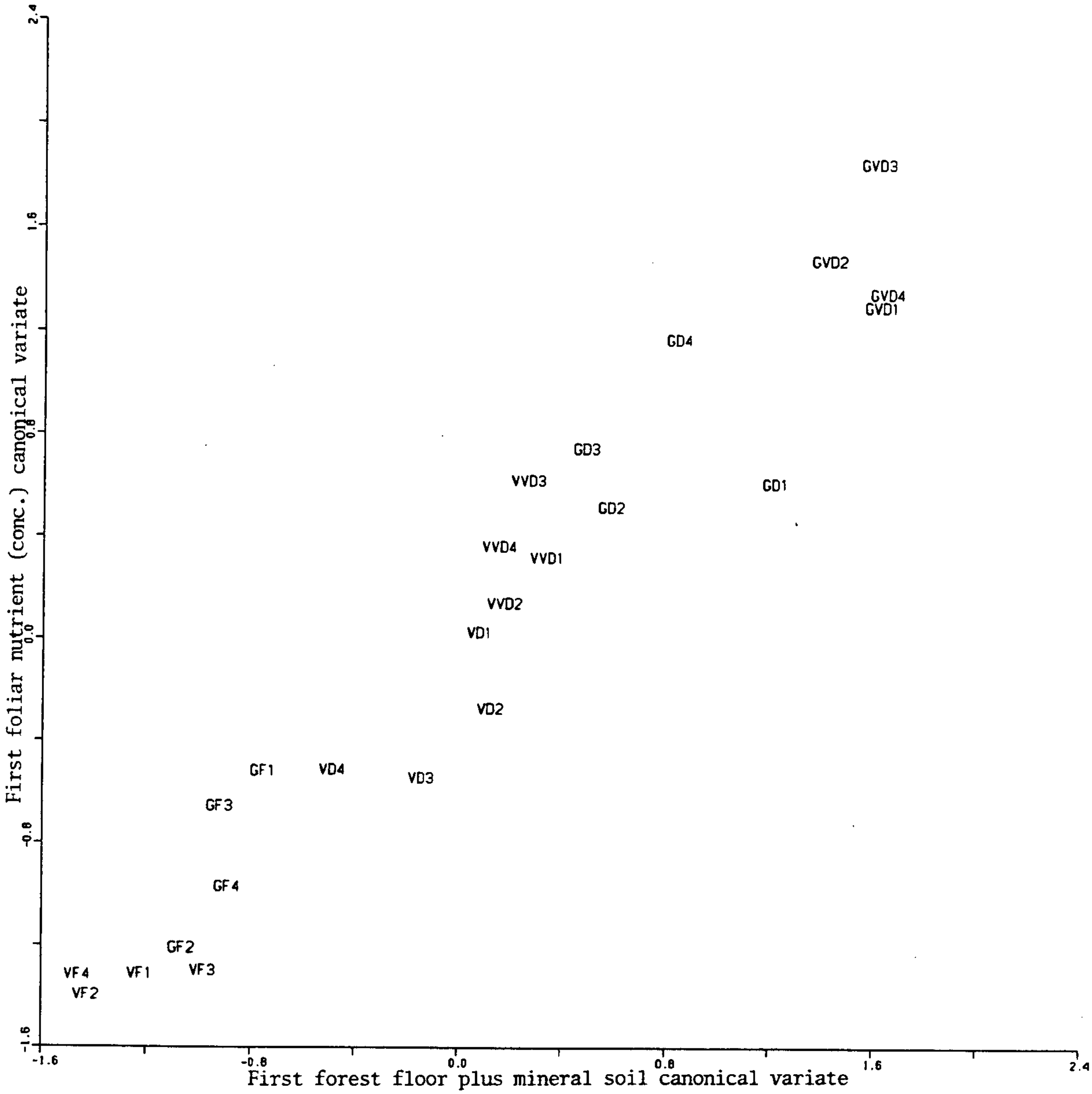

Figure 19. Relationship between forest floor plus mineral soil properties and foliar nutrients (concentration) in the study sites using the first canonical variate

Table 44. Correlations between forest floor PCA axis, foliar nutrient milligrams per 100 needles PCA axes and canonical variates

	Canonical Variates			
Variables	FflCanl	h^2w	FolmgCanl	h^2b
FflPCA1	1.000	1.000	.655	.429
Variance extracted	1.000	1.000	.429	.429
Redundancy	.429	.429	.429	.429

	Canonical Variates			
Variables	FolmgCanl	h^2w	FflCanl	h^2b
FolmgPCA1	.570	.325	.373	.139
FolmgPCA2	.740	.548	.485	.235
FolmgPCA3	.358	.128	.235	.055
Variance extracted	.333	.333	.143	.143
Redundancy	.143	.143	.143	.143

h^2w is the communality between the variables of one data set and the canonical variates of that data set (intraset communality).

h^2b is the communality between the variables of one data set and the canonical variates of the other data set (interset communality).

Table 45. Correlations between mineral soil PCA axes, foliar nutrient milligrams per 100 needles PCA axes and canonical variates

	Canonical Variates					
Variables	MinCan1	MinCan2	h^2w	FolmgCan1	FolmgCan2	h^2b
MinPCA1	-.751	-.650	.987	-.670	-.523	.722
MinPCA2	.284	-.158	.106	.254	-.127	.081
MinPCA3	-.596	.743	.907	.531	.599	.641
Variance extracted	.333	.333	.667	.265	.216	.481
Redundancy	.265	.216	.481	.265	.216	.481

	Canonical Variates					
Variables	FolmgCan1	Folmgcan2	h^2w	Mincan1	MinCan2	h^2b
FolmgPCA1	.400	.916	.999	.357	.738	.672
FolmgPCA2	.883	-.379	.923	.788	-.305	.714
FolmgPCA3	.245	-.130	.077	.218	-.105	.059
Variance extracted	.333	.333	.667	.265	.216	.481
Redundancy	.265	.216	.481	.265	.216	.481

h^2w is the communality between the variables of one data set and the canonical variates of that data set (intraset communality).

h^2b is the communality between the variables of one data set and the canonical variates of the other data set (interset communality).

Table 46. Correlations between forest floor plus mineral soil PCA axes, foliar nutrient milligrams per 100 needles PCA axes and canonical variates

	Canonical Variates			
Variables	FminCanl	h^2w	FolmgCanl	h^2b
FminPCAl	.970	.941	.832	.692
FminPCA2	-.242	.059	-.207	.043
Variance extracted	.500	.500	.367	.367
Redundancy	.378	.378	.367	.367

	Canonical Variates			
Variables	FolmgCanl	h^2w	FminCanl	h^2b
FolmgPCAl	-.831	.691	-.713	.508
FolmgPCA2	.518	.268	.445	.198
FolmgPCA3	-.202	.041	-.173	.030
Variance extracted	.333	.333	.245	.245
Redundancy	.245	.245	.245	.245

h^2w is the communality between the variables of one data set and the canonical variates of that data set (intraset communality).

h^2b is the communality between the variables of one data set and the canonical variates of the other data set (interset communality).

properties was r=.655, for mineral soil properties r=.892, and for forest forest floor plus mineral soil properties r=.858.

Only the first canonical correlation coefficient was significant for the foliar-forest floor CCA, and the foliar-forest floor plus mineral soil CCA. The second canonical correlation coefficient was also significant for the foliar-mineral soil CCA (r=.805).

Foliar nutrients in mg/100 needles which had the highest correlations with the first forest floor canonical variate were B, Mn, Zn, and Mg (App. M). Foliar Mn, B, P, and Al had the highest correlations with the first mineral soil canonical variate (App. M). Foliar P, Mn, B, and Al had the highest correlations with the first forest floor plus mineral soil canonical variate (App. M). Forest floor properties which had the highest correlations with the first foliar canonical variate were exMn, pH(H_2O), exK, and TC (App. M); mineral soil properties were minM, exMg and exCa (App. M); and forest floor plus mineral soil properties were minN, exCa, exMg and TN (App. M).

Foliar nutrients in mg/100 needles which had significant correlations with the second pair of foliar-mineral soil canonical variates included Ca, S, N, K, P, and Al (App. M). Mineral soil properties which had significant correlations with the second pair of foliar-mineral soil canonical variates included exMn, exP, exMg, and exCa (App. M).

The interset redundancy of the first foliar canonical variate was .429 for forest floor properties, .367 for forest floor plus mineral soil properties and .265 for mineral soil properties (Tables 44, 45, 46). The interset redundancy for the first forest floor canonical variate was .143 (Table 44). For the first mineral soil canonical variate interset redundancy was .265 (Table 45). For the first forest floor plus mineral soil canonical variate interset redundancy was .245 (Table 46). Interset redundancies for the second foliar-mineral soil canonical variates were both .216 (Table 45). Overall, the first foliar-forest floor plus mineral soil canonical variates had the greatest interset redundancy. The relatively equal redundancies of the first and second pairs of foliar-mineral soil variates suggests that, unlike the other CCA, there was an important second dimension to the relationship of these data sets.

The ordinations of the first canonical variates of the foliar-forest floor CCA and foliar-forest floor plus mineral soil CCA's were very similar to that of the ordinations with foliar nutrients expressed as concentration and were not presented.

The ordination of the first canonical variates of the foliar-mineral soil CCA is given in Fig. 20. The plots were in three distinguishable groups, each of which was uniform for SMR class. The foliar nutrients most highly correlated to the first pair of foliar-mineral soil canonical variates were Mn, B and P (App M). The mineral soil properties most highly correlated to the first pair of canonical variates were minN, TN and exCa (App. M). The GVD and VVD sites had high foliar

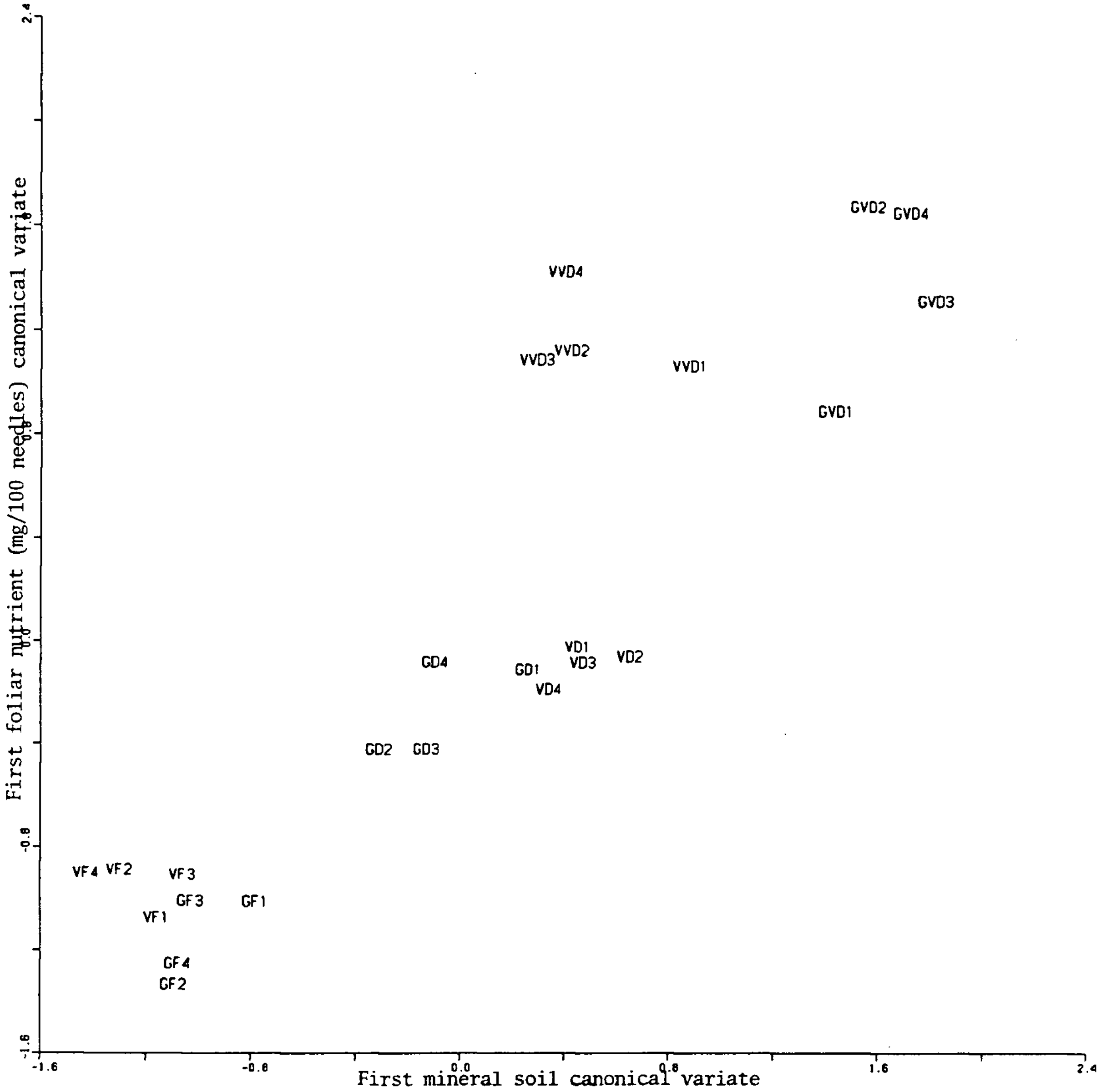

Figure 20. Relationship between mineral soil properties and foliar nutrients (mg/100 needles) in the study sites using the first canonical variates

Mn, B and P content (App. D) but low mineral soil minN, TN and exCa relative to other study sites (App. H). As noted previously, the mineral soil SMR gradient was confounded with bulk density, particularly for TN and exCa. The low foliar B of the GD and GF sites may have been fertilizer induced (Section 4.8). The VF site also had low foliar B levels (App. D). The increased mineral soil minN values were possibly related to increased moisture availability along the SMR gradient. While the arrangement of study sites in Fig. 20 does indicate a general nutrient gradient, the arrangements of sites did not correspond to the SNR assessment as well as other analyses.

5.3.3 Forest Productivity and Soil Properties

Forest productivity was estimated by determining site index of Douglas-fir. Both the site index equations of Hegyi et al. (1979) and Bruce (1981) were utilized to determine site index in m/50 years. There were no differences between the two methods for the relationships described below. Only the Bruce site index (SI) values were reported.

Site index is a useful estimate of productivity for the purposes of this study. However, it has limitations as an accurate measure of forest productivity (Hagglund, 1981). The N fertilization of the GD and GF sites will also limit the comparability of the SI values between sites.

The mean Bruce's SI for all study sites were significantly different (Table 47). The ordering of sites according to increasing SI corresponded to the ordering by SNR.

Table 47. Mean site index of Douglas-fir in study sites

Site	GVD	VVD	GD	GF	VD	VF
SI (m/50 yrs)	17.8*	22.2	26.4	32.1	35.1	39.1

* All values are significantly different at the .05 level.

Table 48. Mean site index of Douglas-fir in study sites arranged according to parent material lithology

Lithology Sites	Granitic GVD, GD, GF	Volcanic VVD, VD, VF
SI (m/50 yrs)	25.4*	32.1

* All values are significantly different at the .05 level.

The two medium SNR sites (VVD, GD) and the two rich SNR sites (GF, VD) were adjacent when arranged by SI although SI of all sites were significantly different. The lower SI of the GF site compared to the VD site was unexpected considering the better moisture status and N fertilization of the GF site. This may be simply a chance result due to the limited number of sites considered in this study. The time since fertilization may not have been sufficient to allow a significant height response to occur. One possible contributing factor may be the low foliar B and Zn levels of the GF site (App. D).

Site index of the study sites was analyzed by the two-way ANOVA with interaction for the parent material lithology and SMR factors. The interaction term was not significant. The volcanic parent material lithology sites had significantly greater SI than granitic lithology sites (Table 48). This supports the suggestion that improved Ca and Mg status of the volcanic lithology may improve overall nutrient availability and indirectly productivity. Increases in soil moisture availability between SMR classes were reflected in significant increases in SI (Table 49). The difference in SI between the dry and fresh SMR classes was larger than differences in AWSC would have suggested (Sec. 4.6). This difference may have been inflated by the limited number of sites included in the study.

There were significant differences in SI between SNR classes (Table 50). The increasing availability of nutrients assumed by the SNR classification, corresponded to the

Table 49. Mean site index of Douglas-fir in study sites arranged according to soil moisture regime (SMR)

SMR Sites	Very dry VVD, GVD	Dry GD, VD	Fresh GF, VF
SI (m/50 yrs)	20.0*	30.8	35.6

* All values are significantly different at the .05 level.

Table 50. Mean site index of Douglas-fir in study sites arranged according to soil nutrient regime (SNR)

SNR Site(s)	Poor GVD	Medium GD, VVD	Rich GF, VD	Very rich VF
SI (m/50 yrs)	17.8*	24.3	33.6	39.1

* All values are significantly different at the .05 level.

increases in SI when pairs of sites with equivalent moisture status were compared.

The correlations between SI and soil properties are presented in Table 51. The SI values of the unfertilized sites were used to avoid the complications due to fertilizer effects.

The forest floor properties most highly correlated with Bruce's SI were exK (-.811), exMn (-.746) and pH(H_2O) (.615). In general, as forest floor total Mn increased, SI decreased in the Douglas-fir stands studied by Carter (1983). Forest floor total Mn had the most consistent relationship to SI of Douglas-fir, but Carter (1983) suggested that this may have been a result of the role played by western hemlock both in determining the conditions for the growth of Douglas-fir and the concentration of Mn in the forest floor. The very minor (<10% mean cover) component of western hemlock in the study sites suggests that soil conditions and/or physiology of Douglas-fir on very dry sites contribute to the observed high foliar Mn and forest floor Mn levels.

The significant negative correlation of exK with SI could be attributed to several factors. The very low productivity GVD site had relatively high K status due to the K content of the parent material lithology. The low productivity VVD site generally had the highest forest floor nutrient content due to higher bulk density and greater depth of forest floor. Increasing pH levels are related to improvements in nutrient availability and conditions for soil organisms important in

Table 51. Correlations between soil properties and site productivity measured by Bruce's site index (m/50 yrs) for the unfertilized study sites

Forest floor		Mineral soil		Forest floor plus mineral soil	
Property	Correlation with Bruce's S.I.	Property	Correlation with Bruce's S.I.	Property	Correlation with Bruce's S.I.
TC	-.632*	TC	.436	TC	.319
TN	-.431	TN	.774**	TN	.766**
minN	.012	minN	.963**	minN	.944**
TP	-.405	exP	.841**	exCa	.871**
TS	-.514*	SO_4	-.753**	exMg	.874**
exCa	-.589*	exCa	.902**	exK	.037
exMg	-.564*	exMg	.885**	exMn	-.692**
exK	-.811**	exK	.265		
exMn	-.746**	exMn	.024		
pH(H_2O)	.615*	pH(H_2O)	.701**		
		pH($CaCl_2$)	.614*		

* Significant at the .05 level.

** Significant at the .01 level.

decomposition of organic matter (Pritchett, 1978) and indirectly to productivity.

The mineral soil properties most highly correlated with SI were minN (.962), exCa (.902), exMg (.885), and exP (.841). The forest floor plus mineral soil properties most highly correlated with SI were minN (.944), exMg (.874), exCa (.871), and TN (.766). The properties most highly correlated with SI (minN, TN, exCa, exMg) were also the properties which best reflected SNR. The exception to this is mineral soil exP. Poor growth of Douglas-fir has been noted where P and other nutrients are in low supply (Krajina et al., 1982), and low soil P has been suggested as the reason for lack of N fertilizer response in areas with low available soil P (Radwan and Shumway, 1982). The volcanic lithology study sites have both higher exP content and higher SI. It is possible that the correlation was inflated by the small number of study sites.

The positive correlations between SI and N mineralized from humus of upper mineral soil horizons have been described for several tree species (e.g. Zöttl, 1960; Powers, 1980; Rehfuess and Baum, 1980). In a regression equation using N mineralized from the 0-15 cm depth of mineral soil and stand density, 86% of the variation in growth response of Douglas-fir to N fertilizer was accounted for (Shumway and Atkinson, 1978). For Douglas-fir stands in Washington, N mineralized during an anaerobic incubation had a .36 correlation to fertilizer response compared to .14 for total N (J. Shumway, pers. comm. as cited by McNabb, 1984). An improved correlation was obtained by 'correcting' the minN values for coarse fragment content. The correlation of mineralized N with fertilizer response also differed with the amount of exchangeable bases in the soil. The fertilizer response was greater when amounts of exchangeable bases and other nutrients were greater (J. Shumway, pers. comm. as cited by McNabb, 1984). The greater soil N and Ca quantities of highly productive Douglas-fir sites has been previously noted (eg. Klinka et al., 1981b; Roy, 1984). This would support the indirect effect on N availability for sites with better base status as suggested previously (sec. 5.2.1).

5.4 CLASSIFICATION OF SOIL NUTRIENT REGIMES

5.4.1 Characteristics and Classification of Recognized Classes

The sum of mineral soil (0-50 cm depth) and forest floor minN, TN, exCa, and exMg expressed on a kg/ha basis were the properties which best characterized the four SNR classes recognized in this study (Table 52). These four properties have been shown to be significantly correlated with major trends in variation of soil properties (Section 5.2.2), vegetation, and forest productivity for the study sites (Section 5.3).

The vegetation analysis and PCA of mineral soil properties identified groups of study plots which were the same as the field-assessed SNR class. Both DA and CA consistently differentiated the SNR classes of the study sites using forest floor plus mineral soil exMg and minN. The consistency of these groupings suggests that important differences between the

Table 52. Mean and range of one standard deviation (in parenthesis) of forest floor plus mineral soil properties which characterize the soil nutrient regime classes recognized in this study

Property	Soil nutrient regime class			
	Poor	Medium	Rich	Very rich
TN (kg/ha)	2328 (2095-2585)	3193 (2790-3655)	4108 (3123-5404)	7121 (6117-8291)
minN (kg/ha)	18 (15-22)	54 (45-65)	113 (95-134)	242 (185-315)
exCa (kg/ha)	512 (436-602)	609 (409-905)	1660 (1081-2547)	4821 (3729-6234)
exMg (kg/ha)	86 (80-93)	86 (76-98)	168 (140-203)	650 (506-834)

Table 53. Coefficients and the constants used in the classification functions for the four soil nutrient regime classes recognized in this study

Nutrient regime class	Constant	Coefficients	
		exMg	minN
poor	-389.14282	206.30174	-49.62115
medium	-367.93667	155.47197	9.56474
rich	-486.82642	172.06049	18.54732
very rich	-770.02441	240.54950	-3.82374

nutrient regimes of the six sites could be identified using soil properties alone.

Classification of SNR for soils comparable to the population studied is proposed using the coefficients and constants found in Table 53. To assign a site to a SNR class, a classification score for that site must be calculated for each of the four classes. The score for each class is calculated by multiplying the coefficients by the value of the appropriate soil variable, summing these products and adding the constant. The class which corresponds to the highest score is the group to which the site belongs. It should be noted that the classification functions were derived for variables which had been mathematically transformed (log + 1).

The proposed classification is based on a limited number of study sites in one climatic region. Further studies over a wider range of environmental conditions with a larger sample size are required. The use of other soil analysis techniques (e.g. different indexes of N availability) should also be examined in the future.

5.4.2 Comparison of the Classification Proposed by Courtin *et al*. (1985) and This Study

The discriminant analysis coefficients and constants for the classification of the SNR classes proposed by Courtin *et al*. (1985) were used to classify the GVD, GD, GF, VVD, and VD sites of this study. The comparison of SNR classifications for the study sites is presented in Table 54. The soil properties

Table 54. Comparison of nutrient regime classification of study sites using the characteristics of this study and the discriminant analysis functions proposed by Courtin *et al.* (1985)

Study sites	Nutrient regime classification: This study	Nutrient regime classification: Courtin *et al.* (1985)
GVD	poor	medium (N low, soil group 4)
VVD	medium	medium (N low, soil group 3)
GD	medium	medium (N low, soil group 3)
VD	rich	medium (N low, soil group 3)
GF	rich	rich (soil group 6)

Table 55. Interpretive nutrient regime class, and means of pH(H_2O), C/N, TN and sum of exchangeable bases (SEB) for the five study sites where sampling methodology was comparable to that of Courtin *et al.* (1985)

Study sites	Nutrient regime class	Humus form		Mineral soil (kg/ha)	
		pH(H_2O)	C/N	TN	SEB
GVD	poor	4.3	45	1989	501
VVD	medium	4.0	36	2778	676
GD	medium	4.1	33	2544	398
VD	rich	4.2	35	2833	1251
GF	rich	4.7	31	4827	2350

of the study sites and those of the soil groups classified by Courtin _et_ _al_. (1985) are given in Tables 55 and 56, respectively.

Differences in sampling methodology between this study and Courtin _et_ _al_. (1985) complicate comparison of the two classifications. The Ah horizon was sampled as part of the humus form by Courtin _et_ _al_. (1985) but as part of the mineral soil in this study. Due to this difference in sampling methodology, the mull humus form of the VF site could not be classified using the proposed classification of Courtin _et_ _al_. (1985). The soil properties used by Courtin _et_ _al_. (1985) were based on one sampling location in a 400 m^2 plot compared to 15 sampling locations in a 400 m^2 plot in this study. Soil samples were collected to rooting depth which varied from 10 to 150 cm, compared to the 50 cm (or less if a restricting layer was present) sampling depth used in this study. The GVD, VD and GF sites all had average rooting depths of approximately 90 to 100 cm (App. E). For the GVD and VVD sites, whose average rooting depths were 55 cm and 43 cm, respectively (App. E), there was little potential difference due to sampling depth.

The nutrient regime of the GVD site was classified as poor in this study and medium (N low, soil group 4) using the methods of Courtin _et_ _al_. (1985). The humus form values for the GVD site were more similar to the medium (soil group 4) SNR than the poor (soil group 2) SNR. Mineral soil values for the GVD site were within the ranges of either the poor or medium SNR classes of Courtin _et_ _al_. (1985).

Table 56. Interpretive nutrient regime class, means and standard deviations (in parenthesis) of pH(H_2O), C/N, TN and sum of exchangeable bases (SEB) for the seven soil groups classified using discriminant analysis functions by Courtin *et al*. (1985)

		Humus form		Mineral soil	
Soil group	Nutrient regime class	pH(H_2O)	C/N	TN (kg/ha)	SEB (kg/ha)
1	very poor	3.8 (0.3)	73 (7)	1743 (1786)	1386 (1683)
2	poor	3.6 (0.3)	52 (5)	3010 (2421)	871 (764)
3	medium (N low)	3.8 (0.3)	37 (4)	4593 (2102)	944 (776)
4	medium (N low)	4.5 (0.3)	43 (4)	2045 (1268)	795 (346)
5	medium (N high)	4.1 (0.6)	34 (7)	12989 (3749)	1255 (577)
6	rich	4.5 (0.4)	20 (5)	4069 (2405)	1743 (1088)
7	very rich	5.0 (0.4)	21 (5)	8404 (3902)	5066 (1961)

The VVD and GD sites were classified as medium in both classifications. Increasing the sampling depth of the GD site might have increased the TN and SEB values, but the increase probably would not have been great enough to change the nutrient classification to rich.

The nutrient regime of the VD site was classified as rich in this study and medium (N low, soil group 4) using the methods of Courtin et al. (1985). Sampling the entire rooting depth of the VD site would have increased TN and SEB values, making them more similar to the rich (soil group 6, Table 56) SNR class of Courtin et al. (1985). The C/N ratio of the VD site was much higher (35) than the C/N ratio (20) of the rich (soil group 6, Table 56) SNR class.

The GF site was classified as rich by both methods. Increasing mineral soil sampling depth probably would not have increased values to the range of the very rich (soil group 7, Table 56) class. The major difference between the GF site and the rich SNR class of Courtin et al. (1985) was the C/N ratio of the humus form. The opposing effects of thinning (probable effect of increasing the C/N ratio) and N fertilization of the GF site (probable effect of decreasing the C/N ratio) complicate this comparison.

6. SUMMARY

The study sites were all located on southern Vancouver Island in the vicinity of Cowichan Lake. Second growth Douglas-fir, established after logging and fire, between the ages of 33 and 67 years dominated the tree layers of the vegetation. The GD site had been fertilized with approximately 200 kg N/ha in 1968 and 1976. The GF site had been fertilized at a similar rate in 1968 and 1979 as well as being thinned to approximately 700 stems/ha in 1979.

All study sites were within the East Vancouver Island Variant of the Drier Maritime Coastal Western Hemlock subzone (CWHa1). The climate of the CWHa1 subzone is characterized as humid, cool mesothermal.

Based on coarse fragment and bedrock samples the study sites were divided into two groups of parent material lithologies, granite and volcanic. The granitic group included sites 1, 2 and 3 (GVD, GD, GF). The volcanic group included sites 4, 5 and 6 (VVD, VD, VF). The field assessments of parent material lithology were retained. The granitic lithology was expected to be higher in K status but lower in Ca and Mg than the volcanic lithology. Glacial till was the parent material of the GVD, GD and VVD sites; glaciofluvial material for the GF site; colluvial/alluvial materials for the VD site; and alluvial materials for the VF site. The VF site soils were Orthic Cumulic Regosols; the soils of all other study sites were classified as Orthic Humo-ferric Podzols. The values of forest floor pH(H_2O), TC, TN, minN, TP, TS, exCa, exMg, exK, exMn, and mineral soil pH(H_2O), pH($CaCl_2$), minN, exP, SO_4, exCa, exMg, exK, and exMn were similar to the values of those properties in the literature reviewed.

The assessment of SNR done in the field was described for two study sites. A similar procedure was followed for all study sites.

The analysis of growing-season soil moisture deficits and AWSC for the study sites were in the same order as the relative rankings of SMR with the possible exception of the GD site. Each pair of sites within the SMR class had comparable growing-season soil moisture regimes, with the possible exceptions of the GD and VD sites. Within the limits of the methods used, the field assessments of soil moisture regime were confirmed and retained.

The understory vegetation of the study sites displayed a consistent pattern using three types of multivariate analysis. The arrangement of study sites corresponded to the assessment SNR and SMR for each study site.

Foliar nutrient analysis of the study sites indicated that N deficiencies ranged from very severe to slight. All sites were possibly deficient in K, while Ca and Mg were adequate. Excluding the N fertilized sites, the decrease in severity of N deficiency corresponded to the assumed increase in N availability of the SNR assessment. Foliar Ca, Mg and K status did not reflect the differences expected due to parent material lithology or the SNR classification. B, Zn and Fe deficiencies may affect productivity of the GD, GF and VF sites.

The two-way ANOVA of nutrient properties with parent material lithology and SMR was useful for displaying some trends. There were consistent significant interactions between the two factors which indicated that they could not be discussed independently. A one-way ANOVA of forest floor properties using field-assessed SNR of the site was also an inadequate interpretation of the forest floor variation. The forest floor nutrient quantities were best interpreted by noting differences in type of humus form, depth of forest foor, and time since last disturbance. Plot within site variability was significant for all properties, reflecting the variability of nutrient concentrations, forest floor depth and bulk density.

The mineral soil properties of exP, SO_4, exCa, exMg, exK, exMn, pH(H_2O), and pH($CaCl_2$) all had significant interaction between the parent material and SMR factors of the two-way ANOVA. These factors did not account very well for the patterns of variation observed, although the arrangement of plot means could be interpreted in some cases, for example, parent material lithology for exP. The differences in TC and TN between SMR classes reflected differences in bulk density, as well as humus form for TC, and possibly lithology of parent material for TN. Only for minN did the SMR gradient offer an explanation for increasing nutrient availability. There were significant differences between SNR classes for minN and TN.

Significant differences between the very rich, rich, and grouped poor and medium SNR classes were apparent for exCa and exMg. For all mineral soil properties except minN and pH($CaCl_2$) there was significant within-site variability. This was due in part to nutrient variability, and bulk density variability. However, the within-site variability also supported the SNR class assignment, as plots identified as having the same SNR class were adjacent for some properties (e.g., minN).

Forest floor plus mineral soil nutrient quantities displayed a significant parent material lithology-SMR interaction for exMg and exMn. For TC, TN and minN the pattern of the mineral soil was repeated. This indicated that mineral soil quantities dominated this analysis, due to the thin forest floors of the study sites. The difference in exCa along the SMR gradient again reflected how the SMR gradient was confounded with a bulk density gradient. The exK values provided an example of the compensating effects of bulk density, parent material and soil moisture regimes. Significant within-site variability was present for all properties.

While univariate analyses were useful for displaying some trends which could be interpreted in light of changes in soil bulk density and humus form, interrelationships between variables and identification of differences were not clear. A better understanding of the ecological relationships was obtained by insights into compensating factors and relationships using multivariate techniques.

The results of the MSS analysis indicated that the forest floor variables were all highly interrelated and TS was the most useful summary of the variation between forest floors of the study plots. For mineral soil, exCa was the single variable with the greatest dispersion and redundancy. All mineral soil properties were highly interrelated. This was probably due to increases in bulk density resulting in increased quantities of all nutrients except SO_4. The property with greatest dispersion and redundancy for forest floor plus mineral soil was TN. Unique information was provided by exMn and possibly by exK. The four variables (TN, minN, exCa, exMg) which were highly interrelated in the forest floor plus mineral soil data were also those which reflected the SNR assessment of the study sites in the univariate analysis.

For all three data sets there was one PCA axis accounting for 58% to 84% of the variation between study plots and which was significantly correlated to almost all properties. The PCA of forest floor properties was in agreement with the overall interpretation of the univariate analyses that forest floor humus form, bulk density and depth were the most important factors for explaining the variation among study plots. The MSS analysis and PCA both highlighted the interrelatedness of the forest floor properties.

The major trend for mineral soil variation among the study sites was for increasing soil nutrient quantities and increasing pH. Exceptions to this pattern were SO_4 which was negatively correlated (decreased) with the first PCA axis, and the unique variation of exMn among the study sites. The ordination of study sites using the first two PCA axes was interpreted as arranging most plots in a manner similar to the moisture-nutrient gradient of the vegetation analysis and the SNR assessment.

The forest floor plus mineral soil nutrient properties also displayed a trend for increasing quantities of TN, exCa, exMg, minN, and TC. The variation pattern of exK reflected a combination of lithology, bulk density, susceptibility to leaching, and other factors. The variation pattern for exMn among study sites was distinct from other nutrients.

With each of the data sets all plots were correctly classified according to the site of origin using DA. However, with each data set more variables were utilized to correctly classify sites than were required for parent material lithology, SMR, or SNR. Each site was unique, but other potential groupings of plots utilized fewer properties. This suggests that the alternative groupings of plots revealed important similarities.

Differences between parent material lithologies were most clearly expressed with mineral soil exP. Forest floor TP was also an important characteristic to separate plots on the basis of lithology. However, the mineral content of the rock types would not suggest great differences in P (Table 4). The Ca and Mg status of the plots would be expected to differ between lithologies, but only in the forest floor data set was exCa utilized in discriminating between the two lithologies. The N status of plots was utilized to separate according to lithology. This N difference between lithologies was noted in the univariate analyses for mineral soil. A few plots were misclassified for parent material lithology in all data sets. This was due to variability of properties obscuring separation, mixing of lithologies in surficial materials, and possibly the indirect relationships between lithology and the properties studied.

The SMR classes were well separated by DA in all data sets. However, SMR was confounded with humus form of forest floor and bulk density of mineral soil in this study. Properties which were utilized in two or more data sets to discriminate between SMR classes were TN and/or minN, exCa and exMn.

SNR classes of study plots were not well separated in the forest floor data set. The overlap of nutrient content between thin Mor (GVD4, GD2, GD3) and Moders (VD1, VD2) was noted in the univariate analyses. SNR classes were not well separated on the basis of forest floor properties expressed quantitatively. Six mineral soil properties were utilized to separate SNR classes. However, when forest floor and mineral soil quantities were summed, only three properties were required for separation. This supports the integration of both forest floor and mineral soil properties when SNR assessment is made. Properties which were consistently utilized to separate SNR were N status (TN, minN), base status (particularly exMg, exCa), and pH (forest floor pH(H_2O), and pH($CaCl_2$) of mineral soils). For the study plots, N status and base status had the closest correspondence with the univariate assessment of SNR.

Between all data sets and possible groupings of plots, several properties were consistently important for separating groups of plots using DA. These properties were pH(H_2O), exCa, TN and/or minN for forest floor; exP, exMn and exCa and/or exMg for mineral soil; and minN, TN, exMn and exCa and/or exMg for forest floor plus mineral soil. The variables which were consistently valuable in discriminating between study plot groupings emphasized trends noted in previous analyses. In particular the pattern of variation of exMn was unique. Parent material lithology was reflected at least indirectly in mineral soil exP, and N status between study plots.

The CA using all forest floor properties separated the study plots into three groups which differed in humus form and thickness. When different combinations of variables were used, there were changes in group membership for three plots, which could also be interpreted by differences in humus form and thickness. The results of CA were in agreement with previous analyses which suggested that humus form and thickness best explained forest floor property differences between plots.

The CA using all mineral soil properties separated the study plots into three groups which reflected a nutrient gradient. When minN, exMg and TC were used the plots were grouped into the SNR classes, with the exception of two plots.

The CA using all forest floor plus mineral soil properties separated the plots into three groups which reflected a combination of parent material lithology and bulk density. Four groups which were the same as their SNR class were the result of the CA using forest floor plus mineral soil minN and exMg. Only one plot was 'incorrectly' grouped according to SNR class in the CA using forest floor plus mineral soil minN and exMg plus pH(H_2O) of the forest floor.

For the study sites the most important trend in vegetation variation was correlated with the major trend in mineral soil and forest floor plus mineral soil properties. The mineral soil and forest floor plus mineral soil properties which correlated most highly with these trends were minN, TN, exCa and exMg. The vegetation-mineral soil and vegetation-forest floor plus mineral soil ordinations arranged the study sites in the same way as the SNR assessment.

The forest floor properties were correlated with vegetation, but the major trend of vegetation variation was a much better predictor of forest floor variation than vice versa. The ordination of forest floor properties and vegetation reflected differences between plots which were similar to those noted in previous analyses of forest floor properties and attributed to humus form, depth of forest floor and time since last disturbance.

The major trends in foliar nutrient status and soil properties were correlated. Of the three soil property data sets, the forest floor properties had the least value for explaining foliar nutrient variation. The ordinations of foliar-forest floor canonical variates were consistent with previous analyses which attributed the forest floor pattern of variation to humus form, depth of forest floor and time since last disturbance.

The foliar-forest floor plus mineral soil ordinations arranged the study sites in the same way as the SNR assessment. Expression of foliar nutrients on a mg/100 needle basis might have changed relationships based on foliar concentration data if 'dilution' or 'concentration' affects were present (Ballard and Carter, 1983). The arrangement of study sites did not change with the method of foliar nutrient expression for the foliar-forest floor plus mineral soil ordinations. However, the foliar nutrients most highly correlated with the first canonical variates did change. The forest floor plus mineral soil variation was consistently correlated with TN, minN, exMg, and exCa. However, only foliar N expressed as concentration was highly correlated with the forest floor plus mineral soil canonical variate. Foliar Mn and Al were consistently correlated with the first forest floor plus mineral soil variate. Within the limitations of this study, these correlations suggest that the groupings of plots based on soil properties were correlated with groupings based on foliar properties. However, the nutrients with which the soil groupings were best correlated (N, Ca, Mg) were not the same as the foliar groupings (Mn, Al).

The ordination of the first canonical variate of foliar data expressed as concentration of mineral soil arranged the study sites in the same way as the SNR assessment. The ordination using mg/100 needles foliar data with mineral soil indicated a general nutrient gradient but did not reflect the SNR assessement as well as other analyses. The arrangement of sites was interpreted to reflect physiological and stand management factors as well as changes in soil nutrient quantities.

In spite of possible complications due to fertilization the productivity of study sites measured by SI increased in the same pattern as SNR assessment. The soil properties most highly correlated with SI (minN, TN, exCa, exMg) were also the properties which best reflected SNR. The negative correlations of SI with exK and exMn of the forest floor reflected the high content of these elements in the driest, nutrient-poor and lowest productivity study sites.

The four SNR classes recognized in this study (poor, medium, rich, very rich) were best characterized by the sum of forest floor and mineral soil minN, TN, exCa, and exMg. A multivariate classification of SNR using minN and exMg was proposed.

The differentiating characteristics of Courtin et al. (1985) were used to classify SNR of the study sites. Differences between the two classifications were mainly attributed to values for pH(H_2O) and C/N ratio of the humus form. Differences in mineral soil sampling depth may also have contributed to the differing classifications of the VD site.

7. CONCLUSIONS

This thesis has reported on a preliminary study whose major objective was to describe and provide initial data for characterization and classification of soil nutrient regime. Based on this study, which was limited to one climatic region and a small number of study sites, the following conclusions can be made regarding the quantitative classification of soil nutrient regimes.

A multivariate classification using forest floor plus mineral soil minN and exMg quantities was proposed for the four SNR classes (poor, medium, rich, very rich) recognized in this study. The final SNR groupings of study sites were the same as those originally determined on the basis of field-assessed vegetation and site characteristics.

Significant differences in available (minN) and total N (TN) existed between the four identified classes. The N fertilization of two study sites did not seem to change soil N status sufficiently to alter the classification. There were no significant differences in exCa and exMg quantities for the poor and medium nutrient classes. The differences in nutrient availability were best distinguished for soil properties when forest floor and mineral soil properties expressed on an areal basis were summed. The humus form was an important characteristic for assessing SNR in the field. However, the nutrient quantities of the humus form reflected differences in bulk density, depth and time since last disturbance and did not effectively distinguish between SNR classes.

The major trend in understory vegetation variation was correlated with increases in nutrient availability. The soil properties most highly correlated with the major trend in variation of the soil properties were minN, TN, exCa, and exMg.

The increases in soil nutrient availability were correlated with increased foliar N concentrations of the current year's foliage. A more consistent correlation was found between increased soil nutrient availability and decreased foliar Mn and Al. This suggests that different chemical elements measured in different ecosystem components may be reflections of a certain level of plant available nutrients in the ecosystem.

Forest productivity measured by site index of Douglas-fir, was significantly greater on sites with greater quantities of most nutrients (in particular N, Mg, Ca) when pairs of sites with equivalent soil moisture status were compared. The small sample size, complicating influence of fertilization and thinning and the other factors which may have influenced productivity of the study sites limit the strength of this conclusion.

LITERATURE CITED

Anonymous. 1974. Technicon Autoanalyzer II. Methodology: Individual/simultaneous determination of nitrogen and phosphorous BD acid digests. Industrial Method No. 334-74A.

Armson, K.A. 1973. Soil and plant analysis technique as diagnostic criteria for evaluating fertilizer needs and treatment response. pp. 155-166 In: Forest Fertilization Symposium proceedings. U.S.D.A. Forest Service General Technical Report NE-3. 246 pp.

Bakuzis, E.V. 1959. Synecological coordinates in forest classification and in reproduction studies. PhD. Thesis. University of Minnesota, St. Paul, Minnesota. 244 p.

Ballard, T.M, and R.E. Carter. 1983. Evaluating forest stand nutrient status. Province of British Columbia, Ministry of Forests. 76 pp.

Bardsley, C.E., and J.D. Lancaster. 1965. Sulfer. pp. 1102-1116. In. C.A. Black, D. Evans, L.E. Ensminger, J.L. White, and F.E. Clark (eds.). Methods of soil analysis. Agronomy Monograph No. 9, American Society of Agronomy, Madison, Wisconsin. 1572 pp.

Barkman, J.J., J. Moravec, and S. Rauschert. 1976. Code of phytosociological nomenclature. Vegetatio 32: 132-185.

Binkley, D. 1983. Ecosystem production in Douglas-fir plantations: interaction of red alder and site fertility. For. Ecol. Manage. 5: 215-227.

Bremner, J.M. and M.A. Tabatabai. 1971. Use of automated combustion techniques for total carbon, total nitrogen and total sulpher analysis of soils. pp. 1-16 In: L.M. Walsh (ed.). Instrumental methods for analysis of soils and plant tissue. Soil Sci. Soc. of Amer., Wisconsin.

Brockley, R.P. 1981. The effects of nutrients and moisture on soil nutrient availability, nutrient uptake, tissue nutrient concentration, and growth of Douglas-fir seedlings. M.F. Thesis, Faculty of Forestry, University of British Columbia, Vancouver, B.C. 170 pp.

Brooke, R.C., E.B. Peterson, and V.J. Krajina. 1970. The subalpine Mountain Hemlock Zone. Ecol. West. North. America 2: 148-349.

Bruce, D. 1981. Consistent height growth and growth rate estimates for remeasured plots. Forest Sci. 27: 711-725.

Canadian Soil Survey Committee. 1978. The Canadian system of soil classification. Can. Dep. Agric. Publ. 1646. Supply and Services Canada. Ottawa. 164 pp.

Carmean, W.H. 1975. Forest site quality evaluation in the United States. Adv. Agronomy 27: 209-269.

Carter, R.E. 1983. Forest floors under second growth Douglas-fir stands: their chemical variability and some relationships to productivity. M.Sc thesis, Department of Soil Science, University of British Columbia, Vancouver, B.C. 89 pp.

Clark, J.S. 1965. The extraction of exchangeable cations from soils. Can. J. Soil Sci. 45: 311-322.

Clapp, R.B., and G.M. Hornberger. 1978. Empirical equations for some soil hydraulic properties. Water Resources Research 14: 601-604.

Courtin, P., M.C. Feller, and K. Klinka. 1983. Lateral variability in some properties of disturbed forest soils in southwestern British Columbia. Can. J. Soil Sci. 63: 629-539.

Courtin, P.J., K. Klinka, M.C. Feller, and J.P. Demaerschalk. 1985. An approach to quantitative classification of nutrient regimes of forest soils. B.C. Ministry of Forests. (Manuscript)

Dean, J.A. 1960. Flame photometry. McGraw-Hill Book Co., New York. 354 pp.

Dixon, W.J. (ed.). 1983. BMDP statistical software. University of California Press, Los Angeles. 734 pp.

E.L.U.C. Secretariat. 1975a. Provisional map of landforms - N.T.S. sheets 92/C-16 East and West (Cowichan Lake). Map at scale 1:50,000. Victoria, B.C.

E.L.U.C. Secretariat. 1975b. Provisional map of landforms - N.T.S. sheets 92/C-9 East and West (Port Renfrew). Map at scale 1:50,000. Victoria, B.C.

Emanuel, J. 1984a. F405:VTAB A vegetation classification program. Faculty of Forestry, University of British Columbia. Vancouver, B.C. 16 pp.

Emanuel, J. 1984b. Foliar nutrient analysis. Faculty of Forestry, University of British Columbia, Vancouver, B.C. 8 pp.

Emanuel, J. 1984c. Multivariate sample size analysis. Faculty of Forestry, University of British Columbia, Vancouver, B.C. 11 pp.

Fox, D.J., and K.E. Guire. 1976. Documentation for MIDAS (3rd ed.). Statistical Research Laboratory, University of Michigan. 203 pp.

Gauch, H.G. 1977. ORDIFLEX - A flexible computer program for four ordination techniques: weighted averages, polar ordination, principal components analysis, and reciprocal averaging, Release B. Ecology and Systematics, Cornell University, Ithaca, New York. 185 pp.

Gauch, H.G. 1982. Multivariate analysis in community ecology. Cambridge studies in ecology. Cambridge University Press, New York. 298 pp.

Giles, D.G. 1983. Soil water regimes on a forested watershed. M.Sc. thesis, Department of Soil Science, University of British Columbia, Vancouver, B.C. 282 pp.

Giles, D.G., T.A. Black, and D.L. Spittlehouse. 1985. Determination of growing season soil water deficits on a forested slope using water balance analysis. Can. Jour. For. Res. 15: 107-114.

Giles, D.G. 1985. Personal communication.

Gittins, R. 1979. Ecological application of canonical analysis. pp. 309-535 In: L. Orloci, C.R. Rao, and W.M. Stiteler (eds.). Multivariates methods in ecological work. Publishing House, Fairfield, M.A.

Greacen, E.L., R.L. Correll, R.B. Cunningham, G.G. Johns, and K.D. Nicolls. 1981. Calibration. pp. 50-81 In: E.L. Greacen (ed.). Soil water assessment by the neutron method. Commonwealth Scientific and Industrial Research Organization. East Melbourne, Victoria, Australia. 140 pp.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley and Sons, New York. 257 pp.

Grieg, M., and D. Osterlin. 1978. UBC ANOVAR - Analysis of variance and covariance. Computing Centre, University of British Columbia, Vancouver, B.C. 69 pp.

Grier, C.C., and J.G. McColl. 1971. Forest floor characteristics within a small plot in Douglas-fir in western Washington. Soil Sci. Soc. Amer. Proc. 35: 988-991.

Hagglund, B. 1981. Evaluation of forest site productivity. For. Abstr. 42: 515-527.

Hale, M.E., and W.L. Culberson. 1970. A fourth checklist of the lichens of the Continental United States and Canada. The Bryologist 73: 499-543.

Hart, K. 1983. Personal communication.

Hay, J.E. 1979. An analysis of solar radiation data for British Columbia. RAB bulletin 14, Resource Analysis Branch, Ministry of Environment, Province of British Columbia, Victoria, B.C. 125 pp.

Hegyi, F., J. Jelinek, and D.B. Carpenter. 1979. Site index equations and curves for the major tree species in British Columbia. For. Inv. Report No. 1. Inventory Branch, Ministry of Forests, Province of British Columbia, Victoria, B.C. 23 pp.

Heilman, P.E. 1979. Minerals, chemical properties, and fertility of forest soils. pp. 121-136 In: P.E. Heilman, H.W. Anderson, and D.M. Baumgartner (eds.). Forest soils of the Douglas-fir region. Washington State University, Cooperative Extension Service, Pulmann, Wash. 298 pp.

Hill, M.O. 1979. DECORANA - A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Ecology and Systematics, Cornell University, Ithaca, New York. 90 pp.

Hills, G.A. 1952. The classification and evaluation of site for forestry. Ontario Dept. Lands and For., Res. Rep. 24. 41 pp.

Hills, G.A. 1961. The ecological basis for land use planning. Ontario Dept. Lands and For., Res. Rep. 46. 204 pp.

Hills, G.A. 1976. An integrated iterative approach to ecosystem classification. pp. 73-97 In: I. Thie and G. Ironside (eds.). Ecological (biophysical) land classification in Canada. Ecological Land Classification Series No. 1, Lands Directorate, Environment Canada, Ottawa, Ontario. 269 pp.

Husch, B., C.I. Miller, and T.W. Beers. 1972. Forest mensuration. Second edition. The Ronal Press Co., New York. 410 pp.

Hyndman, L. 1972. Petrology of igneous and metamorphic rocks. McGraw Hill, New York. 533 pp.

Ireland, R.R., C.D. Bird, G.R. Brassard, W.B. Schofield, and D.H. Vitt. 1980. Checklist of the mosses of Canada. Pub. in Botany No. 8. National Museums of Canada, Ottawa. 75 pp.

Jarvis, P.G., G.B. James, and J.J. Landsberg. 1976. Coniferous forest. pp. 171-240 In: J.L. Monteith (ed.). Vegetation and the atmosphere. Vol. 2. Case studies. Academic Press, New York.

Kimmins, J.P. 1986. Chapter 16. Forest ecology. MacMillan, New York. In press.

Klinka, K., R.N. Green, P.J. Courtin, and F.C. Nuszdorfer. 1984a. Site diagnosis, tree species selection, and slashburning guidelines for the Vancouver Forest Region. Province of British Columbia. Ministry of Forests. Land Manage. Rep. No. 25. 180 pp.

Klinka, K., P.J. Courtin, and R.N. Green. 1984b. An approach to quantitative classification of hygrotopes and trophotopes of forest soils. Paper presented at IUFRO Workshop of Qualitative and Quantitative Assessment of Forest Sites with Special Reference to Soils. Swiss Federal Institute of Forest Research, CH-8903 Birmensdorf, Switzerland. September 10 - 15, 1984. 40 pp.

Klinka, K., R.N. Green, R.L. Trowbridge, and L.E. Lowe. 1981a. Taxonomic classification of humus forms in ecosystems of British Columbia (First Approx.). Province of British Columbia, Ministry of Forests. Land Manage. Rep. No. 8. 54 pp.

Klinka, K., M.C. Feller, and L.E. Lowe. 1981b. Characteristics of the most productive ecosystems for growth of Pseudotsuga menziesii var. menziesii in southwestern British Columbia. Province of British Columbia, Ministry of Forests. Suppl. to Land Manage. Rep. No. 6. 49 pp.

Klinka, K., F.C. Nuszdorfer, and L. Skoda. 1979. Biogeoclimatic units of central and southern Vancouver Island. Province of British Columbia, Ministry of Forests, Victoria, B.C. 120 pp. + map.

Kojima, S., and V.J. Krajina. 1975. Vegetation and environment of the Coastal Western Hemlock Zone in Strathcona Provincial Park, British Columbia, Canada. Syesis 8 (Suppl. 1): 1-123.

Korelus, V.J., and T. Lewis. 1976. Biophysical mapping (forest site mapping) of Cowichan Division - South. Pacific Logging Company, Victoria, B.C. 84 pp. + Appendices.

Krajina, V.J. 1969. Ecology of forest trees in British Columbia. Ecol. of Western North America 2:1-146.

Krajina, V.J., K. Klinka, and J. Worral. 1982. Distribution and ecological characteristics of trees and shrubs of British Columbia. Faculty of Forestry, University of British Columbia, Vancouver, B.C. 131 pp.

Krajina, V.J., S. Kojima, K. Klinka and E.B. Peterson. 1984. Ecology of vascular plants of British Columbia. Dept. of Botany, University of British Columbia, Vancouver, B.C. (Manuscript)

Lai, C. 1982. UBC CGROUP Hierarchical grouping analysis with optional contiguity constraint. Computing Centre, University of British Columbia, Vancouver, B.C. 24 pp.

Lavkulich, L.M. 1978. Methods manual. Pedology laboratory. Department of Soil Science. University of British Columbia, Vancouver, B.C. 224 pp.

Legendre, L., and P. Legendre. 1983. Numerical ecology. Elsevier Scientific Publishing Company. 420 pp.

Lewis, T. 1976. The till-derived podzols of Vancouver Island. Ph.D. thesis, Department of Soil Science, University of British Columbia, Vancouver, B.C. 158 p.

Lowe, L.E., and T.F. Guthrie. 1984. A comparison of methods for total sulphur analysis of tree foliage. Can. J. For. Res. 14: 470-473.

Lowe, L.E., and K. Klinka. 1981. Forest humus in the Coastal Western Hemlock Biogeoclimatic Zone of British Columbia in relation to forest productivity and pedogenesis. Province of British Columiba, Ministry of Forests, Res. Note No. 89. 83 pp.

Mader, D.L. 1973. Fertilizer needs and treatment responses for wood fiber production: field assessment. pp. 140-154 In: Forest Fertilization. Symposium proceedings. U.S.D.A. Forest Service Gen. Tech. Rep. NE-3. 246 pp.

Malcolm, P.C. 1981. Dynamics of forest ecosystems in relation to their utilization: North Temperate Zone. pp. 48-62 In: P. Laban (ed.). Proceedings of the workshop on land evaluation for forestry. Publ. 28. Inst. for Land Reclamation and Improvement, Wagennigen, The Netherlands. 355 pp.

MacDonald, G.A. 1972. Volcanoes. Prentice-Hill, Englewood Cliffs, New Jersey. 510 pp.

McGowan, M., and J.B. Williams. 1980. The water balance of an agricultural catchment. I. Estimation of evaporation from soil water records. Soil Science 31: 217-230.

McNabb, D.H. 1984. Using soil tests to predict Douglas-fir response to nitrogen fertilizer. pp. 80-84 In: Nitrogen assessment workshop. Regional forest nutrition research project Rep. No. 2. College of Forest Resources, University of Washington. 84 pp.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, Toronto. 547 pp.

Muller, J.E. 1977. Geology of Vancouver Island. Geological Survey of Canada, Dept. of Energy, Mines, and Resources, Vancouver, B.C. 2 maps + marginal notes.

Nuszdorfer, F.C. 1981. Bulk density. pp. 49-51 in K. Klinka, R.N. Green, R. Trowbridge, and L.E. Lowe. Taxonomic classification of humus forms in British Columbia. Land Manage. Rep. No. 8. Province of British Columbia, Ministry of Forests, Vancouver, B.C. 54 pp.

Nuszdorfer, F.C., and K. Klinka. 1982. Ecosystem-specific tree species selection. pp. 137-150 In: T. Vold (ed.). Proceedings of the B.C. soil survey workshop on soil interpretation for forestry. A.P.D. Tech. Paper 6. Province of British Columbia, Ministry of the Environment, Victoria, B.C. 333 pp.

Oserkowsky, J. 1933. Quantitative relation between chlorophyll and iron in green and chlorotic pear leaves. Plant. Physiol. 8: 449-468.

Parkinson, J.A., and S.E. Allen. 1975. A wet oxidation procedure suitable for the determination of nitrogen and mineral nutrients in biological material. Comm. Soil Sci. and Plant Anal. 6: 1-11.

Pastor, J., J.D. Aber, C.A. McClaugherty, and J.M. Melillo. 1982. Geology, soils and vegetation of Blackhawk Island, Wisconsin. The Amer. Mid. Nat. 108: 266-277.

Petkau, J. 1985. Personal communication.

Pluth, D.J., and H.F. Arneman. 1965. Forest soil and tree growth characteristics related to a synecological coordinate system. pp. 331-351 In: C.T. Youngberg (ed.). Forest-soil relationships in North America. Paper presented at the Second North America Forest Soils Conference.

Pojar, J., K. Klinka, and D.V. Meidinger. 1985. Biogeoclimatic ecosystem classification in British Columbia. Paper presented at the Canadian Congress of Biology, 23 - 29 June, 1985, London, Ontario.

Pimental, R.A. 1979. Morphometrics: the multivariate analysis of biological data. Kendall/Hunt Pub. Co., Dubuque, Iowa. 276 pp.

Powers, R.F. 1980. Mineralizeable soil nitrogen as an index of nitrogen availability to forest trees. Soil. Sci. Soc. Am. J. 44: 1314-1320

Prebble, R.E., J.A. Forrest, J.L. Honeysett, M.W. Hughes, D.S. McIntyre, and G. Schrale. 1981. Field installation and maintenance. pp. 82-98 In: E.G. Greacen (ed.). Soil water assessment by neutron method. Commonwealth Scientific and Industrial Research Organization, East Melbourne, Victoria, Australia. 140 pp.

Price, W.J. 1978. Analytical atomic absorption spectrometry. Heydon & Son Ltd., London. 239 pp.

Pritchett, W.L. 1979. Properties and management of forest soils. John Wiley and Sons, New York. 500 pp.

Quesnel, H.J. 1980. Forest floors near Port Hardy, British Columbia, Canada. M.Sc. thesis, Department of Soil Science, University of British Columbia, Vancouver, B.C. 152 pp.

Radwan, M.A., and J.S. Shumway. 1982. Available phosphorus to predict growth response of western hemlock and Douglas-fir to nitrogen fertilization. 1982. Presented at the Northwest Forest Soil Council Conference on Soil Nitrogen Assessment, May 19-20, Pack Forest, University of Washington. 6 pp.

Ralston, C.W. 1964. Evaluation of forest site productivity. Int. Rev. For. Research 1: 171-201.

Rehfuess, K.E., and U. Baum. 1980. (Relations between the growth of Norway spruce stands and chemical indices of their nitrogen supply). Forstwissenschaftliches Centralblatt 99: 146-154.

Roy, R.J.J. 1984. Ordination and classification of immature forest ecosystems in the Cowichan Lake area, Vancouver Island. M.Sc. thesis, Faculty of Forestry, University of British Columbia, Vancouver, B.C. 270 pp.

SAS Institute Inc. 1982. SAS user's guide: statistics. SAS Institute Inc., Cary, North Carolina. 584 pp.

Scagel, R., Y.A. El-Kassaby, and J. Emanuel. 1985. Assessing sample size and variable number in multivariate data, with specific reference to cone morphology variation in a population of Picea sitchensis. Can. J. Bot. 63: 232-241.

Shumway, J., and W.A. Atkinson. 1978. Predicting nitrogen fertilizer response in unthinned stands of Douglas-fir. Commun. Soil Sci. Plant Anal. 9: 529-539.

Slavinski, H.C. 1977. Soil variability along a topographic sequence, U.B.C. Endowment Lands. M.Sc. thesis, Department of Soil Science, University of British Columbia, Vancouver, B.C. 203 pp.

Sokal, R.R., and F.J. Rohlf. 1973. Introduction to biostatistics. W.H. Freeman and Co., San Francisco. 368 pp.

Spittlehouse, D.L., and T.A. Black. 1981. A growing season water balance model applied to two Douglas-fir stands. Water Resour. Res. 17: 1651-1656.

Spurr, J.E., and B.V. Barnes. 1980. Forest ecology. John Wiley, New York. 687 pp.

Stanek, W. 1977. Classification of muskeg. pp. 31-62 In: N.W. Radforth and C.O. Brawner (eds.). Muskeg and the northern environment in Canada. University of Toronto Press. 399 pp.

Stotler, R., and B. Crandall-Stotler. 1977. A checklist of the liverworts and hornworts of North America. The Bryologist 80: 405-428.

Tamm, C.O. 1964. Determination of nutrient requirements of forest stands. Int. Rev. For. Res. 1: 115-170.

Taylor, R., and B. McBryde. 1977. Vascular plants of British Columbia: A descriptive resource inventory. Tech. Bull. 4. Botanical Garden, University of British Columbia, U.B.C. Press, Vancouver, B.C. 754 pp.

Trewartha, G.T. 1968. An introduction to climate (4th ed.). McGraw-Hill, New York. 408 pp.

Wali, M.K., and V.J. Krajina. 1973. Vegetation-environment relationships of some Sub-boreal Spruce Zone ecosystems in British Columbia. Vegetatio 26: 237-381.

Walmsley, M., G. Utzig, T. Vold, D. Moon, and J. van Barneveld. 1980. Describing ecosystems in the field. RAB Tech. Paper No. 2. Ministry of Environment and Ministry of Forests, Province of British Columbia, Victoria, B.C. 226 pp.

Watanabe, F.S., and S.R. Olsen. 1965. Test for an ascorbic acid method for determining phosphorous in water and $NaHCO_3$ extracts from soil. Soil Sci. Soc. Amer. Proc. 49: 677-678.

Williams, B.K. 1983. Some observations on the use of discriminant analysis in ecology. Ecology 64: 1283-1291.

Williams, J., and D.F. Sinclair. 1981. Accuracy, bias and precision. pp. 35-49 In: E.L. Greacen (ed.). Soil water assessment by the neutron method. Commonwealth Scientific and Industrial Research Organization, East Melbourne, Victoria, Australia. 140 pp.

Wolf, B. 1974. Improvements in the Azomethine-H method for the determination of boron. Comm. Soil Sci. Plant Anal. 5: 39-44.

Youngberg, C.T. 1966. Forest floors in Douglas-fir forests: dry weight and chemical properties. Soil Sci. Soc. Amer. Proc. 30: 406-409.

Youngberg, C.T. 1979. Organic matter of forest floors. pp. 137-144 In: P.E. Heilman, H.W. Anderson, and D.M. Baumgartner (eds.). Forest soils of the Douglas-fir region. Washington State University, Cooperative Extension Service, Pullman, Wash. 298 pp.

Zech, W. 1970. Nadelanalytische Untersuchungen Uber die Kalkchlorose der Waldkiefer (Pinus silvestris). Z. f. Pflanzenernahr. u. Bodenk.

Zöttl, H. 1960. Die mineralstickstoffanlieferung in fichten - und kiefernbestanden Bayerns. Forstwiss. Cbl. 79: 221-236.

APPENDIX A LIST OF PLANT SPECIES

1	ABIEAMA	Abies amabilis	(Dougl. ex Loud.) Forbes
2	ACERMAC	Acer macrophyllum	Pursh
3	ACHLTRI	Achlys triphylla	(Sm.) DC.
4	ADENBIC	Adenocaulon bicolor	Hook.
5	ALNURUB	Alnus rubra	Bong.
6	ATHYFIL	Athyrium filix-femina	(L.) Roth
7	BOSCHOO	Boschniakia hookeri	Walp.
8	BROMVUL	Bromus vulgaris	(Hook.) Shear
9	CAMPSCO	Campanula scouleri	Hook. ex A. DC.
10	CAREHEN	Carex hendersonii	Bailey
11	CHIMMEN	Chimaphila menziesii	(R. Br. ex D. Don) Spren
12	CIRCALP	Circaea alpina	L.
13	CLADGRA	Cladonia gracilis	(L.) Willd.
14	CLADMUL	Cladonia multiformis	Merr.
15	CLADSQU	Cladonia squamosa	(Scop.) Hoffm.
16	DICEFOR	Dicentra formosa	(Haw.) Walp.
17	DICRFUS	Dicranum fuscescens	Turn.
18	DICRSCO	Dicranum scoparium	Hedw.
19	DISPHOO	Disporum hookeri	(Torr.) Nicholson
20	DISPSMI	Disporum smithii	(Hook.) Piper
21	DRYOASS	Dryopteris assimilis	S.Walker
22	ELYMGLA	Elymus glaucus	Buckl.
23	FESTOCC	Festuca occidentalis	Hook.
24	GALITRI	Galium triflorum	Michx.
25	GAULSHA	Gaultheria shallon	Pursh
26	GOODOBL	Goodyera oblongifolia	Raf.
27	HIERALB	Hieracium albiflorum	Hook.
28	HOLODIS	Holodiscus discolor	(Pursh) Maxim.
29	HYLOSPL	Hylocomium splendens	(Hedw.) B.S.G.
30	HYPNCIR	Hypnum circinale	Hook.
31	ISOPELE	Isopterygium elegans	(Brid.) Lindb.
32	KINDORE	Kindbergia oregana	(Sull.) Ochyra
33	LEUCMEN	Leucolepis menziesii	(Hook.) Steere ex L. Koc
34	LINNBOR	Linnaea borealis	L.
35	LISTCAU	Listera caurina	Piper
36	LISTCOR	Listera cordata	(L.) R. Br. in Ait.
37	LONIINV	Lonicera involucrata	(Richards.) Banks ex Spr
38	LUZUPAR	Luzula parviflora	(Ehrh.) Desv.
39	MAHONER	Mahonia nervosa	(Pursh) Nutt.
40	MAIADIL	Maianthemum dilatatum	(How.) Nels. & Macbr.
41	MITEPEN	Mitella pentandra	Hook.
42	MONTSIB	Montia sibirica	(L.) Howell
43	MYCEMUR	Mycelis muralis	(L.) Dumort.
44	OSMOCHI	Osmorhiza chilensis	Hook. & Arn.
45	PELTLEU	Peltigera leucophlebia	(Hyl.) Gyel.
46	PHYSCAP	Physocarpus capitatus	(Pursh) Ktze.
47	PINUMON	Pinus monticola	Dougl. ex D. Don in Lamb
48	PLAGINS	Plagiomnium insigne	(Mitt.) Kop.
49	PLAGUND	Plagiothecium undulatum	(Hedw.) B.S.G.
50	POLYCOM	Polytrichum commune	Hedw.
51	POLYMUN	Polystichum munitum	(Kaulf.) Presl
52	PSEUMEN	Pseudotsuga menziesii	(Mirb.) Franco
53	PTERAQU	Pteridium aquilinum	(1.) Kuhn in Decken
54	RANUOCC	Ranunculus occidentalis	Nutt. in Torr. & Gray
55	RHAMPUR	Rhamnus purshianus	DC.
56	RHYTLOR	Rhytidiadelphus loreus	(Hedw.) Warnst.
57	RHYTROB	Rhytidiopsis robusta	(Hook.) Broth.
58	RHYTTRI	Rhytidiadelphus triquetrus	(Hedw.) Warnst.
59	ROSAGYM	Rosa gymnocarpa	Nutt. in Torr. & Gray
60	RUBUSPE	Rubus spectabilis	Pursh
61	RUBUURS	Rubus ursinus	Cham. & Schlecht.
62	SALISCO	Salix scouleriana	Barratt in Hook.
63	SALISIT	Salix sitchensis	Sanson in Bong.
64	SALISPP	Salix spp.	
65	SMILSTE	Smilacina stellata	(1.) Desf.
66	STERTOM	Stereocaulon tomentosum	Fr.
67	STREAMP	Streptopus amplexifolius	(L.) DC.
68	SYMPMOL	Symphoricarpos mollis	Nuttal
69	THUJPLI	Thuja plicata	Donn ex D. Don in Lamb.
70	TIARLAC	Tiarella laciniata	Hook.
71	TIARTRI	Tiarella trifoliata	L.
72	TRACMEG	Trachybryum megaptilum	(Sull.) Schof.
73	TRAUCAR	Trautvetteria caroliniensis	(Walt.) Vail
74	TRIELAT	Trientalis latifolia	Hook.
75	TRILOVA	Trillium ovatum	Pursh
76	TSUGHET	Tsuga heterophylla	(Raf.) Sarg.
77	VACCPAR	Vaccinium parvifolium	Sm. in Rees
78	VIOLSEM	Viola sempervirens	Greene
79	VIOLSPP	Viola spp.	

APPENDIX B. UNDERSTORY VEGETATION TABLES

GVD Site

PLOT NUMBER		AVERAGE VALUES		RKO 001		RKO 002		RKO 003		RKO 004	
ST	SPECIES	P	MC	Percent cover, vigor							
B1											
	PSEUMEN	100.0	15.0	17	+	7	+	17	+	17	1
	THUJPLI	100.0	8.1	7	1	3	1	3	1	17	1
	TSUGHET	75.0	3.7	3	+			3	1	7	1
	PINUMON	50.0	1.1					.6	+	3	+
B2											
	GAULSHA	100.0	87.5	87	1	87	1	87	1	87	1
	THUJPLI	100.0	3.6	3	1	7	1	1	1	1	1
	VACCPAR	100.0	2.1	3	1	1	1	1	1	1	1
	TSUGHET	75.0	1.5	3	1			.6	1	1	1
	MAHONER	75.0	0.5	.2	1	.2	+	1	+		
	PSEUMEN	50.0	0.2	.2	+	.6	+				
	SALISIT	25.0	0.2	.6	1						
C											
	BOSCHOO	100.0	0.6	.6	1	.6	2	.6	1	.6	1
	LISTCOR	75.0	2.5			.6	+	7	1	1	1
	POLYMUN	50.0	0.8					1	1	1	1
	LINNBOR	50.0	0.6			1	1			.6	1
	HIERALB	50.0	0.2	.2	+			.6	+		
	ACHLTRI	25.0	0.2							.6	1
	ELYMGLA	25.0	0.2			.6	1				
	FESTOCC	25.0	0.0	.2	1						
DH											
	TRACMEG	100.0	8.6	17	1	7	1	7	1	1	1
	POLYCOM	100.0	4.6	7	1	3	1	3	1	3	+
	HYLOSPL	100.0	4.1	1	1	7	1	3	1	3	1
	RHYTROB	75.0	6.7	17	1			7	1	1	1
	DICRSCO	75.0	1.5	3	1	1	1	.6	1		
	CLADMUL	75.0	1.2	3	2	.6	1	.6	1		
	CLADGRA	75.0	0.5	.6	+	.6	1	.6	1		
	PELTLEU	75.0	0.4	.2	1	.6	1	.6	1		
	DICRFUS	50.0	1.3	3	1	1	1				
	RHYTLOR	25.0	0.4					1	1		

GD Site

PLOT NUMBER		AVERAGE VALUES		RKO 005		RKO 006		RKO 007		RKO 008	
ST	SPECIES	P	MC	Percent cover, vigor							
B1											
	THUJPLI	100.0	9.1	3	1	7	1	7	2	17	1
	PSEUMEN	100.0	3.6	1	0	7	1	1	0	3	0
	TSUGHET	100.0	2.6	1	1	3	1	3	1	1	1
	SALISIT	50.0	0.8	1	+	1	1				
B2											
	MAHONER	100.0	7.6	3	1	1	1	17	2	7	1
	VACCPAR	100.0	1.9	3	1	.6	1	1	1	1	1
	GAULSHA	75.0	3.2			1	+	7	1	3	1
	THUJPLI	75.0	1.7			3	1	1	1	1	1
C											
	POLYMUN	100.0	3.1	1	+	3	+	3	1	3	1
	ACHLTRI	100.0	2.4	.6	1	3	1	1	1	3	1
	PTERAQU	100.0	0.4	.2	+	.2	+	.6	1	.6	+
	TRILOVA	100.0	0.4	.6	+	.2	+	.6	+	.2	1
	CHIMMEN	75.0	0.6	.6	+	1	1	.2	1		
	RUBUURS	25.0	0.2							.6	1
	LISTCOR	25.0	0.0					.2	1		
DH											
	KINDORE	100.0	22.4	29	1	41	2	1	+	17	1
	HYLOSPL	25.0	0.0	.2	1						

GF Site

PLOT NUMBER		AVERAGE VALUES		RKO 009		RKO 010		RKO 011		RKO 012	
ST	SPECIES	P	MC	Percent cover, vigor							
B1											
	THUJPLI	50.0	1.8					3	2	3	1
	SALISIT	50.0	0.8			1	1	1	0		
	PINUMON	25.0	0.2			.6	+				
	TSUGHET	25.0	0.2			.6	+				
B2											
	GAULSHA	75.0	3.7	3	1	3	+	7	1		
	VACCPAR	75.0	1.7	1	1	1	1	3	1		
	MAHONER	50.0	0.3	.6	2			.6	1		
	ROSAGYM	25.0	0.9					3	1		
	RUBUSPE	25.0	0.2			.6	+				
	THUJPLI	25.0	0.2							.6	+
	TSUGHET	25.0	0.2	.6	1						
	SYMPMOL	25.0	0.0							.2	+
C											
	POLYMUN	100.0	26.2	17	2	29	3	29	2	29	1
	ACHLTRI	100.0	14.4	7	2	17	3	29	2	3	1
	GALITRI	100.0	4.6	3	1	7	2	3	1	3	+
	MYCEMUR	100.0	2.6	1	1	1	1	3	1	3	+
	RUBUURS	100.0	2.6	3	1	3	2	1	1	1	+
	TRILOVA	100.0	2.1	1	1	3	2	1	2	1	+
	MAIADIL	100.0	1.9	3	1	1	1	.6	1	1	+
	ADENBIC	100.0	1.8	.2	1	3	2	1	1	1	+
	RANUOCC	100.0	0.5	.2	1	.6	+	.6	1	.6	1
	TRAUCAR	75.0	2.0			3	1	3	1	.6	+
	PTERAQU	75.0	1.4	.2	1	3	2	1	1		
	BROMVUL	75.0	1.0	.6	1	1	1	1	1		
	VIOLSEM	75.0	1.0	.6	1	1	1	1	1		
	TRIELAT	75.0	0.6	.2	1			1	1	.6	+
	DISPHOO	50.0	0.3			.6	1			.6	+
	STREAMP	50.0	0.3	.6	1			.6	1		
	CAMPSCO	50.0	0.1			.2	1			.2	+
	LINNBOR	25.0	0.9	3	2						
	ATHYFIL	25.0	0.2							.6	+
	DICEFOR	25.0	0.0					.2	1		
	HIERALB	25.0	0.0							.2	1
DH											
	KINDORE	100.0	52.0	62	2	41	2	41	1	62	1
	LEUCMEN	75.0	2.2	3	2	3	2	1	1		
	RHYTTRI	75.0	0.7	1	1			.6	1	.6	1
	PLAGINS	50.0	1.3			3	2			1	1
	RHYTLOR	25.0	0.0					.2	+		

VVD Site

PLOT NUMBER		AVERAGE VALUES		RKO 013		RKO 014		RKO 015		RKO 016	
ST	SPECIES	P	MC	Percent cover, vigor							
B1											
	THUJPLI	100.0	7.6	7	2	17	2	1	2	3	2
	TSUGHET	100.0	4.6	1	2	1	+	7	1	7	1
	HOLODIS	75.0	10.7	7	2	17	2			17	2
B2											
	GAULSHA	100.0	57.3	62	2	62	2	41	2	62	2
	MAHONER	100.0	15.0	17	2	7	2	17	2	17	2
	ROSAGYM	100.0	8.1	3	1	17	1	3	1	7	2
	VACCPAR	100.0	4.6	3	2	7	1	3	2	3	2
	SYMPMOL	75.0	2.2	3	1	3	1			1	1
	THUJPLI	50.0	2.3			7	1	1	2		
	HOLODIS	50.0	1.8	3	1	3	1				
	TSUGHET	25.0	0.2					.6	1		
C											
	ACHLTRI	100.0	6.6	3	2	1	2	17	2	3	2
	POLYMUN	100.0	4.1	3	1	7	2	3	1	1	1
	BROMVUL	100.0	2.6	3	2	3	2	1	2	1	2
	TRIELAT	100.0	0.8	1	2	.2	1	.6	1	.6	1
	LINNBOR	75.0	2.2	1	1	3	2	3	2		
	RUBUURS	75.0	1.0			1	2	.6	1	1	1
	VIOLSEM	25.0	0.4	1	2						
	ADENBIC	25.0	0.2							.6	1
	CHIMMEN	25.0	0.2					.6	2		
	FESTOCC	25.0	0.2	.6	2						
	GOODOBL	25.0	0.2	.6	2						
	PTERAQU	25.0	0.2					.6	1		
	BOSCHOO	25.0	0.0					.2	1		
	CAMPSCO	25.0	0.0	.2	1						
	LISTCOR	25.0	0.0							.2	1
DH											
	HYLOSPL	100.0	23.5	17	2	17	2	17	2	41	2
	RHYTROB	100.0	5.8	7	2	7	2	.6	1	7	2
	KINDORE	75.0	27.3	17	2			29	2	62	2
	RHYTLOR	75.0	2.2			3	2	3	2	1	2
	DICRSCO	75.0	1.2	1	1	1	1	1	1		
	PELTLEU	50.0	0.3			.6	1	.6	+		
	LEUCMEN	25.0	0.2			.6	2				

VD Site

PLOT NUMBER		AVERAGE VALUES		RKO 017		RKO 018		RKO 019		RKO 020	
ST	SPECIES	P	MC	Percent cover, vigor							
B1											
	TSUGHET	00.0	1.6	.6	1	1	1	.6	1	3	2
B2											
	MAHONER	100.0	29.3	29	3	41	3	29	3	17	3
	VACCPAR	100.0	5.1	1	1	7	1	7	2	3	2
	TSUGHET	75.0	2.7	3	2	3	1	3	1		
	SYMPMOL	75.0	1.5	3	2			1	1	.6	1
	GAULSHA	25.0	0.2	.6	+						
	ACERMAC	25.0	0.0					.2	+		
C											
	ACHLTRI	100.0	37.7	41	3	62	2	29	3	17	2
	POLYMUN	100.0	20.4	17	3	17	2	17	2	29	2
	RUBUURS	100.0	4.3	.6	2	7	2	7	2	1	1
	PTERAQU	100.0	2.9	7	2	1	1	1	1	.6	1
	GALITRI	100.0	2.1	1	2	1	1	3	1	1	1
	ELYMGLA	100.0	1.4	.6	1	1	1	1	1	1	+
	MYCEMUR	100.0	1.4	1	2	.6	1	1	1	1	1
	MAIADIL	100.0	0.3	.6	1	.2	1	.2	1	.2	1
	TIARTRI	75.0	1.7	1	1	3	1	1	1		
	TRIELAT	75.0	1.7			3	2	1	1	1	1
	LINNBOR	50.0	7.3	29	3			.2	1		
	DISPSMI	50.0	0.8			1	2			1	1
	DISPHOO	25.0	0.2	.6	2						
	LISTCOR	25.0	0.2	.6	2						
	TRILOVA	25.0	0.2	.6	1						
	ADENBIC	25.0	0.0	.2	+						
	CHIMMEN	25.0	0.0	.2	1						
	GOODOBL	25.0	0.0	.2	1						
DH											
	KINDORE	100.0	87.5	87	3	87	3	87	3	87	2
	HYLOSPL	100.0	5.6	3	3	3	3	7	3	7	3
	RHYTLOR	75.0	1.7	1	2	3	2			1	2
	PELTLEU	25.0	0.2	.6	2						

VF Site

PLOT NUMBER		AVERAGE VALUES		RKO 021		RKO 022		RKO 023		RKO 024	
ST	SPECIES	P	MC	Percent cover, vigor							
B1											
	TSUGHET	50.0	0.8	1	2			1	2		
	THUJPLI	25.0	0.9	3	2						
	VACCPAR	25.0	0.4	1	2						
B2											
	RUBUSPE	100.0	3.6	1	2	7	2	1	2	3	2
	VACCPAR	100.0	3.1	1	1	3	2	3	2	3	2
	TSUGHET	50.0	1.3	3	2			1	1		
	ACERMAC	25.0	0.4							1	1
C											
	POLYMUN	100.0	81.3	87	3	87	3	87	3	62	3
	TIARTRI	100.0	29.5	17	3	17	3	41	3	41	3
	ACHLTRI	100.0	20.1	3	3	17	3	17	3	41	3
	TIARLAC	100.0	3.1	1	2	3	2	3	3	3	3
	CAREHEN	100.0	2.4	.6	3	1	2	3	2	3	3
	ATHYFIL	100.0	2.1	3	3	1	2	1	2	1	1
	DRYOASS	75.0	2.2	3	3	1	2	3	2		
	GALITRI	75.0	2.2	3	3	3	2	1	3		
	MYCEMUR	75.0	1.7	1	2	3	2	1	2		
	MONTSIB	75.0	1.0			.2	2	.2	2	3	3
	TRILOVA	75.0	1.0	1	2	1	2	.6	2		
	TRIELAT	75.0	0.7	.6	2			1	2	.6	1
	BROMVUL	50.0	1.1					.6	2	3	2
	ADENBIC	50.0	0.6			1	2	.6	2		
	CAMPSCO	50.0	0.1			.2	+			.2	1
	DICEFOR	25.0	0.2							.6	2
	RUBUURS	25.0	0.0			.2	1				
DH											
	PLAGINS	100.0	20.4	17	3	17	3	29	3	17	2
	LEUCMEN	50.0	1.3			1	2	3	3		
	RHYTTRI	50.0	0.6	.6	2					1	2
	KINDORE	25.0	0.9	3	2						

APPENDIX C

EIGENVALUES, EIGENVECTORS AND ORDINATION SCORES FROM PCA, RA, AND DCA OF UNDERSTORY VEGETATION

INDEX

C-1 Eigenvalues and eigenvectors from PCA of understory vegetation

TEST	STATISTIC	DF	SIGNIF	N= 24 OUT OF 24
INDEPENDENCE	CANNOT BE TESTED			
EQUICORRELATION	4656.6	1769	0.	

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
COMPONENT	15.492	9.3792	7.2259	5.4357	3.6697	3.1031	2.5752	2.3502	2.0075	1.7103
% VARIANCE	25.82	41.45	53.50	62.55	68.67	73.84	78.13	82.05	85.40	88.25
2.PSEUMEN	-.18860	-.13067	-.11547	-.11850	-.11524	-.54878 -1	-.11786 -2	-.13062 -1	-.54113 -1	.62643 -1
3.TSUGHET	-.10433	.75119 -1	.13390	-.14681	-.44923 -1	.17530	.11186	.42103 -1	-.11610	.11156
4.THUJPLI	-.18271	-.37688 -1	-.52490 -1	.97185 -1	-.22411	.40656 -1	.54806 -1	.27205 -1	-.36212 -1	-.15973
5.GAULSHA	-.20527	.42943 -2	-.54058 -1	.19790	.25475 -1	.22247 -1	.39027 -1	.13513	-.11295 -1	.41554 -1
6.VACCPAR	-.30601 -2	.37694 -1	.23409	.41762 -1	.12041	-.44876 -1	.31323	.32090 -1	.79948 -1	.27690
7.SALISIT	.11638 -1	.19332 -1	-.19930	.24918 -1	-.20025	-.10682	.16277	-.10658	.71098 -1	.35514
8.MAHONER	-.64575 -1	.24870	.17218	-.82967 -1	-.21659 -1	-.30213 -1	-.24916 -1	-.37895 -1	.21570 -1	.21282 -1
9.HIERALB	-.10441	-.94314 -1	-.12835	-.75092 -2	.17310	.21310 -1	-.96150 -1	.11346 -1	-.19632	-.16583
10.FESTOCC	-.77335 -1	.13882 -1	.47568 -1	.23439	.10745 -1	.61192 -1	-.10037 -1	-.44756	-.46700 -1	.45991 -1
11.BOSCHOO	-.19296	-.12965	-.89499 -1	-.25429 -1	.16019	-.32239 -1	.15010 -2	.80852 -1	-.99834 -2	.60780 -1
12.RHYTROB	-.17504	-.44549 -2	.57163 -1	.22328	.74186 -1	.97279 -1	.47013 -1	.32280 -1	-.17033	.11715 -1
13.CLADGRA	-.17259	-.13362	-.99058 -1	-.14644 -1	.21945	-.51062 -1	.41329 -1	-.81108 -1	.92898 -1	-.52226 -2
14.POLYCOM	-.18707	-.14665	-.10821	-.26771 -1	.17423	-.32529 -1	.22009 -1	-.33819 -2	-.48013 -1	.53128 -1
15.TRACMEG	-.18792	-.14683	-.10846	-.22189 -1	.19665	-.40913 -1	.33893 -1	-.39044 -1	.48289 -2	.35071 -1
16.DICRFUS	-.13792	-.11033	-.80316 -1	.58213 -2	.16258	-.73068 -1	.12612	-.26002	.22751	.30889 -1
17.HYLOSPL	-.15033	.14041	.16511	.71011 -1	.17799	.45334 -1	-.28899 -1	.56077 -1	-.71116 -1	.36410 -1
18.PELTLEU	-.14674	.84613 -2	.14986 -1	.33409 -1	.18546	.45704 -1	-.15755	.21973	.35597	.14582 -1
19.CLADMUL	-.16558	-.13051	-.95822 -1	-.21751 -3	.20087	-.52972 -1	.98743 -1	-.17209	.10554	.29985 -1
20.DICRSCO	-.17857	-.28616 -1	.30740 -1	.18596	.12786	.21821 -1	.49974 -1	-.10482	.20460	.15502 -1
21.LINNBOR	-.54997 -1	.12433	.42411 -1	.87756 -1	.97516 -1	.72663 -1	-.24339	.12798	.41861	-.73690 -1
22.LISTCOR	-.14028	-.62951 -1	-.62009 -1	-.65270 -1	.12572	.49742 -1	-.21557	.27045	-.13784	.13224 -1
23.ELYMGLA	-.23743 -3	.13724	.97546 -1	-.23387	.27106	-.94892 -1	-.22521 -1	-.14673	.29293 -1	.58088 -1
24.PINUMON	-.64673 -1	-.56604 -1	-.12718	-.12320 -1	.35179 -1	.59604 -1	-.11811	.25457	-.34896	.26271
25.POLYMUN	.23213	-.44211 -1	.70683 -1	-.19093 -2	.64901 -1	.91084 -1	-.52969 -2	.67616 -1	-.36391 -1	-.21689 -1
26.RHYTLOR	-.60900 -1	.16467	.13682	-.18836 -1	.17458	.20662 -1	.65640 -2	.29673	.42697 -3	.30143 -1
27.ACHLTRI	.19316	.12156	.11133	-.32458 -1	.86524 -1	-.10608	-.49972 -1	.28645 -1	.41139 -1	.14832
28.PTERAQU	.67475 -1	.20969	-.68491 -1	-.13946	.53981 -1	-.74266 -1	-.92547 -1	.13256 -1	.15787	.32077
29.TRILOVA	.17034	-.16238 -1	-.21633	.48568 -2	-.83190 -1	.17572	.69700 -2	.52762 -2	.12748	-.25859 -1
30.CHIMMEN	-.36542 -1	.49177 -1	.70030 -2	-.11648	-.35225	-.25988 -1	-.89688 -1	.22791 -1	.25106	.12174
31.KINDORE	.77981 -1	.26746	-.44326 -1	-.95919 -1	-.38743 -1	-.51733 -1	-.30536 -1	-.12062	-.42799 -1	-.71463 -1
32.RUBUURS	.87187 -1	.23394	-.36773 -1	-.31953 -1	.19032	-.63524 -1	.90098 -1	.81743 -1	-.78930 -1	-.32263 -1
33.GALITRI	.19167	.61507 -1	-.11762	-.65340 -1	.21392	.12556	.67208 -1	-.49954 -1	.12422 -1	-.19038 -1
34.MAIADIL	.11807	.14115	-.22715	.14870 -1	.14730	-.49338 -1	-.77828 -1	.46280 -2	.47480 -1	-.14643
35.MYCEMUR	.19131	.48794 -1	-.10597	-.61762 -1	.21095	.13645	.51198 -1	-.47391 -1	.33721 -1	-.82983 -1
36.VIOLSEM	.66825 -1	.10493	-.16216	.25843	.10692 -1	-.38783 -1	.93830 -1	-.11859	-.14978 -1	.16138
37.TRIELAT	.99833 -1	.10707	.16146	.51752 -1	.16432	-.81801 -1	.19447	-.10740	-.18447	-.12802
38.RANUOCC	.11311	.71070 -1	-.28527	.12282	.50343 -1	-.56321 -1	.69463 -2	.22075 -1	-.85020 -1	-.47489 -1
39.BROMVUL	.49598 -1	.51946 -1	.79340 -1	.36431	-.72020 -2	-.10560	.38919 -1	.14316	.24912 -1	.11192
40.STREAMP	.70262 -1	.74435 -1	-.16073	.10586	.26723 -1	-.17135	.25803	.11889	.16143	-.22105
41.ADENBIC	.14812	.12376 -1	-.19255	.12262	.78478 -1	.15049	-.34464 -3	.65649 -1	-.69332 -1	.12489
42.LEUCMEN	.13546	-.14665 -1	-.12706	.13698	.74596 -1	.12472	.21681	.15934	.14632	.14358
43.RHYTTRI	.13138	-.64165 -1	-.69581 -1	.10268	.28565 -1	-.24955	.33559 -5	.52730 -1	.39577 -1	-.40836
44.RUBUSPE	.15841	-.21269	.81071 -1	.45794 -1	.46550 -1	.82557 -1	-.15206 -1	.19513 -1	.29519 -1	.16387
45.DISPHOO	.74965 -1	.78841 -1	-.17856	.39034 -2	.97558 -1	.12062	-.39407	-.34876 -1	.22088 -1	.84962 -1
46.TRAUCAR	.10077	.66067 -1	-.25563	.12956	.38959 -1	-.59520 -1	.49199 -1	.35002 -1	-.96723 -1	.20156
47.CAMPSCO	.11291	-.70470 -1	-.38876 -1	.20303	.32362 -1	-.15271 -2	-.27868	-.20673	-.17085	.10050
48.PLAGINS	.17295	-.20704	.42360 -1	.42033 -1	.52389 -1	.12963	-.34932 -1	-.40619 -4	-.20938 -1	.64891 -1
49.ROSAGYM	-.45346 -1	.13645	.10282	.30271	-.42864 -1	.39061 -1	.13290	.17900	.15444 -1	-.32593 -1
50.DICEFOR	.90625 -1	-.99268 -1	.52570 -1	.13188	.10823 -1	-.42752	-.63011 -1	.77093 -1	-.63162 -2	.48691 -1
51.SYMPMOL	-.28218 -1	.18288	.15209	.14204	.93179 -1	.12910	-.19750	-.73852 -1	.85707 -2	-.60524 -1
52.ATHYFIL	.15247	-.21573	.87795 -1	.12982 -1	.35159 -1	.12233	-.25184 -1	-.19025 -1	-.76080 -2	-.15567
53.HOLODIS	-.61270 -1	.10473	.14901	.29332	-.41783 -1	.13399	.14898 -1	.31730 -2	-.12593	-.70894 -1
54.GOODOBL	-.25495 -1	.94545 -1	.81191 -1	.19142	.51345 -2	.12124	-.24929	-.30915	.53104 -1	.47719 -1
55.TIARTRI	.15186	-.16390	.18213	-.51004 -1	.11870	.26410 -1	-.20332 -1	-.35722 -2	.71072 -1	.70860 -1
56.DISPSMI	.22462 -1	.11599	.10029	-.19130	.17759	-.86964 -1	.14409	-.10710	-.20931	.45556 -1
57.ACERMAC	.75438 -1	-.11019	.13655	.53830 -1	.39575 -1	-.39162	-.18296	.71259 -2	-.38019 -1	.44261 -1
58.TIARLAC	.14445	-.22948	.13914	.27045 -1	.38031 -1	.68800 -1	.20722 -1	.24839 -1	.55811 -1	.35127 -1
59.DRYOASS	.11556	-.17089	.84483 -1	-.34081 -1	.28691 -1	.32859	.16567	.39178 -3	.76742 -1	-.33228 -1
60.CAREHEN	.14158	-.22714	.14476	.37366 -1	.39939 -1	.19708 -1	.45274 -2	.34554 -1	.50292 -1	.55634 -1
61.MONTSIB	.10396	-.18184	.13864	.83250 -1	.26015 -1	-.28055	-.15034	.44273 -1	-.82949 -3	.78821 -1

C - 2 Eigenvalues from RA analysis of understory vegetation

AXIS	EIGENVALUE	%EV	SUM %EV	SQRT EV	SCALE
1	0.5593353142E+00	28.38965	28.38965	0.7478873E+00	99.99998
2	0.3452201744E+00	17.52202	45.91167	0.5875544E+00	78.56189
3	0.2165787118E+00	10.99268	56.90434	0.4653801E+00	62.22597
4	0.1734367966E+00	8.80297	65.70731	0.4164574E+00	55.68451
5	0.1305763641E+00	6.62754	72.33484	0.3613535E+00	48.31656
6	0.9629732533E-01	4.88767	77.22250	0.3103181E+00	41.49263
7	0.8355549147E-01	4.24095	81.46344	0.2890596E+00	38.65016
8	0.6218213284E-01	3.15612	84.61955	0.2493635E+00	33.34238
9	0.5449349113E-01	2.76587	87.38542	0.2334384E+00	31.21304
10	0.4514783968E-01	2.29153	89.67694	0.2124802E+00	28.41072
11	0.4391265424E-01	2.22883	91.90576	0.2095535E+00	28.01939
12	0.2800934281E-01	1.42164	93.32739	0.1673599E+00	22.37769
13	0.2389919892E-01	1.21303	94.54042	0.1545936E+00	20.67070
14	0.2256529123E-01	1.14532	95.68575	0.1502175E+00	20.08557
15	0.1915254963E-01	0.97211	96.65785	0.1383927E+00	18.50449
16	0.1705511022E-01	0.86565	97.52350	0.1305952E+00	17.46188
17	0.1121869744E-01	0.56942	98.09291	0.1059183E+00	14.16234
18	0.9922001622E-02	0.50360	98.59651	0.9960926E-01	13.31875
19	0.8545447644E-02	0.43373	99.03024	0.9244162E-01	12.36037
20	0.8029464699E-02	0.40754	99.43777	0.8960730E-01	11.98139
21	0.4707729853E-02	0.23895	99.67671	0.6861287E-01	9.17423
22	0.3542664291E-02	0.17981	99.85652	0.5952029E-01	7.95846
23	0.2824235116E-02	0.14335	99.99986	0.5314353E-01	7.10582
24	0.8363653922E-12	0.00000	99.99986	0.9145301E-06	0.00012

TRACE OF XX' = 0.1970208029255369E+01
AND SUM OF EV = 0.1970208029255373E+01

C - 3 Ordination species scores from RA analysis of understory vegetation

N	NAME	AXIS 1	2	3	4	5	6	7	RANKED 1			RANKED 2		
1	PSEUMEN	20.0880	60.6659	74.2732	60.3750	62.4791	64.1514	50.7216	15	DICRFUS	0.0	55	DISPSMI	0.0
2	TSUGHET	45.9120	34.6790	52.9201	56.8629	48.4996	69.8194	52.7559	18	CLADMUL	1.5674	39	STREAMP	8.0572
3	THUJPLI	35.1475	41.6878	57.1825	45.1504	59.1936	66.8132	55.1456	12	CLADGRA	2.2703	50	SYMPMOL	9.8199
4	GAULSHA	29.4233	42.8986	52.2801	35.8841	45.4808	65.5803	50.5771	14	TRACMEG	3.8556	33	MAIADIL	10.8254
5	VACCPAR	52.1973	38.0661	51.6806	50.2450	44.7581	64.5767	55.2392	13	POLYCOM	4.6879	53	GOODOBL	10.8274
6	SALISIT	48.1531	28.2979	89.6028	40.9085	80.7341	56.1940	70.1401	10	BOSCHOO	8.7443	27	PTERAQU	11.4030
7	MAHONER	45.7417	16.4482	46.9420	60.3768	46.0696	64.3978	54.9473	21	LISTCOR	18.8218	31	RUBUURS	12.1943
8	HIERALB	22.0957	70.2896	78.7674	36.5415	24.5913	67.2513	47.9081	19	DICRSCO	19.1703	35	VIOLSEM	12.5809
9	FESTOCC	24.5349	41.0964	23.6192	12.6033	45.0695	62.0602	84.5646	1	PSEUMEN	20.0880	48	ROSAGYM	13.1525
10	BOSCHOO	8.7443	78.0669	67.2911	46.0956	29.3299	64.4396	45.9982	8	HIERALB	22.0957	52	HOLODIS	13.3435
11	RHYTROB	22.6392	46.6589	34.3339	28.1209	42.0634	69.4080	52.3744	11	RHYTROB	22.6392	30	KINDORE	13.6957
12	CLADGRA	2.2703	89.4669	72.1030	44.7447	17.4565	59.0152	69.2157	9	FESTOCC	24.5349	37	RANUOCC	14.8745
13	POLYCOM	4.6879	86.4548	72.3810	45.0393	26.4529	63.9709	49.1360	17	PELTLEU	24.5935	44	DISPHOO	15.1569
14	TRACMEG	3.8556	87.5392	72.3291	44.8206	23.6052	62.2420	56.3270	23	PINUMON	26.2481	45	TRAUCAR	15.2139
15	DICRFUS	0.0	93.6732	74.2670	41.8471	15.5491	51.3361	100.0000	4	GAULSHA	29.4233	22	ELYMGLA	16.1190
16	HYLOSPL	35.4689	29.3273	38.3122	48.9668	32.3209	66.4234	52.1195	3	THUJPLI	35.1475	7	MAHONER	16.4482
17	PELTLEU	24.5935	47.1111	46.6803	44.4050	27.9234	65.4450	54.1075	16	HYLOSPL	35.4689	25	RHYTLOR	17.4609
18	CLADMUL	1.5674	91.2440	72.8529	42.4311	19.5794	57.1396	80.3463	52	HOLODIS	37.0001	29	CHIMMEN	18.6541
19	DICRSCO	19.1703	53.3064	40.0105	31.6378	34.2990	62.5189	69.7214	20	LINNBOR	40.8948	20	LINNBOR	23.8835
20	LINNBOR	40.8948	23.8835	44.2526	39.3253	31.5368	65.3934	48.8953	48	ROSAGYM	42.0838	36	TRIELAT	26.9309
21	LISTCOR	18.8218	61.6094	63.3854	52.1635	33.5555	71.9711	22.4165	53	GOODOBL	42.9334	6	SALISIT	28.2979
22	ELYMGLA	50.1898	16.1190	54.2663	84.1749	5.2050	59.7913	58.8167	25	RHYTLOR	43.1287	16	HYLOSPL	29.3273
23	PINUMON	26.2481	62.7403	80.3192	35.6161	43.0213	76.4679	0.0	29	CHIMMEN	43.4057	32	GALITRI	29.6209
24	POLYMUN	65.6139	38.9909	55.5128	47.9645	44.0075	66.4887	52.4788	7	MAHONER	45.7417	26	ACHLTRI	30.5179
25	RHYTLOR	43.1287	17.4609	36.8881	54.3094	28.7855	67.6444	47.8510	2	TSUGHET	45.9120	34	MYCEMUR	30.8985
26	ACHLTRI	63.3704	30.5179	53.8454	50.8823	42.3369	62.2599	52.5721	50	SYMPMOL	47.6220	38	BROMVUL	31.9962
27	PTERAQU	56.5577	11.4030	67.7076	57.9974	41.1599	61.5667	51.9594	6	SALISIT	48.1531	40	ADENBIC	33.6087
28	TRILOVA	70.0806	34.7187	77.1008	37.7042	52.3973	71.9882	56.3160	22	ELYMGLA	50.1898	2	TSUGHET	34.6790
29	CHIMMEN	43.4057	18.6541	67.0772	75.9361	100.0000	61.8517	62.2486	5	VACCPAR	52.1973	28	TRILOVA	34.7187
30	KINDORE	56.1928	13.6957	62.1406	52.8082	45.2257	63.4564	56.0091	30	KINDORE	56.1928	5	VACCPAR	38.0661
31	RUBUURS	58.9349	12.1943	59.5019	45.7658	29.2469	63.3138	52.9678	27	PTERAQU	56.5577	24	POLYMUN	38.9909
32	GALITRI	73.0140	29.6209	69.8566	43.1832	28.2487	70.6990	55.7837	31	RUBUURS	58.9349	41	LEUCMEN	39.2358
33	MAIADIL	66.4587	10.8254	84.1678	29.1283	24.7890	60.3432	50.9084	38	BROMVUL	59.3633	9	FESTOCC	41.0964
34	MYCEMUR	73.4912	30.8985	68.8262	43.3314	28.2765	71.2898	56.2443	55	DISPSMI	59.5294	3	THUJPLI	41.6878
35	VIOLSEM	59.6223	12.5809	69.6214	0.5611	43.3438	58.2446	56.2263	35	VIOLSEM	59.6223	4	GAULSHA	42.8986
36	TRIELAT	64.0092	26.9309	44.1115	48.6295	32.3828	62.3329	57.0789	26	ACHLTRI	63.3704	42	RHYTTRI	46.1606
37	RANUOCC	70.3090	14.8745	98.9794	3.6508	35.2596	58.8663	51.7365	36	TRIELAT	64.0092	11	RHYTROB	46.6589
38	BROMVUL	59.3633	31.9962	34.6511	19.9758	47.3301	55.4913	51.7614	24	POLYMUN	65.6139	17	PELTLEU	47.1111
39	STREAMP	65.9616	8.0572	89.4561	3.6914	35.8738	48.1734	55.5015	39	STREAMP	65.9616	46	CAMPSCO	49.5609
40	ADENBIC	73.5590	33.6087	73.9624	19.3645	37.7471	72.6398	53.3326	33	MAIADIL	66.4587	19	DICRSCO	53.3064
41	LEUCMEN	74.9789	39.2358	68.2864	17.8755	38.8149	73.0323	55.4123	44	DISPHOO	67.3946	1	PSEUMEN	60.6659
42	RHYTTRI	80.2338	46.1606	65.4394	26.9403	39.7303	44.2138	50.3177	45	TRAUCAR	69.9517	21	LISTCOR	61.6094
43	RUBUSPE	93.8983	82.5257	46.1949	42.6568	45.3032	68.3896	53.8328	28	TRILOVA	70.0806	23	PINUMON	62.7403
44	DISPHOO	67.3946	15.1569	88.8235	26.7505	26.3153	68.8158	45.2232	37	RANUOCC	70.3090	54	TIARTRI	68.3607
45	TRAUCAR	69.9517	15.2139	100.0000	0.0	40.1783	58.0960	51.4839	32	GALITRI	73.0140	8	HIERALB	70.2896
46	CAMPSCO	76.9756	49.5609	54.1804	20.7157	42.0620	57.0820	51.5640	34	MYCEMUR	73.4912	49	DICEFOR	73.4210
47	PLAGINS	91.1506	74.6230	53.0794	39.8159	43.3966	70.8128	54.5093	40	ADENBIC	73.5590	47	PLAGINS	74.6230
48	ROSAGYM	42.0838	13.1525	20.3961	15.7291	50.2084	66.5704	56.1184	41	LEUCMEN	74.9789	10	BOSCHOO	78.0669
49	DICEFOR	89.2835	73.4210	36.5397	31.5945	52.1087	2.3531	39.1412	46	CAMPSCO	76.9756	51	ATHYFIL	79.9892
50	SYMPMOL	47.6220	9.8199	26.9317	40.7190	31.9146	68.8052	54.2030	42	RHYTTRI	80.2338	56	ACERMAC	80.9064
51	ATHYFIL	92.8727	79.9892	47.6762	45.6966	43.7248	72.2598	56.7083	54	TIARTRI	86.6592	43	RUBUSPE	82.5257
52	HOLODIS	37.0001	13.3435	0.0	11.4818	50.6465	73.3757	57.0275	49	DICEFOR	89.2835	58	DRYOASS	84.4574
53	GOODOBL	42.9334	10.8274	16.7374	23.7717	41.6843	68.3174	59.9677	47	PLAGINS	91.1506	13	POLYCOM	86.4548
54	TIARTRI	86.6592	68.3607	40.1505	59.4765	36.8290	64.9083	54.1395	56	ACERMAC	91.3792	14	TRACMEG	87.5392
55	DISPSMI	59.5294	0.0	50.2291	100.0000	0.0	61.8372	58.7329	51	ATHYFIL	92.8727	12	CLADGRA	89.4669
56	ACERMAC	91.3792	80.9064	19.7941	58.4740	43.0621	0.0	35.7233	43	RUBUSPE	93.8983	57	TIARLAC	90.8973
57	TIARLAC	96.6212	90.8973	37.2349	49.1015	46.2057	68.4224	55.4505	58	DRYOASS	93.9530	18	CLADMUL	91.2440
58	DRYOASS	93.9530	84.4574	47.1406	50.6271	44.6131	100.0000	65.5993	57	TIARLAC	96.6212	59	CAREHEN	92.0567
59	CAREHEN	97.0717	92.0567	35.1365	48.8229	46.3702	63.4753	53.8436	59	CAREHEN	97.0717	15	DICRFUS	93.6732
60	MONTSIB	100.0000	100.0000	21.8738	47.9413	49.3283	21.0462	40.5194	60	MONTSIB	100.0000	60	MONTSIB	100.0000

C - 4 Ordination plot scores from RA analysis of understory vegetation

TRANSFORMATION: NONE

SAMPLES SCORES

N	NAME	AXIS 1	2	3	4	5	6	7	RANKED 1			RANKED 2		
1	RK0001	0.0	91.5136	70.6364	37.4865	20.1183	58.4332	100.0000	1	RK0001	0.0	20	RK0020	0.0
2	RK0002	1.2390	85.3043	68.9045	51.4463	3.0680	58.0877	77.2640	2	RK0002	1.2390	18	RK0018	5.9179
3	RK0003	7.0393	78.1688	64.3742	49.6563	19.2676	77.6538	28.0016	3	RK0003	7.0393	17	RK0017	8.2482
4	RK0004	13.5349	71.6278	68.3551	49.5526	39.5264	83.9603	0.0	4	RK0004	13.5349	19	RK0019	8.5840
5	RK0005	45.8070	18.3629	78.9206	86.8173	93.8360	64.6111	74.9261	14	RK0014	34.8349	9	RK0009	9.8472
6	RK0006	41.6614	24.1486	79.9459	85.2684	100.0000	63.9504	69.7725	13	RK0013	36.9213	11	RK0011	10.8469
7	RK0007	40.6568	27.8496	64.1274	79.6619	71.7455	74.2949	50.3706	15	RK0015	38.4021	16	RK0016	11.6407
8	RK0008	43.0320	23.1309	65.6495	77.8236	63.5968	69.0077	55.6243	16	RK0016	38.7936	13	RK0013	15.2066
9	RK0009	66.0440	9.8472	82.9798	15.1160	18.0354	59.6434	55.7112	7	RK0007	40.6568	15	RK0015	17.6524
10	RK0010	71.0744	20.5302	100.0000	1.6575	30.1407	71.8695	49.3179	6	RK0006	41.6614	5	RK0005	18.3629
11	RK0011	64.5125	10.8469	83.7973	0.0	36.1503	51.6223	61.6785	8	RK0008	43.0320	14	RK0014	18.7355
12	RK0012	74.8009	21.7926	96.1850	17.1039	18.0059	72.7865	57.2338	5	RK0005	45.8070	10	RK0010	20.5302
13	RK0013	36.9213	15.2066	2.0283	5.1753	40.2726	71.7011	68.9624	17	RK0017	54.1792	12	RK0012	21.7926
14	RK0014	34.8349	18.7355	0.0	12.5277	34.4173	79.3153	57.3955	20	RK0020	57.5714	8	RK0008	23.1309
15	RK0015	38.4021	17.6524	28.7294	50.9275	38.4904	67.1946	57.0601	18	RK0018	60.3576	6	RK0006	24.1486
16	RK0016	38.7936	11.6407	9.7133	26.9676	37.7303	79.2869	52.9739	19	RK0019	60.9118	7	RK0007	27.8496
17	RK0017	54.1792	8.2482	52.2945	69.0206	12.9822	74.1754	47.6630	11	RK0011	64.5125	4	RK0004	71.6278
18	RK0018	60.3576	5.9179	48.0584	100.0000	3.7698	65.4783	60.3797	9	RK0009	66.0440	21	RK0021	74.3050
19	RK0019	60.9118	8.5840	47.9993	84.2836	9.5472	60.9365	59.2755	10	RK0010	71.0744	3	RK0003	78.1688
20	RK0020	57.5714	0.0	49.0184	96.4028	0.0	68.7048	61.5939	12	RK0012	74.8009	23	RK0023	83.4337
21	RK0021	87.3469	74.3050	48.8584	60.7636	38.0928	100.0000	67.9339	21	RK0021	87.3469	22	RK0022	84.4893
22	RK0022	97.6509	84.4893	49.3650	43.2380	29.1107	99.1615	64.1995	23	RK0023	94.4892	2	RK0002	85.3043
23	RK0023	94.4892	83.4337	40.0529	49.0731	31.4672	98.1408	65.0229	22	RK0022	97.6509	1	RK0001	91.5136
24	RK0024	100.0000	100.0000	12.6661	50.7296	39.6762	0.0	39.7975	24	RK0024	100.0000	24	RK0024	100.0000

C - 5 Eigenvalues and species scores from DCA of understory vegetation

N	NAME	AX1	AX2	AX3	AX4	RANKED 1		RANKED 2		RANKED 3		RANKED 4	
						EIG=0.559		EIG=0.110		EIG=0.052		EIG=0.029	
1	PSEU MEN	394	301	142	10	15 DICR FUS	507	29 CHIM MEN	477	49 DICE FOR	573	56 ACER MAC	422
2	TSUG HET	239	180	-17	144	18 CLAD MUL	498	6 SALI SIT	373	45 TRAU CAR	410	49 DICE FOR	324
3	THUJ PLI	311	198	181	1	12 CLAD GRA	494	1 PSEU MEN	301	53 GOOD OBL	400	60 MONT SIB	316
4	GAUL SHA	342	2	175	-3	14 TRAC MEG	486	28 TRIL OVA	225	9 FEST OCC	382	42 RHYT TRI	274
5	VACC PAR	193	99	72	32	13 POLY COM	481	27 PTER AQU	208	35 VIOL SEM	376	8 HIER ALB	271
6	SALI SIT	223	373	319	-134	10 BOSC HOO	458	3 THUJ PLI	198	39 STRE AMP	368	9 FEST OCC	247
7	MAHO NER	241	125	-21	148	21 LIST COR	401	58 DRYO ASS	185	56 ACER MAC	348	53 GOOD OBL	239
8	HIER ALB	383	44	-41	271	19 DICR SCO	399	2 TSUG HET	180	6 SALI SIT	319	36 TRIE LAT	189
9	FEST OCC	369	-212	382	247	1 PSEU MEN	394	30 KIND ORE	179	60 MONT SIB	297	29 CHIM MEN	177
10	BOSC HOO	458	80	86	126	8 HIER ALB	383	55 DISP SMI	178	37 RANU OCC	292	38 BROM VUL	175
11	RHYT ROB	380	-79	144	135	11 RHYT ROB	380	7 MAHO NER	125	42 RHYT TRI	273	55 DISP SMI	175
12	CLAD GRA	494	39	47	35	9 FEST OCC	369	24 POLY MUN	115	38 BROM VUL	244	54 TIAR TRI	172
13	POLY COM	481	54	147	1	17 PELT LEU	369	23 PINU MON	101	48 ROSA GYM	234	19 DICR SCO	170
14	TRAC MEG	486	50	132	11	23 PINU MON	359	5 VACC PAR	99	15 DICR FUS	215	20 LINN BOR	167
15	DICR FUS	507	58	215	-161	4 GAUL SHA	342	26 ACHL TRI	98	46 CAMP SCO	208	59 CARE HEN	164
16	HYLO SPL	309	-40	-37	30	3 THUJ PLI	311	45 TRAU CAR	95	44 DISP HOO	204	33 MAIA DIL	158
17	PELT LEU	369	-8	42	123	16 HYLO SPL	309	10 BOSC HOO	80	3 THUJ PLI	181	46 CAMP SCO	154
18	CLAD MUL	498	53	172	43	52 HOLO DIS	300	32 GALI TRI	77	28 TRIL OVA	180	51 ATHY FIL	152
19	DICR SCO	399	-49	170	170	20 LINN BOR	274	43 RUBU SPE	76	40 ADEN BIC	180	7 MAHO NER	148
20	LINN BOR	274	-58	165	167	48 ROSA GYM	266	34 MYCE MUR	75	4 GAUL SHA	175	2 TSUG HET	144
21	LIST COR	401	20	5	135	53 GOOD OBL	260	47 PLAG INS	69	27 PTER AQU	173	25 RHYT LOR	141
22	ELYM GLA	209	40	-169	13	25 RHYT LOR	259	15 DICR FUS	58	18 CLAD MUL	172	11 RHYT ROB	135
23	PINU MON	359	101	122	0	29 CHIM MEN	257	41 LEUC MEN	56	19 DICR SCO	170	21 LIST COR	135
24	POLY MUN	78	115	82	65	7 MAHO NER	241	13 POLY COM	54	20 LINN BOR	165	10 BOSC HOO	126
25	RHYT LOR	259	-10	-105	141	2 TSUG HET	239	18 CLAD MUL	53	59 CARE HEN	156	17 PELT LEU	123
26	ACHL TRI	94	98	108	121	50 SYMP MOL	227	37 RANU OCC	53	29 CHIM MEN	154	26 ACHL TRI	121
27	PTER AQU	155	208	173	1	6 SALI SIT	223	51 ATHY FIL	52	13 POLY COM	147	30 KIND ORE	121
28	TRIL OVA	52	225	180	-75	22 ELYM GLA	209	14 TRAC MEG	50	11 RHYT ROB	144	39 STRE AMP	85
29	CHIM MEN	257	477	154	177	5 VACC PAR	193	40 ADEN BIC	50	52 HOLO DIS	144	24 POLY MUN	65
30	KIND ORE	158	179	18	121	30 KIND ORE	158	57 TIAR LAC	45	1 PSEU MEN	142	18 CLAD MUL	43
31	RUBU URS	133	29	-62	1	27 PTER AQU	155	8 HIER ALB	44	14 TRAC MEG	132	57 TIAR LAC	38
32	GALI TRI	37	77	0	-45	31 RUBU URS	133	22 ELYM GLA	40	50 SYMP MOL	132	12 CLAD GRA	35
33	MAIA DIL	73	13	117	158	38 BROM VUL	129	12 CLAD GRA	39	41 LEUC MEN	123	5 VACC PAR	32
34	MYCE MUR	34	75	26	-59	35 VIOL SEM	127	31 RUBU URS	29	57 TIAR LAC	123	16 HYLO SPL	30
35	VIOL SEM	127	-80	376	-2	55 DISP SMI	127	54 TIAR TRI	24	23 PINU MON	122	22 ELYM GLA	13
36	TRIE LAT	90	-28	30	189	26 ACHL TRI	94	59 CARE HEN	21	43 RUBU SPE	119	47 PLAG INS	13
37	RANU OCC	51	53	292	-42	36 TRIE LAT	90	21 LIST COR	20	33 MAIA DIL	117	14 TRAC MEG	11
38	BROM VUL	129	-79	244	175	24 POLY MUN	78	44 DISP HOO	14	47 PLAG INS	112	1 PSEU MEN	10
39	STRE AMP	76	-17	368	85	39 STRE AMP	76	33 MAIA DIL	13	26 ACHL TRI	108	3 THUJ PLI	1
40	ADEN BIC	34	50	180	-224	33 MAIA DIL	73	4 GAUL SHA	2	51 ATHY FIL	96	13 POLY COM	1
41	LEUC MEN	26	56	123	-170	44 DISP HOO	67	17 PELT LEU	-8	10 BOSC HOO	86	27 PTER AQU	1
42	RHYT TRI	-3	-31	273	274	45 TRAU CAR	53	25 RHYT LOR	-10	24 POLY MUN	82	31 RUBU URS	1
43	RUBU SPE	-84	76	119	-67	28 TRIL OVA	52	39 STRE AMP	-17	5 VACC PAR	72	23 PINU MON	0
44	DISP HOO	67	14	204	-11	37 RANU OCC	51	36 TRIE LAT	-28	12 CLAD GRA	47	35 VIOL SEM	-2
45	TRAU CAR	53	95	410	-204	32 GALI TRI	37	42 RHYT TRI	-31	17 PELT LEU	42	4 GAUL SHA	-3
46	CAMP SCO	15	-52	208	154	34 MYCE MUR	34	16 HYLO SPL	-40	36 TRIE LAT	30	50 SYMP MOL	-8
47	PLAG INS	-68	69	112	13	40 ADEN BIC	34	19 DICR SCO	-49	34 MYCE MUR	26	44 DISP HOO	-11
48	ROSA GYM	266	-102	234	-67	41 LEUC MEN	26	46 CAMP SCO	-52	54 TIAR TRI	19	37 RANU OCC	-42
49	DICE FOR	-57	-79	573	324	46 CAMP SCO	15	60 MONT SIB	-55	30 KIND ORE	18	32 GALI TRI	-45
50	SYMP MOL	227	-115	132	-8	42 RHYT TRI	-3	20 LINN BOR	-58	21 LIST COR	5	34 MYCE MUR	-59
51	ATHY FIL	-78	52	96	152	54 TIAR TRI	-41	11 RHYT ROB	-79	32 GALI TRI	0	43 RUBU SPE	-67
52	HOLO DIS	300	-198	144	-98	49 DICE FOR	-57	38 BROM VUL	-79	2 TSUG HET	-17	48 ROSA GYM	-67
53	GOOD OBL	260	-246	400	239	47 PLAG INS	-68	49 DICE FOR	-79	7 MAHO NER	-21	28 TRIL OVA	-75
54	TIAR TRI	-41	24	19	172	56 ACER MAC	-69	35 VIOL SEM	-80	16 HYLO SPL	-37	52 HOLO DIS	-98
55	DISP SMI	127	178	-397	175	51 ATHY FIL	-78	56 ACER MAC	-92	8 HIER ALB	-41	6 SALI SIT	-134
56	ACER MAC	-69	-92	348	422	43 RUBU SPE	-84	48 ROSA GYM	-102	31 RUBU URS	-62	15 DICR FUS	-161
57	TIAR LAC	-100	45	123	38	58 DRYO ASS	-84	50 SYMP MOL	-115	58 DRYO ASS	-72	41 LEUC MEN	-170
58	DRYO ASS	-84	185	-72	-181	57 TIAR LAC	-100	52 HOLO DIS	-198	25 RHYT LOR	-105	58 DRYO ASS	-181
59	CARE HEN	-103	21	156	164	59 CARE HEN	-103	9 FEST OCC	-212	22 ELYM GLA	-169	45 TRAU CAR	-204
60	MONT SIB	-120	-55	297	316	60 MONT SIB	-120	53 GOOD OBL	-246	55 DISP SMI	-397	40 ADEN BIC	-224

C - 6 Eigenvalues and plot scores from DCA of understory vegetation

DECORANA OPTIONS -- DOWNWEIGHTING 0 RESCALING 4 ANALYSIS 0 SEGMENTS 26 THRESHOLD 0.0
TRANSFORMATION 0.0 0.0

SAMPLE SCORES - WHICH ARE WEIGHTED MEAN SPECIES SCORES

N	NAME	AX1	AX2	AX3	AX4	RANKED 1 EIG=0.559			RANKED 2 EIG=0.110			RANKED 3 EIG=0.052			RANKED 4 EIG=0.029		
1	RK0001	376	75	132	40	1	RK0001	376	6	RK0006	197	11	RK0011	147	24	RK0024	136
2	RK0002	373	62	113	32	2	RK0002	373	5	RK0005	195	24	RK0024	145	18	RK0018	93
3	RK0003	352	68	89	65	3	RK0003	352	7	RK0007	151	10	RK0010	134	15	RK0015	88
4	RK0004	329	87	109	47	4	RK0004	329	8	RK0008	147	1	RK0001	132	20	RK0020	81
5	RK0005	209	195	93	59	14	RK0014	253	21	RK0021	101	13	RK0013	129	17	RK0017	79
6	RK0006	224	197	106	62	13	RK0013	244	10	RK0010	94	2	RK0002	113	19	RK0019	79
7	RK0007	228	151	90	65	15	RK0015	238	18	RK0018	93	4	RK0004	109	13	RK0013	72
8	RK0008	218	147	83	61	16	RK0016	237	20	RK0020	90	9	RK0009	107	3	RK0003	65
9	RK0009	124	70	107	58	7	RK0007	228	12	RK0012	89	6	RK0006	106	7	RK0007	65
10	RK0010	104	94	134	0	6	RK0006	224	4	RK0004	87	12	RK0012	104	6	RK0006	62
11	RK0011	130	79	147	20	8	RK0008	218	19	RK0019	81	14	RK0014	103	8	RK0008	61
12	RK0012	89	89	104	38	5	RK0005	209	11	RK0011	79	5	RK0005	93	5	RK0005	59
13	RK0013	244	0	129	72	17	RK0017	175	22	RK0022	79	7	RK0007	90	9	RK0009	58
14	RK0014	253	5	103	50	20	RK0020	161	23	RK0023	76	3	RK0003	89	21	RK0021	55
15	RK0015	238	63	80	88	18	RK0018	150	1	RK0001	75	22	RK0022	88	16	RK0016	52
16	RK0016	237	27	79	52	19	RK0019	148	17	RK0017	74	8	RK0008	83	14	RK0014	50
17	RK0017	175	74	61	79	11	RK0011	130	9	RK0009	70	23	RK0023	81	4	RK0004	47
18	RK0018	150	93	0	93	9	RK0009	124	3	RK0003	68	15	RK0015	80	23	RK0023	46
19	RK0019	148	81	31	79	10	RK0010	104	15	RK0015	63	16	RK0016	79	1	RK0001	40
20	RK0020	161	90	0	81	12	RK0012	89	2	RK0002	62	21	RK0021	74	12	RK0012	38
21	RK0021	48	101	74	55	21	RK0021	48	24	RK0024	34	17	RK0017	61	2	RK0002	32
22	RK0022	7	79	88	21	23	RK0023	19	16	RK0016	27	19	RK0019	31	22	RK0022	21
23	RK0023	19	76	81	46	22	RK0022	7	14	RK0014	5	18	RK0018	0	11	RK0011	20
24	RK0024	0	34	145	136	24	RK0024	0	13	RK0013	0	20	RK0020	0	10	RK0010	0

APPENDIX D FOLIAR NUTRIENT DATA FOR STUDY PLOTS

Code*	N	P	Ca	Mg	K	Fe	AFe	B	Al	Zn	Mn	Cu	S	100 needle weight
	%					ppm							%	
011111.	.879	.171	.590	.305	.100	24.380	15.000	14.200	240.000	12.500	1109.000	3.000	.113	442.
021111.	.937	.180	.573	.289	.095	23.960	10.000	15.290	275.000	17.000	1114.000	3.400	.118	546.
031111.	.874	.199	.586	.254	.098	17.500	10.000	15.750	270.000	10.500	1051.000	3.000	.109	482.
041111.	.803	.180	.535	.290	.095	14.380	10.000	14.840	230.000	13.500	1237.000	2.900	.107	543.
052122.	1.277	.163	.625	.249	.124	38.000	25.000	8.660	225.000	19.000	367.000	4.100	.120	557.
062122.	1.140	.165	.658	.254	.124	33.130	25.000	7.960	225.000	16.000	257.000	5.400	.118	569.
072122.	1.202	.163	.616	.263	.133	37.710	28.000	7.450	255.000	14.500	369.000	3.600	.092	537.
082122.	1.248	.178	.703	.293	.153	44.380	29.000	8.660	310.000	18.000	431.000	3.900	.113	505.
093133.	1.206	.139	.598	.351	.125	22.290	19.000	8.400	95.000	6.000	173.000	3.200	.101	555.
103133.	1.252	.134	.561	.358	.101	23.960	24.000	9.290	100.000	7.500	183.000	5.400	.094	528.
113133.	1.210	.146	.536	.339	.100	20.630	19.000	5.960	85.000	7.000	184.000	3.400	.106	511.
123133.	1.248	.144	.538	.340	.108	26.670	19.000	6.050	85.000	7.500	171.000	4.500	.103	483.
134212.	1.081	.191	.608	.401	.123	32.920	24.000	16.430	150.000	22.500	1459.000	3.800	.113	441.
144212.	1.077	.190	.606	.399	.123	30.420	22.000	19.300	150.000	23.000	1441.000	4.600	.124	428.
154212.	1.038	.182	.709	.433	.143	35.420	19.000	18.890	205.000	20.500	1276.000	4.300	.125	443.
164212.	1.104	.196	.633	.405	.125	34.170	22.000	20.530	165.000	23.000	1360.000	4.300	.125	469.
175223.	1.076	.178	.616	.299	.114	42.710	49.000	16.110	140.000	15.500	740.000	4.600	.112	409.
185223.	1.088	.168	.564	.320	.116	37.500	39.000	15.100	135.000	15.000	734.000	4.500	.120	401.
195223.	1.134	.168	.583	.325	.134	36.670	44.000	15.900	125.000	20.000	566.000	5.000	.121	434.
205223.	1.154	.172	.564	.325	.141	35.210	34.000	14.370	115.000	18.500	465.000	4.600	.118	421.
216234.	1.325	.160	.536	.312	.144	32.500	37.000	10.590	85.000	15.000	214.000	5.500	.103	381.
226234.	1.275	.160	.498	.356	.151	40.000	27.000	10.840	70.000	14.000	221.000	4.800	.114	378.
236234.	1.262	.166	.516	.329	.149	27.080	37.000	9.220	85.000	16.500	277.000	5.200	.120	435.
246234.	1.331	.173	.544	.330	.141	29.790	37.000	12.260	75.000	14.500	212.000	5.500	.115	384.

*There is a six numeral code for each study plot. The first two numerals identify the plot (01-24); the third numeral identifies the site (1-6); the fourth numeral identifies the parent material lithology (1,2), where 1=granitic and 2=volcanic; the fifth numeral identifies the soil moisture regime (1-3) where 1=very dry, 2=dry, and 3=fresh; the sixth numeral identifies the soil nutrient regime (1-4) where 1=poor, 2=medium, 3=rich, and 4=very rich.

APPENDIX E

ENVIRONMENT TABLES

In this appendix, selected environment variables are shown in tables produced by the F405:ENV program (Emanuel, 1984a). The code for study plots is RK0001 - 04, GVD replicate plots; RK0005 - 8, GD replicate plots; RK0009 - 12; GF replicate plots; RK0013 - 16, VVD replicate plots; RK0017 - 20, VD replicate plots; RK0021 - 24, VF replicate plots. The four replicate plots were all consecutively numbered left to right in the environmental tables. To understand these tables, several terms and abbreviations must first be defined. These definitions are as follows:

1. SLOPE POSITION: us = upper slope, ms = mid-slope, ls = lower slope, fl = flat

2. HUMUS FORM: refers to humus form order classified according to system proposed by Klinka _et al_. (1981a) where mor = Mor, mod = Moder, mul - Mull

3. LITHOLOGY AND BASE STATUS: field assessment of parent material lithology and base status using methods described in Klinka _et al_. (1984a) where GL = granitic lithology, low base status, VM = volcanic lithology, medium base status, VH = volcanic lithology, high base status

4. RELATIVE OM CONTENT: field assessement of mineral soil organic matter content (Klinka _et al_., 1984a) where L = low, M = medium, H = high

5. SOIL SUBGROUP: (CSSC, 1978) where HFP = Orthic Humo-Ferric Podzol and CR = Orthic Cumulic Regosol

6. PARENT MATERIALS: where A = alluvial, C = colluvial, F = fluvial, M = moraine

7. SOIL TOTAL DEPTH: depth to restricting layer if found, 150 was used if restricting layer not encounterd

8. ROOTING DEPTH: observed depth from ground surface down to the level at which the majority of roots stopped

9. COARSE FRAGMENTS > 11 mm: percentage volume occupied by coarse fragments sieved from soil pit using 11 x 11 mm mesh

10. COARSE FRAGMENTS > 2 mm: percentage volume occupied by coarse fragments in bulk density sample (this would not include the largest coarse fragments of 9. above)

11. COARSE FRAGMENT FREE B.D.: mineral soil bulk density determined as average of three 0 - 50 cm depth samples (Nuszdorfer, 1981)

12. FOREST FLOOR B.D.: bulk density of forest floor materials determined as average of three samples

13. SI (B): average site index of Douglas-fir on the study plot, determined using the formulas of Bruce (1981)

14. SI (H): average site index of Douglas-fir on the study plot, determined using the formulas of Hegyi et al. (1979)

PLOT NUMBER	MEAN	RKOO 13	RKOO 14	RKOO 15	RKOO 16
ELEVATION (m)		240	240	240	240
SLOPE POSITION		US	US	US	US
ASPECT		320	320	320	320
SLOPE GRADIENT (%)		35	40	30	30
HUMUS FORM		MOR	MOR	MOR	MOR
FOREST FLOOR DEPTH (cm)	4.02	3.8	3.0	4.5	4.8
LITHOLOGY AND BASE STATUS		VH	VH	VH	VH
RELATIVE OM CONTENT		M	M	M	M
SOIL SUBGROUP		HFP	HFP	HFP	HFP
PARENT MATERIAL		M	M	M	M
SOIL TOTAL DEPTH (cm)	43.0	41.	41.	48.	42.
ROOTING DEPTH (cm)	43.0	41.	41.	48.	42.
COARSE FRAGMENTS > 11 mm (%)	14.8	14.	22.	11.	12.
COARSE FRAGMENTS > 2 mm (%)	31.5	27.	39.	27.	33.
COARSE FRAGMENT FREE B.D.(g/cc)	0.6420	.682	.547	.726	.613
FOREST FLOOR B.D. (g/cc)	0.1560	.175	.169	.157	.123
AGE (yrs)	67.8	69.	70.	66.	66.
SI (B) (m/50 yrs)	22.20	22.0	20.6	23.2	23.0
SI (H) (m/50 yrs)	25.10	24.9	23.4	26.2	25.9

PLOT NUMBER	MEAN	RKOO 17	RKOO 18	RKOO 19	RKOO 20
ELEVATION (m)		220	220	225	225
SLOPE POSITION		MS	MS	MS	MS
ASPECT		220	220	210	210
SLOPE GRADIENT (%)		25	25	25	25
HUMUS FORM		MOD	MOD	MOD	MOD
FOREST FLOOR DEPTH (cm)	3.10	3.0	3.1	3.5	2.8
LITHOLOGY AND BASE STATUS		VM	VM	VM	VM
RELATIVE OM CONTENT		M	M	M	M
SOIL SUBGROUP		HFP	HFP	HFP	HFP
PARENT MATERIAL		CA	CA	CA	CA
SOIL TOTAL DEPTH (cm)	150.0	150.	150.	150.	150.
ROOTING DEPTH (cm)	93.8	90.	85.	105.	95.
COARSE FRAGMENTS > 11 mm (%)	40.0	34.	44.	39.	43.
COARSE FRAGMENTS > 2 mm (%)	51.8	44.	48.	58.	57.
COARSE FRAGMENT FREE B.D.(g/cc)	0.5085	.585	.589	.514	.346
FOREST FLOOR B.D. (g/cc)	0.1362	.112	.131	.150	.152
AGE (yrs)	61.0	62.	61.	62.	59.
SI (B) (m/50 yrs)	35.13	33.3	35.1	34.6	37.5
SI (H) (m/50 yrs)	38.60	36.7	38.6	38.1	41.0

PLOT NUMBER	MEAN	RKOO 21	RKOO 22	RKOO 23	RKOO 24
ELEVATION (m)		200	200	200	200
SLOPE POSITION		FL	FL	FL	FL
ASPECT		200	200	200	200
SLOPE GRADIENT (%)		2	2	2	2
HUMUS FORM		MUL	MUL	MUL	MUL
FOREST FLOOR DEPTH (cm)	1.15	0.9	1.5	0.7	1.5
LITHOLOGY AND BASE STATUS		VM	VM	VM	VM
RELATIVE OM CONTENT		H	H	H	H
SOIL SUBGROUP		CR	CR	CR	CR
PARENT MATERIAL		A	A	A	A
SOIL TOTAL DEPTH (cm)	150.0	150.	150.	150.	150.
ROOTING DEPTH (cm)	97.5	100.	100.	100.	90.
COARSE FRAGMENTS > 11 mm (%)	23.3	29.	25.	18.	21.
COARSE FRAGMENTS > 2 mm (%)	48.5	50.	49.	43.	52.
COARSE FRAGMENT FREE B.D.(g/cc)	0.8177	.837	.795	.683	.956
FOREST FLOOR B.D. (g/cc)	0.1000	.100	.100	.100	.100
AGE (yrs)	67.0	68.	66.	67.	67.
SI (B) (m/50 yrs)	39.10	39.2	38.4	38.3	40.5
SI (H) (m/50 yrs)	42.60	42.7	41.9	41.8	44.0

PLOT NUMBER	MEAN	RKOO 01	RKOO 02	RKOO 03	RKOO 04
ELEVATION (m)		440	440	440	440
SLOPE POSITION		US	US	US	US
ASPECT		250	260	260	260
SLOPE GRADIENT (%)		15	10	15	15
HUMUS FORM		MOR	MOR	MOR	MOR
FOREST FLOOR DEPTH (cm)	3.63	3.8	4.1	3.2	3.4
LITHOLOGY AND BASE STATUS		GL	GL	GL	GL
RELATIVE OM CONTENT		L	L	L	L
SOIL SUBGROUP		HFP	HFP	HFP	HFP
PARENT MATERIAL		M	M	M	M
SOIL TOTAL DEPTH (cm)	62.3	40.	49.	70.	90.
ROOTING DEPTH (cm)	54.8	40.	49.	55.	75.
COARSE FRAGMENTS > 11 mm (%)	27.0	24.	31.	25.	28.
COARSE FRAGMENTS > 2 mm (%)	48.0	47.	42.	51.	52.
COARSE FRAGMENT FREE B.D.(g/cc)	0.6020	.536	.580	.620	.672
FOREST FLOOR B.D. (g/cc)	0.1040	.121	.072	.119	.104
AGE (yrs)	34.3	35.	34.	33.	35.
SI (B) (m/50 yrs)	17.77	17.6	18.0	18.6	16.9
SI (H) (m/50 yrs)	20.27	20.1	20.5	21.2	19.3

PLOT NUMBER	MEAN	RKOO 05	RKOO 06	RKOO 07	RKOO 08
ELEVATION (m)		390	390	390	395
SLOPE POSITION		MS	MS	MS	MS
ASPECT		40	30	50	50
SLOPE GRADIENT (%)		30	35	45	45
HUMUS FORM		MOR	MOR	MOR	MOR
FOREST FLOOR DEPTH (cm)	3.45	4.4	2.9	3.2	3.3
LITHOLOGY AND BASE STATUS		GL	GL	GL	GL
RELATIVE OM CONTENT		L	H	M	M
SOIL SUBGROUP		HFP	HFP	HFP	HFP
PARENT MATERIAL		M	M	M	M
SOIL TOTAL DEPTH (cm)	98.8	65.	100.	110.	120.
ROOTING DEPTH (cm)	87.5	50.	90.	100.	110.
COARSE FRAGMENTS > 11 mm (%)	16.3	27.	14.	10.	14.
COARSE FRAGMENTS > 2 mm (%)	35.8	45.	26.	30.	42.
COARSE FRAGMENT FREE B.D.(g/cc)	0.5212	.433	.540	.566	.546
FOREST FLOOR B.D. (g/cc)	0.1112	.124	.124	.102	.095
AGE (yrs)	34.5	35.	33.	35.	35.
SI (B) (m/50 yrs)	26.40	26.8	27.1	24.5	27.2
SI (H) (m/50 yrs)	29.55	30.0	30.3	27.5	30.4

PLOT NUMBER	MEAN	RKOO 09	RKOO 10	RKOO 11	RKOO 12
ELEVATION (m)		300	300	300	300
SLOPE POSITION		LS	LS	LS	LS
ASPECT		350	350	340	340
SLOPE GRADIENT (%)		5	5	5	5
HUMUS FORM		MOD	MOD	MOD	MOD
FOREST FLOOR DEPTH (cm)	2.27	2.2	2.4	2.7	1.8
LITHOLOGY AND BASE STATUS		GL	GL	GL	GL
RELATIVE OM CONTENT		M	M	M	M
SOIL SUBGROUP		HFP	HFP	HFP	HFP
PARENT MATERIAL		F	F	F	F
SOIL TOTAL DEPTH (cm)	150.0	150.	150.	150.	150.
ROOTING DEPTH (cm)	88.8	110.	80.	90.	75.
COARSE FRAGMENTS > 11 mm (%)	18.5	17.	19.	13.	25.
COARSE FRAGMENTS > 2 mm (%)	31.3	40.	32.	32.	21.
COARSE FRAGMENT FREE B.D.(g/cc)	0.7215	.836	.634	.671	.745
FOREST FLOOR B.D. (g/cc)	0.1232	.126	.110	.127	.130
AGE (yrs)	32.8	33.	33.	33.	32.
SI (B) (m/50 yrs)	32.13	30.2	31.3	34.3	32.7
SI (H) (m/50 yrs)	35.52	33.5	34.7	37.8	36.1

APPENDIX F

DESCRIPTION OF REPRESENTATIVE SOILS FROM STUDY SITES

Study site: GVD4 (site 1, rep. plot 4) Elevation: 440 m

Parent material: gravelly sandy loam granitic/volcanic till Aspect: 250°

Landform: morainal veneer

Classification: Orthic Humo-Ferric podzol

3.5 - 3.0	Lv	loose mixture of coniferous and salal litter; abrupt, smooth boundary;
3.0 - 0	Fq	variegated; compact matted; few coarse roots; abrupt, smooth boundary;
0 - 4	Ae	light gray (2.5 Y 7/0 d) gravelly, loamy sand; structureless, single grained, very friable when moist; few coarse roots; clear, smooth boundary;
4 - 13	Bf1	pale yellow (2.5 Y 7/4 d) gravelly sandy loam; moderate, medium subangular blocky; very friable when moist; common, fine, spheroid, red (2.5 YR 5/6 m) concretions, few fine roots, very few medium roots; clear, smooth boundary;
13 - 92	Bf2	white (2.5 Y 8/2 d) gravelly sandy loam; moderate, medium subangular blocky; very friable when moist; common, fine, prominent, yellowish red (5 YR 5/8 m) mottles; plentiful medium, few fine roots, abrupt, smooth boundary;
92+		lithic contact.

Study site: GD1, (site 2, rep plot 1) Elevation: 390 m

Parent material: gravelly sandy loam granitic/volcanic till Aspect: 40°

Landform: moraine over basal till

Classification: Orthic Humo-Ferric podzol

5 - 4	Lv	loose coniferous litter; abrupt, smooth boundary;
4 - 3	Fq	variegated; compact matted; few fine roots; abrupt, smooth boundary;
3 - 0	Hd	black (7.5 YR 2/0 m); structureless; few fine roots, very few medium roots; clear, smooth boundary;
0 - 3	Ae	light grey (7.5 YR 7/2 d); loamy sand; structureless, single grained, very friable when moist; very few medium roots; clear, smooth boundary;
3 - 38	Bf1	brownish yellow (10 YR 6/6 d); gravelly, loamy sand; structureless, single grained; very friable when moist; very few coarse, very few fine roots; clear, smooth boundary;
38 - 69	Bf2	light grey (2.5 YR 7/2 d); gravelly, loamy sand; structureless, single grained; very friable when moist; common, fine, spheriodal, red (2.5 YR 5/6 m) concretions; few, medium roots; clear, wavy boundary;
69+	IIC	brownish yellow (10 YR 6/6 d); gravelly loamy sand; structureless, massive; extremely firm when moist; many, medium, prominent, reddish yellow (7.5 YR 6/6 m) mottles.

Study site: GD2 (site 2, rep. plot 2) Elevation: 390 m

Parent material: gravelly sandy loam granitic/volcanic till Aspect: 30°

Landform: moraine over basal till Slope: 35%

Classification: (disturbed) Humo-Ferric Podzol

2.5 - 2.0		Lv	loose coniferous litter; abrupt, smooth boundary;
2.0 - 0		Fq	variegated; compact matted; very few fine roots; abrupt, irregular boundary;
0 - 44		Bmu	very pale brown (10 YR 7/4 d); loam; weak, medium granular; extremely friable when moist; few fine, few coarse roots; abrupt, smooth boundary;
44 - 58		Hdb	dark reddish brown (2.5 YR 2.5/4 m); buried organic material, structureless; few fine roots; abrupt, smooth boundary;
58 - 59		Aejb	light grey (2.5 Y 7/0 m); sandy loam; structureless, single grained; loose when moist; no roots; abrupt, smooth boundary;
59 - 125		BfB	brownish yellow (10 YR 6/6 d); gravelly, sandy loam; weak, coarse subangular blocky; very friable when moist; few fine, few coarse roots; clear, wavy boundary;
125 - 166+		BCb	light brownish grey (2.7 Y 6/2 m); gravelly, loamy sand; strong subangular blocky; very firm when moist; common, fine, prominent, yellowish red (5 YR 5/8 m) mottles; very few fine roots.

Study site: GD3 (site 2, rep. plot 3) Elevation: 390 m

Parent material: gravelly sandy loam granitic/volcanic till Aspect: 50°

Landform: moraine over basal till

Classification: Orthic Humo-Ferric Podzol

3.5 - 2.5		Lv	loose coniferous litter; abrupt, smooth boundary;
2.4 - 0.5		Fq	variegated; compact matted; very few roots; abrupt, smooth boundary;
0.5 - 0		Hdi	variegated; structureless; inorganic inclusions; very few fine roots; abrupt, smooth boundary;
0 - 23		Bmu	yellowish brown (10 YR 5/4 d); gravelly, sandy loam; weak, medium granular; very friable when moist; plentiful fine, plentiful medium roots; gradual, smooth boundary;
23 - 78		Bf	reddish yellow (7.5 YR 6/6 d); gravelly, sandy loam; weak, subangular blocky; loose when moist; common, fine, spheroidal, strong brown (7.5 YR 5/8 m) concretions; plentiful coarse, plentiful fine roots; gradual, smooth boundary;
78 - 100		BC	very pale brown (10 YR 7/4 d); gravelly, sandy loam; massive; very firm when moist; common, medium, prominent, strong brown (5 YR 5/8 m) concretions; plentiful coarse; plentiful fine roots; gradual, smooth boundary;
100+		IIC	grayish brown (2.5 Y 5/2 m); gravelly, sandy loam; massive; extremely firm when moist; many, coarse, prominent, dusky red (2.5 YR 3/2 m) mottles; no roots.

Study site: GF1, (site 3, rep. plot 1) Elevation: 300 m

Parent material: gravelly sand to loam granitic/volcanic glaciofluvial deposits Aspect: 350°

Landform: glaciofluvial terrace Slope: 5%

Classification: Orthic Humo-Ferric Podzol

1 - 0	Fa	variegated; compact matted and granular; abrupt, smooth boundary;
0 - 38	Bf1	dark brown (7.5 YR 4/4 m); loam; weak, moderate subangular blocky; very friable when moist; plentiful fine, few coarse roots; abrupt, smooth boundary;
38 - 57	Bf2	red (2.5 YR 5/8 m); loam; moderate, coarse subangular blocky; friable when moist; plentiful medium, few fine roots; clear, wavy boundary;
57 - 77	Bf3	yellowish red (5 YR 5/6 m); gravelly, loamy sand; structureless, single grained; loose when moist; very few medium roots; clear, irregular boundary;
77 - 108	Bf4	yellowish red (5 YR 4/6 m); loamy; medium, moderate coarse subangular blocky; friable when moist; few, medium roots; gradual, broken boundary;
77 - 108	Bf4	dark yellowish brown (10 YR 4/6 m); gravelly sand; structureless, single grained; loose when moist; no roots; clear, broken boundary (occurs as inclusions within loamy matrix).

Study site: VVD4 (site 4, rep. plot 4) Elevation: 240 m

Parent material: gravelly sandy loam volcanic till Aspect: 320°

Landform: morainal veneer Slope: 30%

Classification: Orthic Humo-Ferric Podzol

4.5 - 4.0	Lv		loose, mainly coniferous litter; abrupt, smooth boundary;
4.0 - 3.0	Fq		variegated; compact matted; very few fine roots; abrupt, smooth boundary;
3.0 - 0	Hd		black (10 YR 1/0); structureless; few fine roots; abrupt, smooth boundary;
0 - 0.5	Aej		grey (10 YR 6/1 d); sandy loam; structureless, single grained; very few fine roots; abrupt, broken boundary;
0.5 - 45	Bf		strong brown (7.5 YR 5/6 d); gravelly loam; weak to moderate, moderately coarse subangular blocky; few, fine, spheroidal, yellowish red (5 YR 4/6 m) concretions; few fine roots; abrupt, wavy boundary;
45+			lithic contact.

Study site: VD3, (site 5, rep. plot 3) Elevation: 225 m

Parent material: gravelly sandy loam to loam volcanic colluvium/alluvium Aspect: 210°

Landform: colluvial and alluvial deposits Slope: 25%

Classification: Orthic Humo-Ferric Podzol

4 - 3	Lv	variegated; moss and coniferous litter; abrupt, wavy boundary;
3 - 0	Hd	black (10 YR 2/1 m); structureless; few fine roots; abrupt, smooth boundary;
0 - 10	Bf1	very pale brown (10 YR 7/4 d); gravelly sandy loam; moderate, medium subangular blocky and moderate to strong medium granular; very friable when moist; few fine roots; clear, smooth boundary
10 - 38	Bf2	very pale brown (10 YR 7/4 d); gravelly sandy loam; weak, medium subangular blocky; very friable when moist; few fine and few medium roots; abrupt, smooth boundary;
38 - 74	Bf3	reddish yellow (7.5 YR 6/6 d); gravelly sandy loam; weak to moderate, medium subangular blocky; friable when moist; few medium and very few fine roots; clear, irregular boundary;
74 - 100+	Bm	light yellowish brown (2.5 Y 6/4 m); gravelly sand; structureless, single grained; loose when moist; common, medium, prominent strong brown (7.5 YR 5/8 m) mottles; very few fine roots.

Study site: VF1 (site 6, rep. plot 1) Elevation: 200 m

Parent material: gravelly sand to loam alluvial deposits Aspect: 200°

Landform: alluvial fan Slope: 2%

Classification: Orthic Cumulic Regosol

1 - 0	Lv	variegated; coniferous and herbaceous litter; abrupt, broken boundary;
0 - 6	Ah	dark grayish brown (10 YR 4/2 d); loam; weak, moderate subangular blocky, and strong, very coarse granular; friable when moist; inclusions of charcoal and dead wood; plentiful fine roots; abrupt, irregular boundary;
6 - 13	Bm	light yellowish brown (10 YR 6/4 d); loam; weak, moderate subangular blocky, and moderate to strong, coarse granular; friable when moist; few fine roots; abrupt, smooth boundary;
13 - 66	IICb	brown (10 YR 4/3 m); gravelly, loamy sand; structureless, single grained; loose when moist; included lenses of sandy loam in matrix; few fine, few coarse roots; gradual, smooth boundary;
66 - 138	IIICb	grayish brown (10 YR 5/2 m): gravelly sand; structureless, single grained; loose when moist; very few fine roots; abrupt, smooth boundary;
138 - 140	IVAhjb	dark brown (7.5 YR 3/2 m); gravelly loam; structureless, single grained; very friable when moist; charcoal inclusions; few medium roots; abrupt, smooth boundary;
140+	IVCb	grayish brown (10 YR 5/2 m); gravelly sand; structureless, single grained; loose when moist; no roots.

APPENDIX G

CONVERSION FROM CONCENTRATION TO KG/HA

To convert the quantity of nutrient "n" from concentration (ppm, %, or m.e. per 100 g) to weight on an areal basis (kg ha^{-1}) for a given soil layer, the following procedure was used. This procedure was modified from Lewis (1976) by Roy (1984).

1. Calculate the proportion of the soil fine (<2 mm) fraction (f) which consists of nutrient "n" (P):

a) for concentration given in ppm -

$$P = \text{ppm n} \times 10^{-6}$$

$$\frac{\text{kg of n}}{\text{kg of soil f}} = \frac{\text{mg of n}}{\text{kg of soil f}} \times \frac{1 \text{ kg}}{10^6 \text{ mg}}$$

b) for concentration given in % -

$$P = (\%\text{n}) \times 10^{-2}$$

$$\frac{\text{kg of n}}{\text{kg of soil f}} = \frac{(\text{kg of n} \quad 10^2)}{\text{kg of soil f}} \times \frac{1}{10^2}$$

c) for concentration given in m.e. per 100 g -

$$P = \frac{\text{m.e. of n}}{10^2 \text{ g of soil f}} \times 10^3 \times \begin{matrix}\text{equivalent}\\ \text{weight}\end{matrix} \times 10^{-6}$$

$$\frac{\text{kg of n}}{\text{kg of soil f}} = \frac{\text{m.e. of n}}{10^2 \text{ g of soil f}} \times \frac{10^3 \text{g}}{1 \text{ kg}} \times \frac{\text{mg n}}{\text{m.e. n}} \times \frac{1 \text{ kg}}{10^6 \text{ mg}}$$

$$(= \text{m.e. of n} \quad \text{equivalent weight} \times 10^{-5})$$

2. Calculate the weight of soil fine (<2 mm) fraction (f) on an areal basis for the same soil layer (CF):

$$CF = A \times B \times C \times TH$$

$$= \frac{Mf}{Vt} \times 10^{-3} \times 10^{8} \times \text{layer thickness}$$

$$\frac{\text{kg of soil f}}{\text{ha}} = \frac{\text{g of soil f}}{\text{cm}^3 \text{ of soil}} \times \frac{1 \text{ kg}}{10^3 \text{g}} \times \frac{10^8 \text{cm}^2}{1 \text{ ha}} \times \text{cm}$$

where A is the weight of the soil fine fraction (Mf) per unit volume of whole soil (Vt)

B converts A from g of soil f x cm^{-3} to kg of soil f x cm^{-3}

C converts the results of (A x B) from kg of soil f x cm^{-3} to kg of soil f x cm^{-1} x ha^{-1}

TH converts the results of (A x B x C) from kg of soil f x cm^{-1} x ha^{-1} to kg of soil f x ha^{-1}

3. Calculate the weight of nutrient "n" in that soil layer (N):

$$N = P \times CF$$

$$\frac{\text{kg of n}}{\text{ha}} = \frac{\text{kg of n}}{\text{kg of soil f}} \times \frac{\text{kg of soil f}}{\text{ha}}$$

where P is the proportion of soil fine (<2 mm) fraction (f) which consists of nutrient "n" (see item 1 above)

CF is the conversion factor which converts this proportion to kg of n x ha^{-1} (see item 2 above)

APPENDIX H

FOREST FLOOR AND MINERAL SOIL ANALYTICAL DATA

Forest floor and mineral soil analytical data are given in this appendix. The codes used are as follows:

1. Tables H-1, and H-2 for variability plot within each site, have a three numeral code; the first numeral identifies the site (1 to 6); the second and third numerals identify the sample within the plot (01 to 15)

2. Tables H-3 to H-4 for the three composite samples within each plot, have a four numeral code; the first two numerals identify the plot (01 to 24); the third numeral identifies the site (1 to 6); and the fourth numeral identifies the soil nutrient regime (1 to 4), where 1 = poor, 2 = medium, 3 = rich, 4 = very rich

3. Tables H-5 to H-7 for the plot mean values have six numeral codes, the first two numerals identify the plot (01 to 24); the third numeral identifies the site (1 to 6); the fourth numeral identifies the parent material lithology (1 or 2), where 1 = granitic and 2 = volcanic; the fifth numeral identifies the soil moisture regime (1 to 3) where 1 = very dry, 2 = dry, and 3 = fresh; the sixth numeral identifies the soil nutrient regime (1 to 4), where 1 = poor, 2 = medium, 3 = rich, 4 = very rich

INDEX

Table H-1. Forest floor variability data

Code	pH H2O	TC %	TN %	minN ppm	TS %	TP %	exCa ppm	exMg ppm	exK ppm	CEC meq/100g	exMn ppm	TCa %	TMg %	TK %	TMn %
101.	4.0	45.530	1.194	216.580	.228	.167	5127.900	716.190	1289.140	40.480	2306.120	.673	.100	.135	12.600
102.	4.0	43.050	.967	183.570	.131	.158	6073.270	902.400	1489.670	39.240	2291.800	.627	.123	.140	9.740
103.	4.4	43.030	1.071	300.680	.116	.162	5686.530	515.660	701.860	46.710	1231.840	.811	.140	.109	12.600
104.	3.9	36.150	1.082	119.170	.101	.123	4311.450	401.070	644.570	35.500	1260.490	.344	.126	.129	11.460
105.	4.4	41.540	.911	172.570	.139	.115	6288.130	487.010	716.190	43.590	1604.260	.733	.103	.115	17.530
106.	4.4	39.080	1.006	194.800	.147	.130	6631.900	773.480	1575.610	55.430	2735.840	.751	.109	.158	17.190
107.	4.4	38.740	.941	225.510	.131	.140	4483.330	658.890	1088.610	43.590	1976.680	.579	.129	.140	12.380
108.	4.4	41.640	.941	264.190	.133	.155	5285.460	802.130	1145.900	38.620	2076.940	.630	.163	.155	14.320
109.	4.5	42.780	.998	284.530	.158	.164	6073.270	744.840	1375.080	47.330	2506.660	.779	.126	.143	18.910
110.	4.2	41.840	.876	178.530	.113	.123	4168.210	444.040	802.130	38.620	1461.020	.501	.103	.126	11.800
111.	4.1	38.880	.933	182.660	.110	.112	6259.480	687.540	1160.220	35.500	2005.330	.499	.092	.109	10.600
112.	4.3	41.360	1.162	222.990	.138	.160	6273.800	787.810	974.020	43.590	2148.560	.619	.149	.126	13.520
113.	3.8	42.350	.990	182.200	.123	.155	3967.680	501.330	916.720	37.370	1518.320	.478	.112	.126	8.310
114.	4.4	39.460	.914	193.660	.121	.145	7290.790	730.510	1360.760	41.720	2578.280	.490	.195	.140	14.320
115.	4.6	44.190	.991	233.760	.132	.155	7419.700	974.020	1418.050	41.720	2864.750	.765	.155	.143	19.250
201.	3.9	43.140	1.408	303.790	.160	.170	4761.070	500.410	843.770	30.460	772.070	.423	.215	.137	3.830
202.	4.3	40.350	1.204	270.390	.128	.168	6777.020	629.090	600.640	44.760	671.980	.526	.235	.109	4.290
203.	4.3	39.640	1.050	256.670	.121	.145	5833.380	457.520	572.050	39.160	772.070	.420	.237	.112	5.640
204.	4.1	32.360	1.040	391.410	.133	.123	4618.090	443.220	400.430	31.710	543.310	.300	.260	.103	4.040
205.	4.2	33.190	1.063	285.260	.128	.159	5189.990	600.500	629.250	27.980	614.790	.280	.309	.120	3.870
206.	4.3	37.600	1.083	252.550	.126	.134	5504.540	529.010	743.660	31.080	872.150	.303	.269	.120	4.320
207.	4.2	36.160	1.026	277.030	.120	.141	5004.130	428.930	529.140	39.780	600.500	.323	.326	.109	4.170
208.	4.8	39.380	1.075	306.310	.116	.160	8178.170	714.880	557.750	52.840	629.090	.735	.257	.114	6.210
209.	4.2	40.500	1.123	237.680	.126	.154	3588.670	386.030	414.730	38.550	514.710	.400	.229	.123	4.230
210.	4.2	38.330	1.278	367.850	.149	.153	5075.610	386.030	614.950	41.650	743.470	.383	.220	.123	6.690
211.	4.6	32.100	1.067	417.720	.140	.117	6119.330	471.820	486.240	38.550	428.930	.303	.349	.120	4.040
212.	4.4	38.240	1.145	291.440	.124	.152	6662.640	500.410	586.350	46.620	786.360	.672	.203	.114	7.300
213.	3.8	36.140	1.358	259.640	.140	.170	4417.930	629.090	600.640	38.550	543.310	.300	.243	.123	2.800
214.	4.5	37.290	1.146	610.330	.153	.145	5733.300	486.120	543.440	37.300	814.960	.317	.277	.120	9.150
215.	4.4	34.510	1.080	591.800	.135	.130	4703.880	457.520	686.450	31.710	629.090	.177	.303	.114	4.580
301.	4.8	44.430	1.361	580.620	.138	.185	7909.080	814.170	756.210	41.090	581.550	.872	.154	.099	3.430
302.	4.7	42.030	1.568	705.300	.137	.186	11049.450	741.480	727.120	53.100	1046.790	1.245	.157	.093	5.730
303.	4.4	45.560	1.285	282.870	.145	.189	6716.900	945.020	1483.340	39.820	770.550	1.285	.119	.142	2.770
304.	3.8	44.440	1.129	202.840	.129	.157	5466.570	625.170	1003.430	28.450	886.860	.753	.175	.108	3.120
305.	4.4	49.490	1.161	225.180	.106	.164	8592.400	712.400	625.330	44.240	494.320	1.044	.148	.076	2.150
306.	4.2	46.620	1.390	284.730	.142	.197	7618.310	843.250	959.800	36.030	988.640	1.506	.125	.105	3.720
307.	4.3	48.250	1.448	368.470	.136	.181	7400.220	741.480	741.660	34.140	886.860	1.105	.096	.084	3.200
308.	4.1	27.440	1.162	303.340	.113	.119	5350.260	494.320	378.100	37.300	901.400	.305	.288	.108	4.940
309.	5.1	42.710	1.536	813.240	.127	.194	11703.690	1003.170	523.530	67.010	421.620	1.605	.151	.058	4.300
310.	4.3	43.770	1.536	409.410	.149	.198	8621.480	683.320	872.550	44.880	1715.570	.564	.079	.061	6.370
311.	4.9	43.430	1.142	266.120	.119	.154	7400.220	639.710	741.660	39.200	814.170	.701	.250	.116	3.900
312.	4.6	43.370	1.673	621.560	.144	.182	7342.070	654.240	567.150	46.780	668.780	.814	.137	.087	3.490
313.	4.2	46.020	1.624	381.500	.143	.197	7792.770	988.640	712.580	42.990	1541.110	1.087	.172	.110	6.160
314.	4.8	40.520	1.318	757.410	.122	.181	11020.370	799.630	421.730	55.630	828.710	.846	.192	.070	6.080
315.	4.8	41.280	1.318	487.570	.141	.183	9173.950	814.170	567.150	53.740	1206.720	.927	.233	.102	8.720
401.	3.6	43.350	1.302	363.800	.169	.162	6376.960	605.960	793.720	45.790	1789.010	.571	.095	.115	10.100
402.	3.7	43.090	1.322	256.690	.152	.186	5338.180	504.960	663.830	40.140	908.930	.554	.107	.104	8.370
403.	4.2	41.200	1.107	380.420	.174	.124	4039.700	346.260	606.110	37.640	1240.770	.436	.193	.144	17.600
404.	4.2	38.910	1.126	400.740	.190	.154	4645.660	360.690	591.680	39.520	1442.750	.384	.202	.136	21.350
405.	4.4	39.280	1.166	587.260	.145	.159	6001.840	490.540	620.540	43.280	1197.480	.548	.173	.121	18.180
406.	4.3	41.290	1.213	439.520	.144	.164	5482.450	476.110	707.130	43.910	1226.340	.612	.121	.133	20.490
407.	4.0	32.010	.951	358.260	.199	.117	3938.710	375.120	591.680	34.500	1572.600	.179	.369	.164	14.430
408.	4.2	41.810	1.096	426.590	.187	.143	4674.510	403.970	721.560	33.880	1154.200	.427	.202	.153	15.580

409.	4.4	40.550	1.111	561.400	.160	.135	6102.830	504.960	909.170	42.020	1789.010	.551	.141	.153	27.410
410.	4.2	36.030	1.259	587.260	.155	.178	6232.680	476.110	533.950	45.160	1558.170	.352	.222	.121	24.820
411.	4.1	45.530	1.230	439.520	.162	.170	6420.240	591.530	1096.770	37.640	1659.160	.658	.107	.150	17.310
412.	4.1	43.210	1.349	489.380	.215	.144	6102.830	620.380	837.010	46.420	1803.440	.545	.156	.162	21.060
413.	4.2	38.450	.988	583.560	.245	.130	4876.500	389.540	735.990	37.640	1731.300	.257	.280	.153	22.510
414.	4.3	36.250	.998	332.410	.209	.141	5395.890	461.680	750.420	40.780	1284.050	.364	.222	.141	20.200
415.	4.1	37.430	1.412	496.770	.224	.156	6030.700	548.250	663.830	38.260	1558.170	.430	.167	.118	24.820
501.	4.4	35.840	1.008	358.450	.140	.166	6439.400	668.110	469.210	37.700	995.050	.245	.887	.117	8.240
502.	4.0	37.290	1.055	252.910	.148	.161	4506.160	483.310	369.680	42.030	597.030	.250	.614	.108	7.960
503.	4.2	33.650	1.219	374.820	.143	.172	7121.720	710.750	469.210	48.210	938.190	.216	1.114	.134	8.530
504.	3.6	38.240	1.362	394.840	.139	.195	4634.090	625.460	597.180	38.320	696.540	.282	.432	.100	4.350
505.	4.2	37.860	1.257	578.610	.199	.189	5885.010	710.750	739.370	44.500	1023.480	.432	.500	.145	6.820
506.	4.3	37.050	1.171	433.050	.185	.154	5714.430	611.250	440.780	43.880	1051.910	.395	.660	.125	10.520
507.	4.4	28.170	1.066	352.990	.219	.133	6510.470	668.110	469.210	38.320	739.180	.162	1.274	.122	11.370
508.	4.7	33.240	1.190	420.310	.189	.154	6240.390	724.970	398.120	51.910	625.460	.378	.864	.122	10.230
509.	4.0	36.810	1.190	553.130	.136	.160	4932.610	426.450	455.000	46.970	1236.710	.378	.432	.111	13.080
510.	3.8	32.090	1.315	578.610	.209	.158	4037.060	597.030	483.430	40.790	540.170	.188	.773	.122	3.870
511.	4.4	35.460	1.310	433.050	.169	.174	7462.880	767.610	611.400	46.350	952.410	.344	.842	.128	11.370
512.	4.5	38.810	1.068	482.170	.141	.135	5941.870	625.460	540.310	43.260	1009.270	.418	.569	.114	8.530
513.	4.4	28.660	1.077	574.970	.191	.120	5671.790	625.460	455.000	39.550	668.110	.230	.910	.122	10.230
514.	4.6	30.860	1.058	327.510	.184	.125	7192.790	781.830	469.210	43.880	639.680	.313	.705	.114	13.080
515.	4.6	35.120	1.124	489.450	.166	.145	7647.670	838.690	696.710	46.350	1009.270	.299	.864	.148	11.090
601.	4.9	47.490	1.559	763.060	.150	.193	6383.060	959.640	741.730	42.350	276.260	1.186	.201	.128	2.210
602.	4.9	41.650	1.299	880.310	.140	.189	6615.700	1192.280	1367.110	46.140	421.660	.878	.346	.195	2.210
603.	4.9	44.950	1.309	647.670	.141	.176	6339.440	974.180	945.340	38.560	436.200	.814	.323	.151	2.040
604.		44.270	1.107		.156							.893	.154	.320	1.110
605.	4.8	45.840	1.275		.155							1.157	.212	.195	1.830
606.	5.0	47.550	1.188	675.590	.136	.202	6572.080	799.700	1047.150	34.770	265.210	1.186	.140	.134	1.570
607.	4.9	44.910	1.246	604.860	.148	.173	6455.760	828.780	1061.690	39.200	335.000	.916	.288	.172	2.410
608.	5.1	48.560	1.373	774.230	.152	.196	5714.220	814.240	988.970	34.140	223.330	1.332	.212	.160	2.120
609.	5.0	46.730	1.411	789.110	.144	.184	4740.040	785.160	901.710	39.830	279.170	1.231	.186	.183	1.570
610.	5.2	45.700	1.548	720.250	.171	.195	6732.020	799.700	814.450	42.990	335.000	1.102	.227	.154	2.560
611.	5.1	44.250	1.896	580.670	.137	.194	5423.420	1090.500	1032.600	45.520	251.250	.960	.273	.204	1.660
612.	4.9	46.810	1.285	359.200	.147	.203	3082.480	886.940	1614.350	31.600	237.290	.945	.239	.343	1.310
613.	5.2	47.660	1.421	759.340	.195	.173	5089.000	799.700	1628.900	35.400	279.170	1.012	.215	.279	1.690
614.	4.9	46.630	1.246	483.890	.143	.175	5845.080	785.160	1119.870	35.400	335.000	1.256	.189	.174	1.450
615.	4.9	45.530	1.245	671.860	.135	.191	7051.900	1235.900	1905.230	47.410	390.840	.974	.270	.238	1.800

Table H-2. Mineral soil variability data

CODE	pH H2O	pH Ca	TC %	TN %	minN ppm	exP ppm	SO4 ppm	exCa ppm	exMg ppm	exK ppm	CEC meq/100g	exMn ppm
101.	4.2	3.8	3.680	.075	2.61	2.19	6.89	16.95	19.56	76.96	3.40	29.99
102.	4.6	4.0	2.200	.046	2.61	1.98	4.80	19.56	13.04	33.91	2.16	37.82
103.	4.9	4.1	5.490	.113	7.82	1.77	8.24	324.70	46.94	117.39	4.54	170.82
104.	4.6	3.9	2.560	.068	3.91	2.40	5.53	0.	16.95	60.00	3.40	15.65
105.	4.5	3.9	3.040	.066	1.30	3.03	4.80	20.86	15.65	61.30	3.17	14.34
106.	4.7	4.1	2.360	.051	1.30	7.09	5.53	213.86	29.99	56.09	3.75	43.03
107.	4.8	4.2	1.150	.031	0.	1.46	4.80	11.74	7.82	27.39	1.25	2.61
108.	4.6	4.0	2.800	.058	2.61	1.04	3.44	52.16	15.65	43.04	2.38	28.69
109.	4.7	4.2	2.060	.061	6.52	2.92	4.80	27.38	10.43	32.61	1.59	20.86
110.	4.5	3.9	2.850	.061	1.30	1.36	4.17	97.80	24.78	52.17	3.06	26.08
111.	4.6	3.9	4.010	.098	3.91	2.61	8.97	70.42	35.21	53.48	6.57	44.34
112.	4.8	4.2	2.130	.054	6.52	2.09	5.53	13.04	14.34	76.96	1.93	27.38
113.	4.7	4.0	2.570	.059	5.22	1.67	6.89	37.82	13.04	48.26	2.72	23.47
114.	4.6	4.0	3.060	.064	5.22	3.76	4.80	73.02	26.08	61.30	3.29	74.33
115.	4.6	4.0	2.490	.055	1.30	2.50	4.17	87.37	18.26	62.61	2.84	56.07
201.	5.0	4.4	1.780	.065	10.43	1.98	3.44	118.66	15.65	63.91	1.36	2.61
202.	4.5	4.0	4.310	.131	15.65	1.88	7.62	58.68	18.26	48.26	2.49	16.95
203.	4.7	4.4	2.120	.070	14.34	1.57	7.62	6.52	5.22	15.65	.79	1.30
204.	4.4	3.9	4.890	.146	19.56	2.61	4.80	86.06	37.82	49.56	3.86	19.56
205.	4.5	4.0	5.940	.182	36.51	2.30	7.62	195.60	49.55	87.39	4.08	26.08
206.	4.5	4.0	4.070	.131	23.47	1.88	3.44	36.51	13.04	39.13	2.38	9.13
207.	4.6	4.2	4.200	.131	20.86	2.30	8.24	117.36	24.78	54.78	2.61	15.65
208.	4.6	4.2	3.110	.097	10.43	1.67	8.24	13.04	13.04	30.00	1.93	9.13
209.	4.7	4.3	3.110	.110	14.34	1.46	11.68	87.37	16.95	35.22	2.49	15.65
210.	4.9	4.4	1.670	.064	6.52	2.19	2.71	71.72	22.17	82.17	1.70	6.52
211.	4.9	4.4	3.530	.110	22.17	1.57	7.62	207.34	22.17	35.22	2.16	13.04
212.	4.6	4.1	5.780	.149	28.69	2.82	5.53	164.30	26.08	33.91	3.17	20.86
213.	4.3	3.8	7.920	.215	33.90	1.46	8.24	93.89	44.34	75.65	4.54	18.26
214.	4.6	4.1	3.710	.119	20.86	1.57	2.09	88.67	15.65	28.70	2.61	11.74
215.	4.6	4.1	3.460	.108	16.95	.94	6.89	73.02	20.86	56.09	3.29	22.17
301.	5.2	4.7	3.150	.145	35.21	1.36	4.17	581.58	49.55	31.30	3.96	37.82
302.	5.4	4.8	2.100	.107	22.17	1.36	4.80	342.95	24.78	26.09	2.61	13.04
303.	5.5	5.0	2.620	.131	16.95	1.67	2.71	769.36	59.98	79.56	4.42	29.99
304.	5.1	4.6	3.440	.137	35.21	2.19	3.44	279.06	22.17	24.78	2.95	20.86
305.	5.3	4.9	3.350	.135	33.90	1.25	2.09	453.79	37.82	45.65	4.08	19.56
306.	5.1	4.6	4.780	.171	52.16	1.15	2.09	619.40	48.25	36.52	4.77	50.86
307.	5.3	4.6	1.800	.079	22.17	2.61	2.09	302.53	33.90	30.00	2.49	10.43
308.	5.3	4.7	3.140	.110	20.86	2.50	.73	582.89	49.55	44.35	3.75	32.60
309.	5.0	4.5	3.410	.167	27.38	3.13	2.09	354.69	40.42	36.52	4.08	32.60
310.	5.1	4.6	3.920	.170	36.51	3.23	3.44	573.76	49.55	44.35	4.19	56.07
311.	5.1	4.5	1.660	.075	20.86	4.49	.73	434.23	53.46	23.48	3.75	15.65
312.	5.3	4.7	2.550	.102	27.38	1.67	2.09	331.22	24.78	22.17	2.72	16.95
313.	5.0	4.5	2.130	.110	24.78	1.04	5.53	165.61	11.74	35.22	1.47	19.56
314.	5.2	4.6	2.160	.098	18.26	1.46	4.17	228.20	18.26	22.17	2.26	19.56
315.	5.1	4.6	2.760	.126	22.17	2.82	2.71	418.58	44.34	26.09	3.75	27.38
401.	5.4	4.6	3.220	.123	22.17	9.81	6.15	251.67	20.86	54.78	2.61	36.51
402.	5.2	4.4	4.150	.141	19.56	7.30	2.71	256.89	27.38	45.65	3.17	53.46
403.	5.1	4.5	2.460	.116	5.22	6.78	6.15	189.08	19.56	26.35	2.72	27.38
404.	5.2	4.7	2.350	.094	6.52	3.96	3.44	157.78	15.65	52.17	1.70	11.74
405.	5.2	4.7	2.260	.079	6.52	2.92	11.06	182.56	15.65	39.13	1.70	9.13
406.	5.3	4.8	2.260	.086	9.13	9.49	10.33	160.39	15.65	27.39	1.93	10.43
407.	5.3	4.5	4.160	.153	39.12	14.61	2.71	264.71	22.17	50.87	3.40	82.15
408.	5.3	4.7	2.890	.091	7.82	6.05	10.33	166.91	16.95	35.22	2.04	15.65

409.	5.1	4.7	1.850	.103	11.74	3.13	13.77	100.41	6.52	35.22	1.36	5.22
410.	5.0	4.6	2.930	.107	11.74	8.55	6.15	135.62	20.86	58.69	2.16	48.25
411.	5.0	4.4	3.010	.121	13.04	3.23	11.68	87.37	10.43	43.04	1.70	9.13
412.	5.0	4.2	5.720	.220	45.64	17.94	5.53	220.38	29.99	61.30	3.86	79.54
413.	5.2	4.6	3.720	.099	9.13	- 3.34	8.97	264.71	23.47	46.96	2.38	15.65
414.	5.4	4.5	5.020	.114	13.04	3.65	16.48	245.15	22.17	109.56	2.72	28.69
415.	5.3	4.5	6.280	.247	45.64	5.95	11.06	721.11	58.68	84.78	6.12	39.12
501.	5.2	4.5	2.480	.084	31.30	14.19	1.36	445.97	63.90	30.00	4.08	29.99
502.	5.5	4.5	3.700	.134	69.11	30.04	2.71	1011.90	105.62	67.83	6.47	65.20
503.	5.4	4.4	2.580	.098	24.78	20.86	5.53	219.07	48.25	36.52	2.72	29.99
504.	5.4	4.5	3.670	.090	24.78	11.48	3.44	302.53	40.42	56.09	2.61	9.13
505.	5.3	4.4	4.440	.166	44.34	20.45	1.36	752.41	89.98	82.17	5.56	135.62
506.	5.3	4.6	3.290	.105	40.42	14.61	2.09	884.11	116.06	96.52	5.10	79.54
507.	5.4	4.7	4.430	.107	24.78	8.97	2.09	558.11	78.24	67.83	3.96	20.86
508.	5.3	4.5	4.630	.148	54.77	16.69	2.09	989.74	151.26	84.78	6.35	88.67
509.	5.0	4.3	2.690	.097	29.99	23.99	2.09	337.74	48.25	41.74	3.86	52.16
510.	5.2	4.3	2.460	.118	33.90	22.74	.73	271.23	65.20	56.09	2.84	41.73
511.	5.7	4.7	3.250	.101	41.73	18.36	2.09	706.77	79.54	69.13	4.87	48.25
512.	5.2	4.4	2.220	.076	19.56	12.52	1.36	312.96	50.86	50.87	2.84	44.34
513.	5.1	4.4	1.820	.083	22.17	31.51	3.44	172.13	29.99	41.74	1.82	27.38
514.	5.0	4.2	3.480	.119	33.90	25.87	2.71	247.76	54.77	54.78	3.52	63.90
515.	5.7	4.5	2.590	.087	39.12	23.16	4.80	539.86	76.94	156.52	3.86	39.12
601.	5.4	4.4	3.790	.227	46.94	2.50	2.09	1131.87	138.22	36.52	7.94	33.90
602.	5.5	4.7	2.400	.122	41.73	2.71	.73	1040.59	105.62	74.35	6.01	20.86
603.	5.0	4.4	2.630	.128	54.77	5.43	2.09	533.34	67.81	18.26	4.99	20.86
604.	5.1	4.5	2.620	.134	44.34	4.80	1.36	627.22	73.02	41.74	5.45	26.08
605.	5.1	4.2	2.990	.127	35.21	1.25	1.36	490.30	105.62	136.96	5.33	28.69
606.	5.6	4.6	2.480	.112	28.69	5.63	.73	925.84	139.53	40.43	6.01	31.30
607.	5.4	4.5	3.920	.207	61.29	4.17	2.09	1236.19	190.38	31.30	8.17	33.90
608.	5.5	4.9	3.730	.188	83.46	4.17	1.36	1523.07	181.26	109.56	10.55	20.86
609.	4.9	4.3	4.020	.173	89.98	6.26	2.71	1262.27	165.61	151.30	8.05	53.46
610.	5.2	4.6	3.620	.188	62.59	2.71	.73	1392.67	215.16	69.13	9.75	31.30
611.	4.8	4.2	2.190	.104	31.30	6.05	1.36	432.93	48.25	30.00	3.86	19.56
612.	5.0	4.4	3.860	.169	53.46	6.26	1.36	936.27	116.06	37.83	6.57	29.99
613.	5.1	4.4	3.000	.169	32.60	6.68	1.36	1027.55	199.51	41.74	7.71	33.90
614.	5.5	4.6	4.510	.206	66.50	2.09	.73	1314.43	170.82	26.09	10.88	24.78
615.	5.3	4.7	2.830	.138	56.07	2.92	1.36	1143.61	192.99	69.13	7.03	28.69

Table H-3. Forest floor composite sample within plot data

Code	pH	TC	TN	minN	TP	TS	exCa	exMg	exK	CEC	exMn	TCa	TMg	TK	TMn
	H2O	----- %	----	ppm	--- %	---	----------	ppm	-----------	meq/100g	ppm	--------	%		----------
0111.	4.2	37.060	.861	200.760	.112	.103	7706.180	701.860	1260.810	41.720	1962.350	.527	.120	.117	12.950
0111.	4.2	34.510	.814	161.460	.107	.105	6230.830	558.630	945.610	37.990	1747.500	.372	.120	.138	12.030
0111.	4.1	43.530	.937	161.340	.109	.137	6846.750	759.160	1117.540	44.840	2291.800	.559	.129	.132	12.030
0211.	4.1	42.810	.918	170.510	.112	.145	6932.700	644.570	1002.910	43.590	2019.650	.639	.112	.117	9.170
0211.	4.5	43.320	.966	201.680	.128	.151	8164.540	744.840	1174.850	43.590	2578.280	.788	.123	.120	16.390
0211.	4.2	43.570	.919	198.130	.123	.149	6889.720	286.480	1060.230	41.720	2205.860	.788	.115	.120	10.890
0311.	4.4	43.620	1.062	259.200	.142	.155	6388.390	687.540	1103.210	41.100	2148.560	.805	.118	.129	14.900
0311.	4.1	45.650	.939	135.670	.107	.143	6001.650	587.270	945.610	42.350	1804.790	.673	.112	.115	10.600
0311.	4.5	42.360	.949	229.180	.119	.147	7792.120	716.190	1117.540	44.840	2291.800	.702	.115	.117	17.190
0411.	4.0	44.460	1.054	188.840	.118	.137	5715.180	587.270	945.610	41.720	1761.820	.507	.138	.132	12.380
0411.	4.4	41.090	.921	244.310	.128	.151	5801.120	658.890	1131.860	42.350	2005.330	.582	.143	.149	15.240
0411.	4.2	41.990	.969	209.240	.121	.144	5758.150	687.540	1088.880	39.850	2076.940	.559	.129	.126	13.180
0522.	4.2	32.430	.933	261.820	.105	.121	6448.170	543.310	772.260	35.430	943.640	.312	.209	.114	5.030
0522.	3.5	38.020	1.067	190.210	.095	.138	4289.250	586.200	572.050	37.300	500.410	.292	.140	.083	2.400
0522.	3.5	35.400	1.101	192.730	.114	.123	4818.260	471.820	757.960	41.030	629.090	.160	.149	.100	2.800
0622.	4.1	35.780	1.017	300.360	.122	.151	5576.030	557.600	543.440	32.320	686.280	.289	.272	.112	3.870
0622.	4.3	39.150	1.152	312.260	.127	.146	6562.550	586.200	686.450	37.300	743.470	.475	.252	.114	5.490
0622.	4.3	33.400	1.143	349.090	.126	.146	5990.650	557.600	657.860	39.780	700.580	.343	.280	.117	5.640
0722.	4.4	34.180	1.028	394.500	.135	.135	7935.110	600.500	757.960	39.160	729.170	.383	.283	.109	5.490
0722.	4.6	33.670	1.028	492.060	.129	.121	5761.890	500.410	486.240	40.410	571.900	.263	.346	.109	6.840
0722.	4.3	32.800	.971	346.340	.119	.137	5247.180	400.330	543.440	35.430	600.500	.237	.335	.123	4.900
0822.	4.1	36.780	1.184	246.830	.161	.146	7477.020	686.280	958.170	41.030	1172.400	.386	.180	.117	5.700
0822.	4.2	39.680	1.088	314.770	.127	.149	5475.940	543.310	829.470	36.680	772.070	.320	.206	.134	5.200
0822.	4.1	34.550	1.166	399.640	.144	.142	4932.640	543.310	686.450	37.920	872.150	.252	.237	.117	4.840
0933.	4.6	44.850	1.354	495.020	.148	.184	9043.100	857.790	945.260	47.410	886.860	.867	.177	.096	3.810
0933.	4.8	41.960	1.541	720.190	.136	.174	11907.240	974.100	908.900	56.890	523.400	1.256	.180	.079	4.590
0933.	4.7	43.910	1.396	593.650	.129	.178	11049.450	901.400	1854.170	53.740	945.020	.901	.198	.087	6.050
1033.	4.7	39.450	1.179	582.480	.104	.170	10002.660	726.940	1254.290	37.930	537.930	.884	.204	.076	3.020
1033.	4.9	38.710	1.317	694.140	.157	.176	10642.370	901.400	781.660	50.570	552.470	.712	.279	.110	4.220
1033.	4.8	41.170	1.218	720.190	.126	.168	9711.890	785.090	1199.750	53.100	581.550	.744	.256	.096	3.840
1133.	4.8	42.550	1.160	374.050	.123	.158	8490.630	799.630	927.080	43.620	872.330	.855	.227	.108	6.900
1133.	4.5	36.470	1.112	379.640	.109	.143	8185.320	683.320	472.630	41.090	697.860	.596	.262	.093	3.490
1133.	4.6	41.790	1.240	435.460	.119	.159	8185.320	770.550	654.410	39.820	959.560	.733	.241	.099	5.910
1233.	4.7	40.790	1.289	500.600	.112	.186	10656.900	741.480	1090.690	44.880	697.860	.776	.253	.093	5.760
1233.	4.5	38.740	1.397	625.280	.121	.170	9304.800	697.860	927.080	47.410	959.560	.689	.250	.096	5.620
1233.	4.8	37.670	1.379	617.840	.147	.173	10889.520	726.940	708.940	53.740	610.630	1.041	.253	.096	5.910
1342.	4.0	40.250	1.092	511.540	.135	.136	6001.840	533.820	707.130	40.780	2394.970	.387	.193	.118	19.330
1342.	4.1	37.080	1.063	448.750	.155	.127	5670.010	533.820	865.870	40.780	2885.500	.338	.214	.144	19.040
1342.	3.8	46.270	1.219	313.940	.173	.175	5900.850	577.100	880.310	42.020	2539.240	.537	.130	.136	12.410
1442.	4.1	41.740	1.178	398.890	.177	.165	4587.950	476.110	750.420	47.670	1976.570	.418	.173	.136	19.620
1442.	4.1	41.770	1.100	313.940	.182	.147	6059.550	605.960	779.280	40.140	2192.980	.534	.156	.127	15.870
1442.	4.2	41.940	1.120	389.660	.201	.147	6492.380	591.530	952.460	43.280	2741.230	.447	.185	.159	19.040
1542.	3.7	44.070	1.129	319.480	.143	.164	5771.000	533.820	923.590	39.520	2293.970	.479	.107	.121	11.540
1542.	3.8	38.860	1.080	332.410	.148	.149	5410.310	490.540	793.720	40.140	2337.260	.349	.165	.118	14.430
1542.	4.2	40.090	1.206	428.440	.149	.148	6622.220	605.960	822.580	43.910	2741.230	.543	.162	.130	17.890
1642.	3.9	44.290	1.196	380.420	.141	.149	5958.560	577.100	923.600	40.780	2164.130	.485	.150	.130	14.430
1642.	4.2	33.530	1.181	481.990	.197	.154	5886.420	562.670	981.320	46.420	2510.390	.421	.193	.144	21.640
1642.	4.1	39.890	1.283	511.540	.172	.152	5684.440	533.820	865.870	37.640	2279.550	.485	.162	.153	23.080
1753.	4.1	38.140	.842	370.270	.157	.140	5160.050	497.530	568.750	33.380	1179.850	.247	.637	.114	8.810
1753.	4.3	38.940	.919	409.390	.118	.145	6140.880	554.390	668.280	39.550	909.760	.375	.546	.114	8.240
1753.	3.6	40.230	.988	261.100	.125	.146	4548.800	469.100	511.870	38.320	1137.200	.290	.364	.097	4.630
1853.	4.2	40.380	1.105	380.960	.205	.152	5273.770	540.170	611.400	39.550	952.410	.313	.614	.119	9.100
1853.	4.1	42.050	1.106	517.430	.146	.136	6396.750	568.600	625.620	37.080	767.610	.350	.455	.102	7.700
1853.	4.3	36.090	1.122	638.200	.159	.140	5813.940	454.880	554.530	37.700	1137.200	.307	.637	.122	11.940
1953.	4.0	35.870	1.390	474.890	.173	.167	5174.260	540.170	469.210	37.080	753.400	.276	.569	.105	7.390
1953.	4.1	36.370	1.238	533.350	.175	.150	8102.550	682.320	696.710	40.180	1421.500	.287	.728	.114	11.370
1953.	4.5	32.240	.931	554.730	.173	.142	7860.900	682.320	668.280	43.880	966.620	.273	.910	.125	12.220
2053.	4.4	35.510	.931	560.410	.141	.150	7676.100	668.110	412.340	47.590	582.820	.310	.796	.111	6.820
2053.	4.2	35.250	1.373	504.010	.223	.157	7576.600	682.320	639.840	43.260	966.620	.276	.842	.134	7.510
2053.	4.2	38.530	1.238	509.240	.152	.163	8031.480	668.110	625.620	45.740	995.050	.392	.591	.105	6.940
2164.	4.7	42.240	1.225	807.730	.147	.157	5845.080	683.380	639.920	38.560	279.170	.608	.500	.160	2.440
2164.	4.8	46.200	1.417	751.890	.142	.178	5990.480	916.020	945.340	42.350	251.250	1.091	.201	.166	2.010
2164.	4.9	46.830	1.416	930.560	.141	.192	6499.380	785.160	814.450	48.040	223.330	1.268	.198	.151	1.950
2264.	4.5	46.630	1.560	865.420	.130	.145	6586.620	741.540	407.220	46.140	251.250	.887	.227	.111	2.650
2264.	4.9	46.340	1.568	818.890	.164	.173	5743.300	814.240	1047.150	48.680	265.210	1.088	.198	.154	1.890
2264.	5.0	47.450	1.478	1075.730	.161	.149	5946.860	988.720	1323.480	45.520	209.380	.986	.262	.221	1.800
2364.	4.9	45.980	1.333	576.950	.143	.146	5830.540	945.100	945.340	43.620	335.000	.904	.279	.172	1.920
2364.	5.0	47.270	1.390	653.250	.152	.133	6106.800	843.320	1018.060	43.620	279.170	1.091	.212	.160	2.040
2364.	5.0	44.890	1.293	537.860	.144	.153	4216.600	814.240	1076.240	42.990	139.580	1.018	.236	.250	1.630
2464.	4.9	43.990	1.389	764.920	.148	.137	5801.460	756.080	858.080	44.250	223.330	1.225	.221	.151	1.950
2464.	4.6	46.670	1.541	815.170	.145	.185	5990.480	945.100	1323.480	47.410	307.080	1.056	.209	.192	1.540
2464.	4.8	45.280	1.578	750.030	.144	.152	6005.020	814.240	770.820	40.460	251.250	1.219	.207	.145	1.890

Table H-4. Mineral soil composite sample within plot data

Code	pH H2O	pH Ca	TC ---- % ----	TN	minN -------	exP -------	SO4 -------	exCa ppm	exMg -------	exK -------	CEC meq/100g	exMn ppm
0111.	4.6	4.0	3.600	.069	0.	2.19	4.17	92.58	27.38	84.78	3.63	45.64
0111.	4.7	4.1	2.950	.072	6.52	1.88	6.89	57.38	18.26	62.61	2.38	45.64
0111.	4.5	4.0	4.160	.084	7.82	2.30	5.53	173.43	28.69	67.83	3.63	20.86
0211.	4.9	4.1	4.040	.083	3.91	3.34	4.80	189.08	24.78	65.22	3.29	59.98
0211.	4.7	4.0	2.450	.067	2.61	3.13	5.53	116.06	20.86	62.61	2.95	37.82
0211.	4.9	4.0	2.870	.069	3.91	3.23	5.53	114.75	19.56	44.35	2.95	36.51
0311.	4.6	3.9	3.180	.069	3.91	2.92	4.80	114.75	27.38	62.61	3.63	75.63
0311.	4.6	4.0	2.750	.068	5.22	3.65	5.53	56.07	19.56	50.87	3.06	48.25
0311.	4.6	3.9	3.350	.076	6.52	2.71	5.53	50.86	18.26	53.48	2.72	62.59
0411.	4.6	4.0	3.210	.072	3.91	2.19	5.53	53.46	22.17	58.69	3.17	54.77
0411.	4.6	4.1	2.170	.051	1.30	2.61	4.17	89.98	19.56	53.48	2.49	27.38
0411.	4.7	4.0	2.720	.066	2.61	2.30	6.15	54.77	20.86	57.39	3.17	45.64
0522.	4.4	4.0	3.140	.089	10.43	1.67	6.15	29.99	19.56	40.43	3.75	7.82
0522.	4.6	4.1	3.030	.095	15.65	1.98	4.80	59.98	22.17	45.65	3.17	15.65
0522.	4.6	4.1	3.230	.096	10.43	2.30	6.15	18.26	15.65	32.61	2.72	5.22
0622.	4.6	4.1	4.170	.116	24.78	1.98	5.53	86.06	26.08	30.00	2.49	10.43
0622.	4.7	4.2	3.690	.100	19.56	2.30	6.15	73.02	22.17	39.13	2.26	11.74
0622.	4.7	4.1	5.320	.142	23.47	1.77	5.53	146.05	31.30	52.17	4.08	26.08
0722.	4.9	4.4	2.420	.072	10.43	.84	8.24	97.80	27.38	49.56	1.70	11.74
0722.	4.8	4.2	3.100	.094	22.17	1.36	6.89	59.98	20.86	56.09	2.04	11.74
0722.	4.9	4.3	2.940	.091	13.04	1.57	4.17	159.09	37.82	63.91	2.26	18.26
0822.	4.7	4.3	2.930	.086	13.04	1.04	5.53	66.50	19.56	46.96	1.70	16.95
0822.	4.8	4.2	2.600	.089	16.95	.94	6.15	48.25	18.26	33.91	2.16	3.91
0822.	4.7	4.2	2.910	.102	20.86	1.36	2.71	103.02	23.47	70.43	2.26	15.65
0933.	5.4	4.9	3.070	.140	26.08	2.09	3.44	562.02	39.12	58.69	3.52	26.08
0933.	5.1	4.6	2.990	.143	33.90	2.50	2.09	513.78	45.64	45.65	3.75	43.03
0933.	5.1	4.6	2.160	.108	23.47	1.77	4.80	391.20	29.47	36.52	2.38	27.38
1033.	5.3	4.7	3.250	.145	44.34	1.77	3.44	663.74	46.94	46.96	4.19	24.78
1033.	5.3	4.8	3.640	.148	40.42	1.98	2.71	745.89	53.46	36.52	4.42	29.99
1033.	5.3	4.7	3.370	.193	39.12	1.57	2.09	764.14	53.46	40.43	5.22	23.47
1133.	5.4	4.7	2.790	.126	31.30	2.61	3.44	766.75	49.55	61.30	3.86	20.86
1133.	5.2	4.6	2.650	.134	35.21	2.40	1.36	691.12	49.55	32.61	4.54	26.08
1133.	5.5	4.9	2.420	.105	24.78	2.50	1.36	532.03	32.60	32.61	3.17	9.13
1233.	5.2	4.7	2.610	.138	27.38	2.30	3.44	409.46	31.30	39.13	3.06	20.86
1233.	5.3	4.7	2.230	.115	20.86	1.46	4.17	284.27	19.56	27.39	2.49	14.34
1233.	5.5	4.9	2.590	.121	19.56	1.77	2.09	627.22	41.73	48.26	3.52	15.65
1342.	5.2	4.5	2.880	.096	7.82	4.38	9.60	135.62	18.26	28.20	2.26	27.38
1342.	5.3	4.6	2.920	.105	9.13	3.03	9.60	161.70	18.26	31.30	2.26	45.64
1342.	5.2	4.4	3.400	.090	5.22	7.72	8.97	192.99	26.08	49.56	2.61	67.81
1442.	5.2	4.5	3.630	.117	15.65	2.50	10.33	183.86	19.56	32.61	2.61	46.94
1442.	5.3	4.6	3.580	.111	11.74	2.61	6.89	195.60	22.17	45.65	2.38	43.03
1442.	5.3	4.4	4.140	.146	16.95	3.76	4.80	232.11	28.69	41.74	3.06	57.38
1542.	5.1	4.6	2.440	.082	3.91	3.34	8.97	140.83	10.43	39.13	2.04	15.65
1542.	5.2	4.6	2.260	.081	9.13	3.34	5.53	172.58	16.95	33.91	1.93	15.65
1542.	5.3	4.6	2.270	.079	10.43	5.84	6.15	161.70	18.26	39.13	2.04	27.38
1642.	5.3	4.6	2.870	.098	16.95	6.05	4.80	268.62	26.08	52.30	2.16	44.34
1642.	5.2	4.6	2.740	.102	10.43	7.62	5.53	192.99	19.56	45.65	2.04	41.73
1642.	5.1	4.5	4.200	.124	13.04	4.69	8.97	266.02	26.08	48.26	2.84	26.08
1753.	5.3	4.3	3.170	.102	24.78	9.18	4.17	161.70	43.03	41.74	3.17	46.94
1753.	5.3	4.5	2.630	.105	31.30	7.51	6.15	288.18	40.42	40.43	3.29	37.82
1753.	5.0	4.4	2.620	.110	24.78	5.63	7.62	156.48	28.69	35.22	2.61	39.12
1853.	5.3	4.3	3.160	.126	39.12	8.97	2.09	375.55	59.98	61.30	4.19	78.24
1853.	5.0	4.2	2.920	.100	28.69	8.24	2.71	221.68	57.38	45.65	3.86	69.11
1853.	5.0	4.4	2.880	.108	28.69	8.66	2.71	303.83	52.16	48.26	3.40	58.68
1953.	5.3	4.5	3.250	.123	40.42	18.78	4.17	618.10	76.94	63.91	4.54	54.77
1953.	5.1	4.5	3.220	.117	31.30	17.53	1.36	534.64	74.33	83.48	4.08	53.46
1953.	5.2	4.5	2.810	.090	36.51	23.37	.73	445.97	65.20	73.04	3.52	50.86
2053.	5.5	4.5	3.720	.127	39.12	12.52	1.36	555.50	80.85	36.52	5.33	45.64
2053.	5.6	4.5	3.900	.146	54.77	10.22	2.09	783.70	93.89	48.26	6.57	59.98
2053.	5.5	4.4	2.360	.096	31.30	13.56	1.36	457.70	57.38	44.35	3.86	36.51
2164.	5.2	4.5	4.300	.196	66.50	8.76	2.71	1353.55	191.69	69.13	8.39	36.51
2164.	5.2	4.6	3.030	.168	66.50	10.22	1.36	1431.79	177.34	65.22	9.29	35.21
2164.	5.1	4.4	3.490	.185	63.90	10.02	2.09	1027.55	182.56	53.48	8.50	36.51
2264.	5.1	4.4	3.300	.169	56.07	8.35	2.71	844.99	118.66	23.48	7.38	19.56
2264.	5.3	4.6	3.270	.173	45.64	17.73	1.36	1118.83	155.18	44.35	8.73	22.17
2264.	5.4	4.6	3.300	.209	63.90	8.97	2.09	1066.67	148.66	37.83	8.96	22.17
2364.	5.1	4.4	2.740	.154	44.34	2.71	2.09	874.98	103.02	97.83	6.24	24.78
2364.	5.3	4.6	3.470	.174	56.07	4.59	2.09	1366.59	170.82	71.74	7.94	32.60
2364.	5.2	4.5	3.040	.162	44.34	4.17	.73	1001.47	148.66	43.04	7.38	28.69
2464.	5.4	4.7	3.070	.140	60.40	11.06	.73	1379.63	169.52	43.04	8.50	27.38
2464.	5.4	4.6	2.330	.123	46.47	6.68	.73	1187.94	139.53	67.83	7.48	18.26
2464.	5.1	4.4	4.590	.209	78.81	6.47	2.71	1496.99	199.51	44.35	10.78	40.42

Table H-5. Forest floor plot mean data

Code	TC	TN	minN	TP	TS	exCa	exMg	exK	exMn	pH
	Kg / ha									H2O
011111.	17585.453	398.977	7.997	50.067	52.747	317.530	30.853	50.783	91.690	4.2
021111.	12727.199	275.056	5.597	35.647	43.720	215.763	16.447	31.777	66.767	4.3
031111.	16635.906	372.743	7.887	46.483	56.243	255.047	25.160	40.013	78.923	4.3
041111.	14978.566	345.866	7.543	43.200	50.683	202.877	22.707	37.187	68.633	4.3
052122.	19111.426	560.083	11.640	56.793	68.873	280.870	28.913	37.960	37.433	3.7
062122.	12907.070	394.530	11.460	44.700	52.700	216.003	20.270	22.490	25.380	4.2
072122.	10876.715	327.170	13.323	41.403	42.493	204.710	16.223	19.317	20.550	4.4
082122.	11502.863	356.130	9.957	44.797	45.353	185.320	18.370	25.633	29.183	4.1
093133.	10960.430	394.086	16.613	37.927	49.130	293.906	25.107	25.530	21.633	4.7
103133.	10457.238	325.440	17.497	33.837	45.047	266.020	21.150	28.353	14.650	4.8
113133.	13737.039	399.270	13.520	39.943	52.307	282.690	25.627	23.353	28.767	4.6
123133.	9090.855	315.296	13.527	29.410	41.007	239.293	16.803	21.150	17.593	4.7
134212.	27217.855	742.903	28.060	101.917	96.427	386.960	36.213	54.020	172.190	4.0
144212.	21086.465	571.153	18.530	94.093	77.113	288.096	28.133	41.723	116.160	4.1
154212.	28813.305	799.950	25.307	103.000	108.097	417.006	38.187	59.490	161.870	3.9
164212.	23011.387	715.526	26.860	99.737	89.060	342.700	32.720	54.167	135.953	4.1
175223.	13039.004	305.496	11.570	44.493	47.853	176.167	16.907	19.437	35.867	4.0
185223.	15691.441	441.400	20.343	67.447	56.740	231.467	20.700	23.717	37.823	4.2
195223.	18180.664	619.413	27.197	90.637	79.850	367.840	33.147	31.920	54.667	4.2
205223.	15406.398	499.336	22.180	72.777	66.253	328.217	28.450	23.653	35.870	4.3
216234.	4021.532	120.620	7.403	12.760	15.677	54.510	7.090	7.133	2.240	4.8
226234.	6978.949	228.930	13.717	22.600	23.213	90.837	12.647	13.803	3.607	4.8
236234.	3191.070	92.783	4.087	10.160	9.970	37.317	6.010	7.023	1.740	5.0
246234.	6742.777	223.627	11.557	21.693	23.527	88.273	12.477	14.643	3.877	4.8

Table H-6. Mineral soil plot mean data

Code	TC	TN	minN	exP	SO4	exCa	exMg	exK	exMn	pH H2O	pH Ca
	Kg / ha										
011111.	76566.875	1610.366	10.250	4.550	11.853	231.117	53.120	153.807	80.143	4.6	4.0
021111.	88646.688	2075.343	9.823	9.190	15.020	397.776	61.767	163.107	127.237	4.8	4.0
031111.	95939.563	2199.066	16.170	9.597	16.387	229.067	67.373	172.517	192.690	4.6	3.9
041111.	88967.750	2072.477	8.587	7.787	17.407	217.553	68.700	186.113	140.263	4.6	4.0
052122.	67831.063	2017.620	26.353	4.290	12.350	78.107	41.407	85.660	20.703	4.5	4.1
062122.	118674.375	3220.365	61.027	5.447	15.493	274.620	71.590	109.173	43.427	4.7	4.1
072122.	79809.250	2420.850	43.053	3.543	18.203	298.913	81.190	159.957	39.360	4.9	4.3
082122.	76799.250	2515.680	46.280	3.037	13.097	198.170	55.773	137.683	33.227	4.7	4.2
093133.	114537.750	5450.719	116.280	8.867	14.390	2044.020	159.163	196.273	134.450	5.2	4.7
103133.	108467.688	5136.785	130.900	11.463	8.707	2296.946	162.590	130.933	82.673	5.3	4.7
113133.	89614.813	4083.259	102.080	8.400	6.883	2225.376	147.290	141.490	62.707	5.4	4.7
123133.	92225.813	4637.191	84.197	6.867	12.043	1640.180	114.960	142.520	63.147	5.3	4.8
134212.	85759.625	2712.810	20.660	14.100	26.257	456.993	58.340	102.120	131.263	5.2	4.5
144212.	84848.875	2791.903	33.143	6.631	16.453	457.193	52.643	89.707	110.157	5.3	4.5
154212.	81068.063	2823.450	27.263	14.540	23.993	493.800	53.013	130.300	68.163	5.2	4.6
164212.	84245.250	2784.303	34.690	15.760	16.560	624.453	61.553	125.473	96.243	5.2	4.6
175223.	82081.500	3092.043	78.827	21.767	17.493	591.200	109.340	114.453	120.783	5.2	4.4
185223.	91142.563	3287.280	94.730	25.397	7.373	884.546	166.410	152.370	202.253	5.1	4.3
195223.	79537.000	2824.013	92.720	51.103	5.363	1369.556	185.437	188.840	136.283	5.2	4.5
205223.	57571.051	2129.590	72.190	20.937	2.770	1036.220	133.853	74.462	81.967	5.5	4.5
216234.	150910.813	7654.688	274.680	40.457	8.587	5318.988	769.466	262.013	150.983	5.2	4.5
226234.	130621.625	7298.227	219.433	46.457	8.153	4015.406	559.806	139.990	84.663	5.3	4.5
236234.	105332.000	5581.289	164.770	13.063	5.583	3691.688	480.940	242.017	97.970	5.2	4.5
246234.	159069.188	7512.980	295.866	38.563	6.647	6476.203	810.306	247.313	137.130	5.3	4.6

Table H-7. Forest floor plus mineral soil plot mean data

Code	TC	TN	minN	exCa	exMg	exK	exMn
				Kg / ha			
011111.	94152.328	2009.343	18.247	548.647	83.973	204.590	171.833
021111.	101373.887	2350.399	15.420	613.539	78.214	194.884	194.004
031111.	112575.469	2571.809	24.057	484.114	92.533	212.530	271.613
041111.	103946.316	2418.343	16.130	420.430	91.407	223.300	208.896
052122.	86942.489	2577.703	37.993	358.977	70.320	123.620	58.136
062122.	131581.445	3614.895	72.487	490.623	91.860	131.663	68.807
072122.	90685.965	2748.020	56.376	503.623	97.413	179.274	59.910
082122.	88302.113	2871.810	56.237	383.490	74.143	163.316	62.410
093133.	125498.180	5844.805	132.893	2337.926	184.270	221.803	156.083
103133.	118924.926	5462.225	148.397	2562.966	183.740	159.286	97.323
113133.	103351.852	4482.529	115.600	2508.066	172.917	164.843	91.474
123133.	101316.668	4952.487	97.724	1879.473	131.763	163.670	80.740
134212.	112977.480	3455.713	48.720	843.953	94.553	156.140	303.453
144212.	105935.340	3363.056	51.673	745.289	80.776	131.430	226.317
154212.	109881.368	3623.400	52.570	910.806	91.200	189.790	230.033
164212.	107256.637	3499.829	61.550	967.153	94.273	179.640	232.196
175223.	95120.504	3397.539	90.397	767.367	126.247	133.890	156.650
185223.	106834.004	3728.680	115.073	1116.013	187.110	176.087	240.076
195223.	97717.664	3443.426	119.917	1737.396	218.584	220.760	190.950
205223.	72977.449	2628.926	94.370	1364.437	162.303	98.115	117.837
216234.	154932.345	7775.308	282.083	5373.498	776.556	269.146	153.223
226234.	137600.574	7527.157	233.150	4106.243	572.453	153.793	88.270
236234.	108523.070	5674.072	168.857	3729.005	486.950	249.040	99.710
246234.	165811.965	7736.607	307.423	6564.476	822.783	261.956	141.007

Appendix I. Basic statistics for forest floor properties arranged by sampling scheme

		Individual samples --	Composite samples ----	
		Variability plot	Variability plot	All plots
Number of samples		15	3	12
pH (H2O)	GVD x	4.3	4.2	4.2
	SD	.24	.2	.17
	CV	5.61	4.76	3.96
	GD x	4.3	4.23	4.1
	SD	.25	.12	.33
	CV	6.49	2.73	12.60
	GF x	4.5	4.7	4.7
	SD	.36	.10	.13
	CV	7.91	2.13	2.72
	VVD x	4.1	4.1	4.0
	SD	.23	.15	.18
	CV	5.46	3.76	4.36
	VD x	4.3	4.2	4.2
	SD	.31	.26	.23
	CV	7.27	6.30	5.45
	VF x*	5.0	5.0	4.8
	SD	.13	.06	.16
	CV	2.51	1.16	3.33
TC (kg/ha)	GVD x	14552.80	14978.57	15481.77
	SD	859.39	614.90	2162.73
	CV	5.91	4.11	13.97
	GD x	13317.42	12907.07	13599.51
	SD	1147.14	1033.35	3517.73
	CV	8.61	8.01	25.87
	GF x	11926.56	10960.43	11061.38
	SD	1386.27	348.49	1847.24
	CV	11.62	3.12	16.70
	VVD x	23397.03	23011.39	25032.24
	SD	2058.98	3171.97	3845.16
	CV	8.80	13.78	15.36
	VD x	18066.41	18180.66	15579.37
	SD	1775.34	1176.10	2066.35
	CV	9.83	6.47	13.26

	VF	x	3181.01	3191.07	5233.57
		SD	121.42	82.72	1734.70
		CV	3.82	2.59	33.15
TN	GVD	x	351.76	345.87	348.16
(kg/ha)		SD	32.49	23.72	52.10
		CV	9.24	6.86	14.96
	GD	x	408.53	394.53	409.48
		SD	42.30	26.96	97.42
		CV	10.36	6.83	23.79
	GF	x	379.29	394.52	358.52
		SD	50.27	27.08	43.86
		CV	13.25	6.87	12.23
	VVD	x	689.33	715.53	707.38
		SD	81.39	32.54	94.54
		CV	11.81	4.55	13.36
	VD	x	607.96	619.41	466.41
		SD	57.83	121.91	135.61
		CV	9.51	19.68	29.08
	VF	x	94.29	92.78	166.49
		SD	13.36	3.36	63.87
		CV	14.17	3.63	38.36
minN	GVD	x	7.41	7.54	7.26
(kg/ha)		SD	1.66	.99	1.59
		CV	22.39	13.14	21.97
	GD	x	12.20	11.46	11.60
		SD	4.21	.91	2.16
		CV	34.49	7.92	18.63
	GF	x	12.29	16.61	15.29
		SD	5.58	3.11	2.58
		CV	45.43	18.71	16.88
	VVD	x	26.21	26.86	24.69
		SD	6.00	4.03	5.48
		CV	22.90	15.02	22.21
	VD	x	22.99	27.20	20.32
		SD	5.27	2.16	6.47
		CV	22.90	7.94	31.83
	VF	x**	4.64	4.09	9.19
		SD	.97	.41	4.01
		CV	20.79	4.40	43.58

TP (kg/ha)	GVD	x	47.47	43.20	43.85
		SD	10.47	1.85	6.43
		CV	22.05	4.29	14.67
	GD	x	47.63	44.70	46.92
		SD	4.60	.85	7.01
		CV	9.65	1.90	14.93
	GF	x	36.57	37.93	35.28
		SD	3.54	2.59	5.69
		CV	9.68	6.82	16.13
	VVD	x	106.74	99.74	99.69
		SD	18.20	16.61	10.01
		CV	17.05	16.66	10.04
	VD	x	89.02	90.64	68.84
		SD	14.68	.69	19.90
		CV	16.49	.76	28.91
	VF	x	10.39	10.16	16.80
		SD	1.08	.35	5.80
		CV	10.39	3.43	34.51
TS (kg/ha)	GVD	x	50.83	50.68	50.85
		SD	6.68	2.48	6.21
		CV	13.14	4.90	12.22
	GD	x	52.92	52.70	52.36
		SD	5.95	.99	10.98
		CV	11.25	1.86	20.98
	GF	x	48.98	49.13	46.87
		SD	5.88	1.39	4.76
		CV	11.99	2.82	10.16
	VVD	x	88.48	89.06	92.67
		SD	11.62	1.52	14.25
		CV	13.14	1.71	15.38
	VD	x	81.47	79.85	62.67
		SD	11.41	6.61	12.84
		CV	14.01	8.27	20.49
	VF	x**	13.03	9.97	18.10
		SD	.74	.70	6.22
		CV	5.71	6.99	34.37
exCa (kg/ha)	GVD	x	200.45	202.88	247.80
		SD	38.68	1.52	51.92
		CV	19.30	.75	20.95

	GD	x	195.80	216.00	221.73
		SD	40.53	17.70	53.29
		CV	20.70	8.20	24.04
	GF	x	226.23	293.91	270.48
		SD	52.09	40.51	29.44
		CV	23.02	13.78	10.88
	VVD	x	319.29	342.70	358.69
		SD	49.00	8.34	58.47
		CV	15.35	2.43	16.30
	VD	x	313.02	367.84	275.92
		SD	58.11	84.85	88.61
		CV	18.56	23.07	32.11
	VF	x**	40.54	37.32	67.73
		SD	7.46	7.08	24.08
		CV	18.39	18.96	35.55
exMg	GVD	x	23.79	22.71	23.79
(kg/ha)		SD	6.02	1.82	6.65
		CV	25.32	8.01	27.94
	GD	x	18.16	20.27	20.94
		SD	3.42	.59	5.50
		CV	18.85	2.91	26.27
	GF	x	21.13	25.11	22.17
		SD	3.91	1.62	4.01
		CV	18.53	6.44	18.07
	VVD	x	27.98	32.72	33.81
		SD	5.23	1.29	4.70
		CV	18.70	3.95	13.91
	VD	x	34.34	33.15	24.80
		SD	5.64	4.28	7.00
		CV	16.43	12.92	28.21
	VF	x**	6.37	6.01	9.65
		SD	1.11	.48	3.56
		CV	17.42	7.96	35.15
exK	GVD	x	39.13	37.19	39.94
(kg/ha)		SD	10.80	3.43	8.22
		CV	27.59	9.23	20.58
	GD	x	20.99	22.49	26.35
		SD	4.10	2.71	8.34
		CV	19.54	12.04	31.66

	GF	x	20.36	25.53	24.60
		SD	7.51	.51	5.56
		CV	36.91	1.98	22.59
	VVD	x	42.32	54.17	52.35
		SD	8.51	3.39	8.09
		CV	20.12	6.25	15.46
	VD	x	26.67	31.92	24.68
		SD	5.52	6.47	6.07
		CV	20.71	20.26	24.61
	VF	x**	8.09	7.02	10.65
		SD	2.45	.46	5.18
		CV	30.31	6.49	48.67
exMn	GVD	x	71.80	68.63	76.50
(kg/ha)		SD	18.55	5.82	13.09
		CV	25.84	8.48	17.11
	GD	x	23.68	25.38	28.14
		SD	4.55	1.06	8.86
		CV	19.19	4.18	31.49
	GF	x	25.26	21.63	20.66
		SD	9.81	6.30	6.70
		CV	38.81	29.11	32.42
	VVD	x	85.69	135.95	146.54
		SD	16.29	10.34	28.41
		CV	19.01	7.60	19.39
	VD	x	44.28	54.67	41.06
		SD	11.11	17.82	12.53
		CV	25.09	32.59	30.52
	VF	x**	2.17	1.74	2.87
		SD	.48	.70	1.04
		CV	22.25	39.93	36.39
TCa	GVD	x	217.93	193.46	227.26
(kg/ha)		SD	47.95	13.44	40.41
		CV	22.00	6.95	17.78
	GD	x	139.67	131.85	116.11
		SD	53.85	34.16	34.04
		CV	38.55	25.91	29.32
	GF	x	269.24	277.75	231.40
		SD	95.43	59.41	51.54
		CV	35.44	21.39	22.28

	VVD	x	268.54	271.90	276.44
		SD	79.32	21.50	54.65
		CV	29.54	7.91	19.77
	VD	x	157.65	145.45	128.27
		SD	44.99	3.93	22.87
		CV	28.54	2.70	17.83
	VF	x	73.19	69.59	119.62
		SD	11.11	6.51	46.98
		CV	15.17	9.35	39.27
TMg	GVD	x	45.21	48.11	45.58
(kg/ha)		SD	9.88	2.54	8.54
		CV	21.85	5.28	18.73
	GD	x	93.69	95.74	88.57
		SD	15.43	5.25	18.78
		CV	16.48	5.48	21.21
	GF	x	45.48	51.01	64.34
		SD	15.65	3.03	13.39
		CV	34.42	5.95	20.81
	VVD	x	107.80	98.72	101.15
		SD	42.60	13.15	20.69
		CV	39.51	13.32	20.45
	VD	x	398.11	383.92	273.96
		SD	125.57	89.12	99.53
		CV	31.54	23.21	36.33
	VF	x	16.05	16.79	27.30
		SD	4.07	2.36	9.84
		CV	25.32	14.03	36.06
TK	GVD	x	46.83	47.78	46.90
(kg/Ha)		SD	5.24	4.21	9.36
		CV	11.19	8.80	19.97
	GD	x	41.96	40.88	42.39
		SD	2.89	1.03	8.08
		CV	6.90	2.51	19.06
	GF	x	26.06	24.04	26.23
		SD	6.19	2.41	5.42
		CV	23.76	10.00	20.66
	VVD	x	80.86	83.49	82.12
		SD	10.87	6.84	9.34
		CV	13.44	8.19	11.37

	VD	x	63.75	59.87	47.68
		SD	6.76	5.21	9.85
		CV	10.60	8.71	20.67
	VF	x	14.00	13.43	19.00
		SD	4.54	3.40	6.84
		CV	32.40	25.30	36.00
TMn	GVD	x	4803.72	4790.98	4853.94
(kg/ha)		SD	1163.38	520.69	1130.25
		CV	24.22	10.87	23.29
	GD	x	1790.81	1786.63	3394.56
		SD	596.47	351.53	2855.94
		CV	33.31	19.68	84.13
	GF	x	1250.40	1327.86	1373.15
		SD	485.76	312.30	441.95
		CV	38.85	23.52	32.19
	VVD	x	11113.38	11564.36	10546.79
		SD	3113.18	2720.07	2142.71
		CV	28.01	23.52	20.32
	VD	x	4846.58	5392.65	3651.58
		SD	1448.55	1346.75	1393.26
		CV	29.89	24.97	38.16
	VF	x	127.23	128.98	225.27
		SD	28.72	14.54	82.12
		CV	22.57	11.27	36.45
CEC	GVD	x	41.93	41.31	42.13
(meq/		SD	5.19	1.30	1.98
100 g)		CV	12.38	3.15	4.69
	GD	x	38.05	36.47	37.82
		SD	6.78	3.80	2.64
		CV	17.82	10.42	6.97
	GF	x	44.29	52.68	47.52
		SD	9.81	4.83	6.18
		CV	22.15	9.16	13.01
	VVD	x	40.44	41.61	41.92
		SD	3.94	4.45	2.91
		CV	9.73	10.69	6.95
	VD	x	43.47	40.38	40.28
		SD	4.10	3.40	4.10
		CV	9.42	8.43	10.17
	VF	x**	39.49	43.41	44.30
		SD	5.09	.36	3.04
		CV	12.90	0.84	6.87

* n=14
** n=13

Appendix J. Basic statistics for mineral soil properties arranged by sampling scheme

		Individual samples --	Composite samples ----	
		Variability plot	Variability plot	All plots
Number of samples		15	3	12
pH (H2O)	GVD X	4.6	4.6	4.7
	SD	.16	.06	.12
	CV	3.51	1.25	2.64
	GD X	4.6	4.7	4.7
	SD	.19	.06	.14
	CV	4.12	1.24	3.00
	GF X	5.2	5.2	5.3
	SD	.15	.17	.14
	CV	2.82	3.33	2.55
	VVD X	5.2	5.2	5.2
	SD	.14	.10	.08
	CV	2.62	1.92	1.44
	VD X	5.3	5.2	5.3
	SD	.21	.10	.21
	CV	4.02	1.92	3.92
	VF X	5.2	5.20	5.2
	SD	.25	.10	.12
	CV	4.77	1.92	2.35
pHCa (CaCl2)	GVD X	4.0	4.0	4.0
	SD	.13	.06	.07
	CV	3.11	1.33	1.67
	GD X	4.2	4.1	4.2
	SD	.20	.06	.11
	CV	4.72	1.40	2.65
	GF X	4.7	4.7	4.7
	SD	.15	.17	.12
	CV	3.12	3.69	2.43
	VVD X	4.6	4.6	4.5
	SD	.16	.06	.08
	CV	3.40	1.26	1.74

	VD X	4.5	4.5	4.4
	SD	.14	.00	.10
	CV	3.15	0.00	2.33
	VF X	4.5	4.5	4.5
	SD	.19	.10	.11
	CV	4.33	2.22	2.34
TC	GVD X	95087.81	88967.75	87530.06
(kg/ha)	SD	33681.46	17185.55	15904.86
	CV	35.42	19.32	18.17
	GD X	107279.81	118675.38	85778.31
	SD	45233.40	22577.70	23051.89
	CV	42.16	19.03	26.87
	GF X	119742.94	114537.75	101211.38
	SD	35642.13	21077.11	15177.66
	CV	29.77	18.40	15.00
	VVD X	106999.50	84245.25	83980.25
	SD	41096.62	20841.26	10264.80
	CV	38.41	24.74	12.22
	VD X	81777.25	79537.00	77582.88
	SD	22360.25	6436.32	15419.01
	CV	27.34	8.09	19.87
	VF X	110785.00	105332.00	136483.31
	SD	24501.38	12551.70	34408.90
	CV	22.12	11.92	25.21
TN	GVD X	2150.40	2072.48	1989.31
(kg/ha)	SD	668.39	352.55	314.89
	CV	31.08	17.01	15.83
	GD X	3290.40	3220.36	2543.63
	SD	1123.29	569.17	544.08
	CV	34.14	17.67	21.39
	GF X	5191.54	5450.72	4826.98
	SD	1284.69	795.73	786.77
	CV	24.75	14.60	16.30
	VVD X	3876.39	2784.30	2778.12
	SD	1476.54	360.68	259.99
	CV	38.09	12.95	9.36
	VD X	2763.61	2824.01	2833.23
	SD	656.22	456.04	558.79
	CV	23.75	16.15	19.72

	VF	X	5453.74	5581.29	7011.79
		SD	1320.32	342.32	1355.48
		CV	24.21	6.13	19.33
minN (kg/ha)	GVD	X	11.68	8.58	11.21
		SD	7.89	4.30	5.58
		CV	67.51	50.02	49.83
	GD	X	53.04	61.03	44.18
		SD	22.99	7.33	16.10
		CV	43.35	12.01	36.44
	GF	X	115.92	116.28	108.36
		SD	39.12	22.70	23.11
		CV	33.74	19.52	21.32
	VVD	X	54.45	34.69	28.94
		SD	43.48	8.45	9.22
		CV	79.85	24.35	31.85
	VD	X	91.60	92.72	84.62
		SD	34.23	11.77	16.71
		CV	37.38	12.69	19.75
	VF	X	179.88	164.77	238.69
		SD	62.54	23.14	65.38
		CV	34.77	14.04	27.39
exP (kg/ha)	GVD	X	8.48	7.79	7.78
		SD	4.87	.72	2.21
		CV	57.39	9.21	28.34
	GD	X	5.08	5.45	4.08
		SD	1.34	.71	1.16
		CV	26.37	13.04	28.41
	GF	X	8.90	8.87	8.90
		SD	4.12	1.54	2.22
		CV	46.33	17.32	24.95
	VVD	X	21.84	15.76	12.76
		SD	13.63	3.76	5.48
		CV	62.39	23.88	42.93
	VD	X	50.62	51.10	29.80
		SD	17.20	7.88	13.64
		CV	33.99	15.42	45.77
	VF	X	14.51	13.06	34.63
		SD	6.07	3.37	17.02
		CV	41.83	25.80	49.13

SO4 (kg/ha)	GVD	X	18.67	17.07	15.17
		SD	5.21	3.34	2.98
		CV	27.88	19.18	19.68
	GD	X	17.24	15.49	14.79
		SD	7.12	.98	4.15
		CV	41.28	6.30	28.06
	GF	X	11.95	14.39	10.51
		SD	5.81	5.67	4.66
		CV	48.64	39.40	44.35
	VVD	X	25.89	16.56	20.82
		SD	12.70	5.74	6.46
		CV	49.04	34.67	31.02
	VD	X	6.49	5.36	8.25
		SD	3.38	4.71	6.55
		CV	52.02	87.79	79.43
	VF	X	4.89	5.58	7.24
		SD	2.03	2.68	3.33
		CV	41.58	47.98	45.99
exCa (kg/ha)	GVD	X	238.94	217.55	268.88
		SD	296.63	68.20	121.38
		CV	124.15	31.35	45.14
	GD	X	255.37	274.62	212.45
		SD	159.88	105.16	123.18
		CV	62.61	38.29	57.98
	GF	X	1794.01	2044.02	2051.63
		SD	698.93	368.11	453.93
		CV	38.96	18.01	22.13
	VVD	X	696.84	624.45	508.11
		SD	456.09	110.53	99.93
		CV	65.45	17.70	19.67
	VD	X	1328.22	1369.56	970.38
		SD	740.48	221.22	357.75
		CV	55.75	16.15	36.87
	VF	X	3424.14	3691.67	4875.56
		SD	1170.28	871.76	1335.22
		CV	34.18	23.61	27.39
exMg (kg/ha)	GVD	X	68.93	68.70	62.74
		SD	35.15	4.29	11.17
		CV	50.99	6.25	17.81
	GD	X	62.20	71.59	62.49
		SD	39.91	12.37	20.12
		CV	52.91	17.27	32.20

GF X	158.44	159.16	146.00
SD	60.88	34.01	33.59
CV	38.42	21.37	23.01
VVD X	66.72	61.55	56.39
SD	36.40	9.69	10.97
CV	54.55	15.75	19.45
VD X	188.34	185.44	148.76
SD	82.76	15.84	35.83
CV	43.94	8.54	24.09
VF X	481.05	480.94	655.13
SD	180.26	118.07	168.57
CV	37.47	24.55	25.73
exK GVD X	193.42	186.11	168.89
(kg/ha) SD	74.21	8.94	23.21
CV	38.37	4.80	13.74
GD X	132.41	109.17	123.12
SD	56.73	30.09	40.05
CV	42.85	27.56	32.53
GF X	147.21	196.27	152.80
SD	61.61	46.58	44.64
CV	41.85	23.73	29.21
VVD X	157.82	125.47	111.90
SD	66.96	8.62	23.69
CV	42.43	6.87	21.17
VD X	170.07	188.84	132.53
SD	80.25	25.16	47.38
CV	47.19	13.32	35.75
VF X	208.47	242.02	222.83
SD	140.96	93.56	74.12
CV	67.62	38.67	33.26
exMn GVD X	137.87	140.26	135.08
(kg/ha) SD	134.51	45.91	53.76
CV	97.57	32.73	39.80
GD X	37.57	43.43	34.18
SD	19.41	23.44	17.20
CV	51.67	53.98	50.34
GF X	112.28	134.45	85.74
SD	55.92	39.43	37.71
CV	49.81	29.33	43.98

	VVD X	96.62	96.24	101.46
	SD	76.85	25.42	37.74
	CV	79.54	26.41	37.20
	VD X	132.93	136.28	135.32
	SD	81.67	5.12	48.23
	CV	61.43	3.76	35.64
	VF X	99.90	97.97	117.69
	SD	28.84	13.36	36.95
	CV	28.87	13.64	31.40
CEC	GVD X	3.07	2.94	3.08
(meq/	SD	1.29	.39	.41
100 g)	CV	42.14	13.34	13.38
	GD X	2.63	2.94	2.55
	SD	1.02	.99	.76
	CV	38.91	33.67	29.70
	GF X	3.42	3.22	3.68
	SD	.94	.73	.84
	CV	27.42	22.81	22.82
	VVD X	2.64	2.35	2.35
	SD	1.19	.43	.36
	CV	45.22	18.38	15.17
	VD X	4.03	4.05	4.04
	SD	1.40	.51	1.06
	CV	34.65	12.62	26.33
	VF X	7.22	7.19	8.30
	SD	2.06	.87	1.15
	CV	28.58	12.05	13.87

APPENDIX K

EIGENVALUES, EIGENVECTORS AND CORRELATION MATRICES FROM PCA OF SOIL PROPERTIES

INDEX

K - 1 Eigenvalues and eigenvectors from PCA of forest floor properties and correlation matrix

TEST	STATISTIC	DF	SIGNIF	N= 24 OUT OF 24
INDEPENDENCE	467.48	45	0.	
EQUICORRELATION	493.30	44	0.	

	(1)	(2)	(3)
COMPONENT	8.3907	.76410	.41262
% VARIANCE	83.91	91.55	95.67
INDEPENDENCE	208.12	152.24	106.18
DF	44	35	27
SIGNIF	0.	.0000	.0000
2.TC	.34028	-.14732	.84783 -2
3.TN	.33893	.14039	-.10831
4.MINN	.26236	.71190	-.10148
5.TP	.33145	.14437	-.17216
6.TS	.34239	.49419 -1	-.91580 -1
7.EXCA	.31847	.14925	.12587
8.EXMG	.33080	.42580 -1	.11652
9.EXK	.31256	-.32954	.42937
10.EXMN	.30546	-.26249	.43322
11.PHH2O	-.26752	.47636	.73377

CORRELATION MATRIX CASES=CASE#:1-24

N= 24 DF= 22 R@ .0500= .4044 R@ .0100= .5151

VARIABLE	2. TC	3. TN	4. MINN	5. TP	6. TS	7. EXCA	8. EXMG	9. EXK	10. EXMN	11. PHH2O	12. AX1
2.TC	1.0000										
3.TN	.9529	1.0000									
4.MINN	.6741	.8260	1.0000								
5.TP	.9324	.9600	.8312	1.0000							
6.TS	.9739	.9864	.7783	.9595	1.0000						
7.EXCA	.8752	.9038	.7282	.8411	.9209	1.0000					
8.EXMG	.9308	.9394	.7100	.8792	.9441	.9628	1.0000				
9.EXK	.9244	.8377	.4964	.7934	.8636	.8218	.8827	1.0000			
10.EXMN	.9159	.8183	.5500	.8378	.8504	.7251	.7902	.9258	1.0000		
11.PHH2O	-.8122	-.7392	-.3653	-.7394	-.7749	-.6263	-.6912	-.6959	-.6494	1.0000	
12.AX1	.9857	.9818	.7600	.9601	.9918	.9225	.9582	.9054	.8848	-.7749	1.0000

K - 2 Eigenvalues and eigenvectors from PCA of mineral soil properties and correlation matrix

TEST	STATISTIC	DF	SIGNIF	N= 24 OUT OF 24
INDEPENDENCE	354.50	55	0.	
EQUICORRELATION	245.73	54	0.	

	(1)	(2)	(3)
COMPONENT	6.3572	1.7575	1.1491
% VARIANCE	57.79	73.77	84.22
INDEPENDENCE	237.88	194.62	156.63
DF	54	44	35
SIGNIF	0.	0.	.0000
2.TC	.28021	.39082	.30526
3.TN	.36389	.44599 -1	.31032
4.MINN	.35633	-.14421	.24388
5.EXP	.29842	.33054 -1	-.46833
6.SO4	-.22610	.19233	.14353
7.EXCA	.38958	-.41120 -1	-.15957 -2
8.EXMG	.37368	.12859	.60978 -1
9.EXK	.20708	.54084	.89375 -1
10.EXMN	.16758	.33415	-.66994
11.PHH2O	.29273	-.42400	-.21193
12.PHCA	.27176	-.42922	.75346 -1

CORRELATION MATRIX CASES=CASE#:1-24

N= 24 DF= 22 R@ .0500= .4044 R@ .0100= .5151

VARIABLE	2. TC	3. TN	4. MINN	5. EXP	6. SO4	7. EXCA	8. EXMG	9. EXK	10. EXMN	11. PHH2O	12. PHCA	13. AX1
2.TC	1.0000											
3.TN	.8351	1.0000										
4.MINN	.5975	.8861	1.0000									
5.EXP	.4115	.5312	.5764	1.0000								
6.SO4	-.0787	-.3445	-.6009	-.4684	1.0000							
7.EXCA	.6600	.8932	.8518	.6882	-.5780	1.0000						
8.EXMG	.7279	.8665	.8626	.7149	-.6346	.9064	1.0000					
9.EXK	.6466	.4979	.3283	.3036	-.1623	.5058	.6143	1.0000				
10.EXMN	.3479	.2182	.0835	.6088	-.0924	.4052	.3603	.4447	1.0000			
11.PHH2O	.1958	.5930	.6601	.5891	-.4264	.7798	.5308	-.0263	.2924	1.0000		
12.PHCA	.2397	.6560	.6691	.3908	-.2712	.7282	.4501	.0341	.0678	.8995	1.0000	
13.AX1	.7065	.9175	.8984	.7524	-.5701	.9823	.9422	.5221	.4225	.7381	.6852	1.0000
14.AX2	.5181	.0591	-.1912	.0438	.2550	-.0545	.1705	.7170	.4430	-.5621	-.5690	.0000
14.AX3	.3272	.3327	.2614	-.5020	.1539	-.0017	.0654	.0958	-.7182	-.2272	.0808	-.0000

K - 3 Eigenvalues and eigenvectors from PCA of forest floor plus mineral soil properties and correlation matrix

TEST	STATISTIC	DF	SIGNIF	N= 24 OUT OF 24
INDEPENDENCE	164.36	21	0.	
EQUICORRELATION	118.82	20	.0000	

	(1)	(2)	(3)
COMPONENT	4.3623	1.4481	.56968
% VARIANCE	62.32	83.01	91.14
INDEPENDENCE	92.553	54.594	37.619
DF	20	14	9
SIGNIF	.0000	.0000	.0000
2.TC	.37576	-.27396	-.12589
3.TN	.46099	.10641	.63425 -1
4.MINN	.42414	.30033	.22923
5.EXCA	.45297	.50892 -1	.19752
6.EXMG	.45304	.28215 -1	.11340 -1
7.EXK	.23422	-.56701	-.64429
8.EXMN	-.33242 -1	-.70607	.68799

CORRELATION MATRIX CASES=CASE#:1-24

N= 24 DF= 22 R@ .0500= .4044 R@ .0100= .5151

VARIABLE	2. TC	3. TN	4. MINN	5. EXCA	6. EXMG	7. EXK	8. EXMN	9. AX1	10. AX2
2.TC	1.0000								
3.TN	.7671	1.0000							
4.MINN	.5202	.8972	1.0000						
5.EXCA	.6089	.9052	.8677	1.0000					
6.EXMG	.6466	.8539	.8469	.9205	1.0000				
7.EXK	.5354	.3381	.1340	.3872	.4601	1.0000			
8.EXMN	.1506	-.1556	-.2685	-.0372	-.0830	.3064	1.0000		
9.AX1	.7848	.9628	.8859	.9461	.9462	.4892	-.0694	1.0000	
10.AX2	-.3297	.1281	.3614	.0612	.0340	-.6823	-.8497	-.0000	1.0000

APPENDIX L

CORRELATIONS BETWEEN ORIGINAL SOIL PROPERTIES AND CANONICAL VARIATES FOR VEGETATION AND SOIL PROPERTIES

INDEX

Table L-1. Correlations between original forest floor properties, vegetation DCA axes (VegDCA), forest floor PCA axis (FflPCA), and canonical variates (VegCan, FflCan)

Forest floor property	PCA axes and canonical variates					
	Veg DCA1	Veg DCA2	Veg DCA3	Ffl PCA1	Veg Can1	Ffl Can1
TC	.600**	-.302	-.057	.986**	.666**	.986**
TN	.408*	-.247	-.065	.982**	.473*	.982**
minN	-.044	-.358	-.234	.760**	.144	.760**
TP	.428*	-.350	-.112	.960**	.542**	.960**
TS	.504*	-.253	-.081	.992**	.562**	.992**
exCa	.514*	-.195	-.174	.922**	.555**	.922**
exMg	.527**	-.242	-.107	.958**	.580**	.958**
exK	.706**	-.348	-.078	.905**	.782**	.905**
exMn	.621**	-.529**	-.150	.885**	.794**	.885**
pH(H_2O)	-.669**	-.094	-.210	-.775**	-.523**	-.775**

* Significant at the .05 level.

** Significant at the .01 level.

Table L-2. Correlations between original mineral soil properties, mineral soil PCA axes (MinPCA), vegetation DCA axes (VegDCA), and canonical variates (MinCan, VegCan)

	PCA axes and canonical variates									
Mineral soil property	Min PCA1	Min PCA2	Min PCA3	Veg DCA1	Veg DCA2	Veg DCA3	Min Can1	Min Can2	Veg Can1	Veg Can2
TC	.707**	.518**	.327	-.554**	-.125	.142	-.597**	.200	-.557**	.036
TN	.918**	.059	.333	-.892**	-.126	-.103	-.915**	.166	-.902**	.036
minN	.898**	-.192	.261	-.960**	.052	-.030	-.949**	.098	-.934**	.226
exP	.752**	.044	-.502*	-.558**	-.408*	-.125	-.619**	-.627**	-.624**	-.283
SO_4	-.570**	.255	.154	.580**	-.097	.045	.581**	.253	.555**	-.187
exCa	.982**	-.055	-.002	-.847**	-.333	-.225	-.948**	-.175	-.900**	-.187
exMg	.942**	.170	.065	-.853**	-.125	-.016	-.865**	-.101	-.859**	.052
exK	.522**	.717**	.096	-.303	-.129	.157	-.331	.006	-.311	-.012
exMn	.423*	.443*	.718**	.024	-.687**	-.257	-.166	-.779**	-.155	-.668**
pH(H_2O)	.738**	-.562**	.227	-.669**	-.488*	-.399	-.806**	-.356	-.761**	-.404
pH($CaCl_2$)	.685**	-.569**	.081	-.714**	-.348	-.343	.811**	-.044	-.779*	-.257

* Significant at the .05 level.

** Significant at the .01 level.

Table L-3. Correlations between original forest floor plus mineral soil properties, forest floor plus mineral soil PCA axes (FminPCA), vegetation DCA axes (VegDCA), and canonical variates (FminCan, VegCan)

Forest floor plus mineral soil property	PCA axes and canonical variates						
	Fmin PCA1	Fmin PCA2	Veg DCA1	Veg DCA2	Veg DCA3	Fmin Can1	Veg Can1
TC	.683**	.516**	-.461*	-.243	.159	-.534**	-.480*
TN	.963**	.019	-.896**	-.164	-.113	-.928**	-.909**
minN	.913**	-.242	-.962**	-.032	-.058	-.945**	-.941**
exCa	.978**	.001	-.864**	.313	-.188	-.947**	-.917**
exMg	.911**	.176	-.848**	-.166	-.008	-.839**	-.854**
exK	.386	.817**	-.131	-.272	.149	-.171	-.168
exMn	-.091	.428*	.372	-.766**	-.213	.195	.179

* Significant at the .05 level.

** Significant at the .01 level.

APPENDIX M

CORRELATIONS BETWEEN ORIGINAL SOIL PROPERTIES, FOLIAR NUTRIENTS AND CANONICAL VARIATES FOR FOLIAR AND SOIL PROPERTIES

INDEX

Table M-1. Correlations between original forest floor properties, forest floor PCA axis (FflPCA), foliar nutrient concentration PCA axes (FolPCA), and canonical variates (FolCan, FflCan)

Forest floor property	PCA axes and canonical variates					
	Fol PCA1	Fol PCA2	Fol PCA3	Ffl PCA1	Fol Can1	Ffl Can1
TC	.768**	.128	-.085	.986**	.781**	.986**
TN	.600**	.264	-.090	.982**	.650**	.982**
minN	.224	.455*	-.323	.760**	.364	.760**
TP	.678**	.359	-.147	.960**	.756**	.960**
TS	.667**	.190	-.080	.992**	.697**	.992**
exCa	.512*	-.058	-.096	.922**	.493*	.922**
exMg	.602**	.013	-.112	.958**	.599**	.958**
exK	.808**	-.084	-.113	.905**	.776**	.905**
exMn	.853**	.091	-.237	.885**	.876**	.885**
pH(H_2O)	-.728**	-.206	-.380	-.775**	-.695**	-.775**

* Significant at the .05 level.

** Significant at the .01 level.

Table M-2. Correlations between original mineral soil properties, mineral soil PCA axes (MinPCA), foliar nutrient concentration PCA axes (FolPCA), and canonical variates (MinCan, FolCan)

Mineral soil properties	PCA axes and canonical variates									
	Min PCA1	Min PCA2	Min PCA3	Fol PCA1	Fol PCA2	Fol PCA3	Min Can1	Min Can2	Fol Can1	Fol Can2
TC	.707**	.518**	.327	-.481*	-.007	-.270	-.523**	.279	-.501*	.073
TN	.918**	.059	.333	-.748**	.215	-.390	-.878**	.226	-.856**	.090
minN	.898**	-.191	.261	-.832**	.420*	-.214	-.936**	.139	-.921**	.234
exP	.752**	.044	-.502*	-.204	.484*	-.543**	-.616**	-.582**	-.614**	-.405*
SO_4	-.570**	.255	.154	.557**	-.204	.217	.596**	.238	.621**	-.116
exCa	.982**	-.055	-.002	-.672**	.210	-.567**	-.932**	-.121	-.895**	-.115
exMg	.942**	.170	.065	-.669**	.255	-.369	-.826**	-.034	-.825**	.070
exK	.522**	.717**	.096	-.302	-.199	-.141	-.253	.086	-.223	.109
exMn	.423*	.443*	-.718**	.191	-.086	-.652**	-.143	-.729**	-.129	-.604**
pH(H_2O)	.738**	-.562**	-.227	-.402	.402	-.685**	-.848**	-.353	-.791**	-.362
pH($CaCl_2$)	.685**	-.569**	.081	-.515**	.326	-.545**	-.843**	-.042	-.794**	-.191

* Significant at the .05 level.

** Significant at the .01 level.

Table M-3. Correlations between original forest floor plus mineral soil properties, forest floor plus mineral soil PCA axes (FminPCA), foliar nutrient content PCA axes (FolPCA), and canonical variates (FolCan, FminCan)

Forest floor plus mineral soil property	PCA axes and canonical variates						
	Fmin PCA1	Fmin PCA2	Fol PCA1	Fol PCA2	Fol PCA3	Fmin Can1	Fol Can1
TC	.683**	.516**	-.311	.060	-.343	-.483*	-.437*
TN	.963**	.019	-.715**	.269	-.425*	-.907**	-.872**
minN	.913**	-.242	-.781**	.481*	-.284	-.943**	-.932**
exCa	.978**	.001	-.683**	.225	-.592**	-.926**	-.913**
exMg	.911**	.176	-.658**	.297	-.401	-.808**	-.825**
exK	.386	.817**	-.075	-.202	-.208	-.105	-.088
exMn	-.091	.428*	.655**	-.009	-.574**	.223	.235

* Significant at the .05 level.

** Significant at the .01 level.

Table M-4. Correlations between foliar nutrient concentrations, foliar nutrient concentration PCA axes (FolPCA), forest floor PCA axis (FflPCA) and canonical variates (FolCan, FflCan)

Foliar nutrient	PCA axes and canonical variates					
	Fol PCA1	Fol PCA2	Fol PCA3	Ffl PCA1	Fol Can1	Ffl Can2
N	-.806**	.463*	-.076	-.443*	-.683**	-.443*
P	.870**	.265	.027	.486*	.895**	.486*
Ca	.483*	.278	.572**	.592**	.449*	.592**
Mg	.155	.360	.699**	.464*	.328	.464*
K	-.262	.800**	.167	-.142	-.095	-.142
AFE	-.062	.818**	.411*	.120	.068	.120
Fe	-.401	.724**	.048	-.240	-.230	-.240
B	.814**	.305	-.381	.643**	.907**	.643**
Al	.637**	-.256	.700**	.291	.459*	.291
Zn	.599**	.724**	.056	.535**	.734**	.535**
Mn	.951**	-.006	-.234	.714**	.948**	.714**
Cu	-.483*	.682**	-.177	-.298	-.287	-.298
S	.544**	.586**	-.136	.449*	.676**	.449*

* Significant at the .05 level.

** Significant at the .01 level.

Table M-5. Correlations between original foliar nutrient concentrations, foliar nutrient concentration PCA axes (FolPCA), mineral soil PCA axes (MinPCA), and canonical variates (FolCan, MinCan)

Foliar nutrient	PCA axes and canonical variates									
	Fol PCA1	Fol PCA2	Fol PCA3	Min PCA1	Min PCA2	Min PCA3	Fol Can1	Fol Can2	Min Can1	Min Can2
N	-.806**	.463*	.076	.615**	-.382	.565	-.779**	.436*	-.779*	.460*
P	.870**	.265	.027	-.437*	.221	-.495	.585**	-.546**	.549**	-.423*
Ca	.483*	.278	.572	-.599**	-.175	.174	.538**	.105	.473*	.230
Mg	.155	.360	-.699**	.325	-.416*	-.254	-.359	-.712**	-.411*	-.321
K	-.262	.800**	.167	.398	-.224	.228	-.447*	.118	-.477*	.163
AFe	-.062	.818**	.411*	.021	-.407	.093	-.181	.187	-.171	.060
Fe	-.401	.723**	.048	.505*	-.230	-.108	-.581**	.123	-.533**	-.183
B	.814**	.305	-.381	-.204	.057	-.776**	.329	-.840**	.315	-.740**
Al	.637**	-.256	.700**	-.871**	.318	.079	.935**	.226	.908**	.204
Zn	.599**	.724**	.056	-.275	-.193	-.318	.202	-.460*	.233	-.297
Mn	.951**	-.006	-.234	-.541**	.134	-.586**	.632**	.741**	.628**	-.507*
Cu	-.483*	.682**	-.177	.632**	-.229	.147	-.736**	.004	-.686**	.055
S	.544**	.586**	-.136	-.154	-.139	-.378	.123	-.548**	.147	-.366

* Significant at the .05 level.

** Significant at the .01 level.

Table M-6. Correlations between original foliar nutrient concentrations, forest floor plus mineral soil PCA axes (FminPCA), foliar nutrient concentration PCA axes (FolPCA), and canonical variates (FminCan, FolCan)

	PCA axes and canonical variates						
Foliar nutrient	Fmin PCA1	Fmin PCA2	Fol PCA1	Fol PCA2	Fol PCA3	Fmin Can1	Fol Can1
N	.681**	-.414*	-.806**	.463*	.076	-.777**	-.767**
P	-.499*	.277	.870**	.265	.027	.561**	.602**
Ca	-.556**	-.161	.483*	.278	.572**	.476*	.562**
Mg	.373	-.246	.155	.360	-.699**	-.432*	-.356
K	.412	-.210	-.262	.800**	.167	-.457*	-.416*
AFe	-.012	-.473*	-.062	.818**	.411*	-.139	-.144
Fe	.414*	-.291	-.401	.723**	.048	-.485*	-.557**
B	-.294	.173	.814**	.305	-.381	.334	.341
Al	-.868**	.274	.637**	-.256	.700**	.910**	.942**
Zn	-.315	-.118	.599**	.724**	.056	.261	.235
Mn	-.572**	.242	.951**	-.006	-.234	.619**	.636**
Cu	.616**	-.241	-.483*	.682**	-.177	-.661**	-.717**
S	-.222	-.043	.544**	.586**	-.136	.197	.147

* Significant at the .05 level.

** Significant at the .01 level.

Table M-7. Correlations between original forest floor properties, forest floor PCA axis (FflPCA), foliar nutrient milligrams per 100 needles PCA axes (FolmgPCA), and canonical variates (FolmgCan, FflCan)

Forest floor property	PCA axes and canonical variates					
	Ffl PCA1	Folmg PCA1	Folmg PCA2	Fflmg PCA3	Folmg Can1	Ffl Can1
TC	.986**	.380	.555**	.242	.714**	.986**
TN	.982**	.375	.346	.258	.562**	.982**
minN	.760**	.003	.087	.268	.162	.760**
TP	.960**	.275	.436*	.406*	.625**	.960**
TS	.992**	.400	.424*	.238	.626**	.992**
exCa	.922**	.368	.355	-.027	.463*	.922**
exMg	.958**	.346	.436*	.064	.542**	.958**
exK	.905**	.423*	.668**	.046	.752**	.905**
exMn	.885**	.289	.728**	.193	.772**	.885**
pH(H_2O)	-.775**	-.536**	-.363	-.517**	-.759**	-.775**

* Significant at the .05 level.

** Significant at the .01 level.

Table M-8. Correlations between original mineral soil properties, mineral soil PCA axes (MinPCA), foliar nutrient milligrams per 100 needles PCA axes (FolmgPCA), and canonical variates (FolmgCan, MinCan)

Mineral soil property	PCA axes and canonical variates									
	Min PCA1	Min PCA2	Min PCA3	Folmg PCA1	Folmg PCA2	Folmg PCA3	Folmg Can1	Folmg Can2	Min Can1	Min Can2
TC	.707**	.518**	.327	-.397	-.248	-.275	-.445*	-.234	-.578**	-.298
TN	.918**	.059	.333	-.571**	-.514*	-.245	-.742**	-.297	-.870**	-.358
minN	.898**	-.191	.261	-.596*	-.712**	.002	-.867**	-.277	-.885**	-.359
exP	.752**	.044	-.502*	-.713**	.011	.299	-.202	-.697**	-.253	-.869**
SO_4	-.570**	.255	.154	.526*	.393	-.028	.550*	.337	.409*	.445*
exCa	.982**	-.055	-.002	-.738**	-.349	-.227	-.659**	-.515*	-.752**	-.631**
exMg	.942**	.170	.065	-.748**	-.410*	-.044	-.672**	-.524**	-.698**	-.591**
exK	.522**	.717**	.096	-.351	-.039	-.252	-.237	-.274	-.245	-.381
exMn	.423*	.443*	-.718**	-.558**	.534**	-.064	.233	-.705**	.237	-.879**
pH(H_2O)	.738**	-.562*	-.227	-.597**	-.219	-.040	-.442*	-.459*	-.579**	-.560**
pH($CaCl_2$)	.685**	-.569*	.081	-.418*	-.390	-.202	-.561**	-.209	-.724**	-.295

* Significant at the .05 level.

** Significant at the .01 level.

Table M-9. Correlations between forest floor plus mineral soil properties, forest floor plus mineral soil PCA axes (FminPCA), foliar nutrient milligrams per 100 needles PCA axes (FolmgPCA), and canonical variates (FminCan, FolmgCan)

Forest floor plus mineral soil property	PCA axes and canonical variates						
	Fmin PCA1	Fmin PCA2	Folmg PCA1	Folmg PCA2	Folmg PCA3	Fmin Can1	Folmg Can1
TC	.683**	.516**	-.373	.059	-.215	.538**	.384
TN	.963**	.019	-.633**	.416*	-.223	.930**	.787**
minN	.913**	-.242	-.674**	.588**	.040	.945**	.857**
exCa	.978**	.001	-.783**	.262	-.200	.948**	.827**
exMg	.911**	.176	-.788**	.277	.042	.842**	.790**
exK	.386	.817**	-.258	-.204	-.188	.177	.146
exMn	-.091	.428*	-.096	-.834**	.114	-.192	-.376

* Significant at the .05 level.

** Significant at the .01 level.

Table M-10. Correlations between foliar nutrient milligrams per 100 needles, foliar nutrient milligrams per 100 needles PCA axes (FolmgPCA), forest floor PCA axis (FflPCA), and canonical variates (FolmgCan, FflCan)

	PCA axes and canonical variates					
Foliar nutrient	Folmg PCA1	Folmg PCA2	Folmg PCA3	Ffl PCA1	Folmg Can1	Ffl Can1
N	.487**	-.782**	-.307	-.237	-.411*	-.237
P	.875**	.384	.003	.383	.783**	.383
Ca	.945**	-.136	-.131	.319	.391	.319
Mg	.395	.104	-.450*	.486*	.141	.486*
K	.589**	-.605**	.174	-.042	-.050	-.042
AFe	.459*	-.521**	.604**	.166	.092	.166
Fe	-.204	-.672**	.584**	-.216	-.404	-.216
B	.250	.824**	.308	.687**	.863**	.687**
Al	.814**	.241	.094	.219	.676**	.219
Zn	.585**	.213	.697**	.547**	.740**	.547**
Mn	.332	.900**	.184	.675**	.921**	.675**
Cu	.242	-.681**	.077	-.211	-.338	-.211
S	.902**	.057	-.077	.340	.529**	.340

* Significant at the .05 level.

** Significant at the .01 level.

Table M-11. Correlations between foliar nutrient milligrams per 100 needles, foliar nutrient milligrams per 100 needles PCA axes (FolmgPCA), mineral soil PCA axes (MinPCA), and canonical variates (FolmgCan, MinCan)

Foliar nutrient	PCA axes and canonical variates									
	Folmg PCA1	Folmg PCA2	Folmg PCA3	Min PCA1	Min PCA2	Min PCA3	Folmg Can1	Folmg Can2	Min Can1	Min Can2
N	.487*	-.782**	-.307	-.006	-.294	.778**	-.570**	.782**	-.543**	.628**
P	.875**	.384	.003	-.817**	.236	.045	.689**	.656**	.654**	.527**
Ca	.945**	-.136	-.130	-.696**	-.039	.443*	.226	.934**	.247	.788**
Mg	.395	.104	-.450*	-.099	-.358	.093	.140	.381	-.082	.190
K	.589**	-.605**	.174	-.138	-.199	.619**	-.256	.746**	-.322	.582**
Afe	.459*	-.521**	.604**	-.301	-.398	.376	-.129	.539**	-.111	.538**
Fe	-.204	-.672**	.584**	.349	-.302	.088	-.532**	-.008	-.401	-.114
B	.250	.824**	.308	-.422*	.132	-.686**	.903**	-.123	.763**	-.257
Al	.814**	.241	.094	-.859**	.313	.188	.562**	.642**	.622**	.648**
Zn	.585**	.213	.697**	-.527**	-.147	-.126	.592**	.365	.429*	.272
Mn	.332	.900**	.184	-.602**	.198	-.539**	.972**	-.061	.830**	-.041
Cu	.242	-.681**	.077	.214	-.244	.477*	-.468*	.467*	-.514	.254
S	.902**	.057	-.077	-.665**	-.013	.216	.393	.815**	.367	.595**

* Significant at the .05 level.
** Significant at the .01 level.

Table M-12. Correlations between foliar nutrient milligrams per 100 needles, foliar nutrient milligrams per 100 needles PCA axes (FolmgPCA), forest floor plus mineral soil PCA axes (FminPCA), and canonical variates (FminCan, FolmgCan)

	PCA axes and canonical variates						
Foliar nutrient	Fmin PCA1	Fmin PCA2	Folmg PCA1	Folmg PCA2	Folmg PCA3	Fmin Can1	Folmg Can1
N	.112	-.362	.341	.821**	-.391	.196	.221
P	-.791**	.218	.904**	-.272	-.057	-.820**	-.881**
Ca	-.613**	-.082	.894**	.247	-.235	-.575**	-.568**
Mg	.011	-.239	.371	-.067	-.584**	.069	-.226
K	-.051	-.239	.531**	.687**	.049	.009	-.095
AFe	-.282	-.491*	.456*	.606**	.515*	-.155	-.169
Fe	.288	-.390	-.230	.665**	.592**	.374	.416*
B	-.490*	.237	.395	-.768**	.274	-.533**	-.781**
Al	-.841**	.252	.832**	-.136	.062	-.877**	-.775**
Zn	-.537**	-.102	.693**	-.098	.591**	-.497*	-.746**
Mn	-.628**	.295	.470*	-.839**	.155	-.680**	-.857**
Cu	.260	-.299	.160	.712**	.002	.324	.235
S	-.626**	-.014	.885**	.053	-.176	-.604**	-.672**

* Significant at the .05 level.

** Significant at the .01 level.