United States
Department of
Agriculture

Forest Service

**Intermountain
Research Station**

Research Paper
INT-390

April 1988

# Soil Characteristics as an Aid to Identifying Forest Habitat Types in Northern Idaho



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## RESEARCH SUMMARY

Scientists have long hypothesized that soils and plant communities have predictable relationships. High correlation between soil properties and shrub-steppe plant associations has been repeatedly documented, but studies in forested vegetation have produced conflicting results. The objectives of this study were to investigate: spatial patterns of numerically derived taxonomic soil units; relationships between soil taxonomic units and plant associations; and identifying soil characteristics for aid in forest habitat type identification.

Vegetation, soil, and site information were collected on 89 sites within six similar habitat types of the *Abies grandis, Thuja plicata*, and *Tsuga heterophylla* series. Univariate and multivariate statistical analyses were used to evaluate naturally occurring patterns within the soil data and between soil and vegetation data. Four ordination techniques were used to explore potential soil pattern delineation. Factor analysis and descriptive discriminant analysis techniques were employed to identify physical soil property descriptors for use in habitat type discriminant function formulas.

Numerical patterns were not discernible among the physical soil characteristics. Analysis of relationships between forest habitat types and soil taxonomic units—Order, Suborder, Great Group, and Family—proved fruitless. Four soil characteristics were identified as useful for classifying habitat type when used in conjunction with site and vegetation data. Formulas developed from discriminant functions are given for use in the field as an aid to forest habitat type classification in northern Idaho.

The use of habitat types for refinement of silvicultural prescriptions and site productivity assessment in northern Idaho has proven to be highly valuable to forest resource managers. This study indicates that further delineation of these units, based on soil variation, will allow for greater accuracy in predicting site capabilities and response to disturbance.

# Soil Characteristics as an Aid to Identifying Forest Habitat Types in Northern Idaho

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## INTRODUCTION

Habitat types (after Daubenmire 1968) and other vegetation-based land classification systems (Cooper and others 1987; Daubenmire and Daubenmire 1968; Hall 1973; Hironaka and others 1983; Mueggler and Stewart 1980; Pfister and others 1977; Steele and others 1981, 1983; Tisdale 1979) have been adopted for use throughout the Northern Rocky Mountains by the U.S. Department of Agriculture, Forest Service, and other Federal and State agencies. These systems rely on knowledge of the existing floristics for identification of "climax" or long-term stable plant associations. On forested lands that have not been severely disturbed, habitat types can be identified with relative ease by use of species presence lists. But as land is disrupted by forest management, habitat types will have to be identified from a secondary successional plant community, often having little floristic similarity to its climax community. Even highly trained plant ecologists find this to be a speculative and frustrating task. Land managers and scientists need to classify seral communities and also to develop a means for extrapolating seral community types to their respective habitat types with the aid of both biotic and abiotic factors.

In studies of abiotic site factors, Jenny (1941, 1980) theorized that soil development is a function of climate, parent material, relief, and potential organisms interacting over time. Major (1951) felt that species composition of vegetation is a similar function of the same five factors. Although soil and vegetation both appear to respond to the same "functional factors," this relationship cannot be extended to indicate that soil and vegetation are correlated on a one-to-one basis. Although we find sites with similar vegetational composition, often these do not have similar site characteristics, parent material, or age (Barnes and others 1982; Daubenmire 1968; McCune and Allen 1985; Pfister and Arno 1980). Vegetation responds to both long-term and short-term environmental changes (Daubenmire 1956), but is particularly responsive to extremes of temperature and moisture. Climatic pulses tend to have a minor effect on soil formation processes. Thus, different soils often develop beneath similar plant communities and, conversely, different plant communities occur on what outwardly appear to be similar soils.

In most physical systems, both internal and external sets of independent factors determine the development of individual characteristics. Nowhere is this more observable than in the wide variety of soil horizonations. Whether viewed regionally or locally no two cross sections of soil are exactly alike. Yet, in an attempt to understand this variability, taxonomic systems are devised that identify individuals as members of classification units. Soil taxonomy (USDA SCS 1975), a soil classification system, is based on differentiating characteristics assumed to be the result of independent factors.

Jenny (1941, 1980) described five elements critical to all soil development: climate, in the sense of regional macroclimate; parent material, the basement rock or depositional material from which the soil originates; relief (topography), the slope, aspect, elevation, landform, and related ground water conditions; organisms, the micro- and macro-organisms of plant and animal species potentially available for site occupancy; and time, the zero point being calculated from the initiation of soil formation or since major disturbance to existing conditions.

Jenny (1958, 1980) further described plants as being both dependent and independent variables. The species that dominate the vegetational community will exert their own particular influence on both plant community and soil-forming processes. Thus, with all factors remaining constant except time and natural succession, soil development continues as a reaction to both independent and dependent biotic components.

Many taxonomies have been developed for both plant communities and soils, but little direct analysis of their interrelationships has been attempted. In the Northern Rocky Mountains, only one climax community classification (Tisdale and Bramble-Brodahl 1983) and one successional community classification (Hann 1982) have aggressively attempted to correlate specific plant communities with specific soil and site characteristics.

In two of the major plant community classifications developed for the Inland Northwest (Daubenmire 1970; Daubenmire and Daubenmire 1968) extensive soil profile data were collected in hopes of defining a soil-vegetation relationship. But all such attempts failed due to multiple soil series occurring in one habitat type. Further confusion arose when soil families and Great Groups also did not correlate with plant communities. Daubenmire (1970) recognized the importance of soil factors to vegetation and strongly emphasized "those soil properties suspected of playing important roles in vegetation differentiation are not among the characteristics emphasized in soil classification." Soil moisture and temperature regimes, aeration, and nutrients are the important attributes for vegetation (Daubenmire 1970; Loucks 1962). None of these are adequately assessed by current soil taxonomic systems.

McCune and Allen (1985) were unable to statistically relate site characteristics to climax tree species along the eastern front of the Bitterroot Range in western Montana. They attributed only 10 percent of the compositional variation to measured site factors, assigning the rest of the variation mostly to historical factors.

Hann (1982) described three site types for both a forested and nonforested habitat type in western Montana. Although all soils classified to two closely associated families, Hann stated that considerable variation was found between sites. He qualitatively describes a number of soil-parent material-environmental conditions which, in his study area, relate very well to differing successional communities and specific habitat types.

In classifying sagebrush-grass habitat types of southern Idaho, Hironaka and others (1983) conducted a more intensive but similar qualitative analysis of the vegetation-soil relationship. Where soil-series-level classifications were available, correlation between the soil series or series-phase and habitat type was discussed. Statistical analysis of the physical and chemical data collected during this study would have greatly increased the knowledge of individual and combined soil characteristics relative to the vegetation being supported. Even without this further analysis, this study is the most intensive of regional plant communities and soil relationships thus far published for the Western United States.

In a study of the major plant communities of the Guadalupe Mountains of Texas and New Mexico, Bunting (1978) conducted an extensive analysis of topoedaphic variables as predictors of potential natural vegetation groups. In addition to physical site and soil descriptions, samples were analyzed for organic matter, pH, $NO_3^-$, $P_2O_5$, $K_2O$, $Mg^{++}$, $Na^+$, CaO, total soluble salts, and carbonate reaction. Discriminant function classification of stands achieved 90-95 percent accuracy by using a combination of topographic and edaphic variables.

Tisdale and Bramble-Brodahl (1983) conducted a statistically based, intensive study of vegetation communities and soil along the Salmon and Snake Rivers. On their study area, much reduced in geographic scale compared to either the Hironaka and others (1983) or Bunting (1978) studies, they concluded the currently available vegetation and soil classification systems are not compatible, possibly due to a relative difference in scale. Soil units are divided much more finely than vegetational units. A second part of the Tisdale and Bramble-Brodahl study analyzed 16 individual site and soil factors as independent variables for modeling vegetation-site relationships. Discriminant function classification accuracy ranged from 85 to 100 percent. Of the leading six factors, the most important (elevation and radiation index) were site location and orientation dependent. The other four factors were soil related. They concluded that a satisfactory set of soil-site variables could be developed to identify the habitat type of a site, even though only seral vegetation might be present.

In Major's (1951) factorial approach to plant ecology, the same five functional factors that Jenny applied to soil formation were used as independent formative factors in a vegetation equation. Major concluded "...there are no universal correlations between vegetation and soil;...soil is not determined by vegetation, vegetation is not determined by soil; vegetation and soil develop concomitantly." I hasten to submit at this point that even though no universal relationships appear to exist between soil and vegetation, it is exactly this concomitant development in a localized area that should provide quantifiable characteristics by which we can understand the plant community and soil-forming processes.

The objectives of this study were: to investigate numerical taxonomic techniques for analysis of patterns of physical soil characteristics; to investigate the relationship between known habitat types and soil units created by numerical taxonomy; and to develop the ability to predict habitat type using physical soil characteristics. Due to an acknowledged incompatibility of classification systems, this study, unlike those of Daubenmire and Hironaka and others, did not dwell on attempts to correlate habitat types and soil family or series units. With knowledge of the correlations between climax vegetation, soil, and site characteristics within a specific geographic region, we should be able to more accurately classify any given site within that region to habitat type and phase. This will also improve the ability to identify highly disturbed seral vegetation stages to habitat type and phase and more accurately position them within their successional development pathway.

## THE STUDY AREA

The study area comprised northern Idaho from the Salmon River to the Canadian border (fig. 1). Sampling was done on five National Forests (Kaniksu,

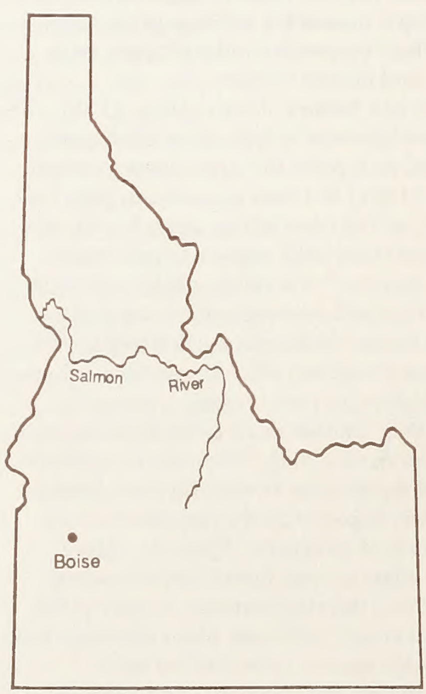


Figure 1—Study area comprised Idaho panhandle north of the Salmon River.

Coeur d'Alene, St. Joe, Clearwater, and Nez Perce), and on forested lands of the Idaho Department of Lands and private properties.

## Setting

The physical settings of the region vary from low-lying riverine valleys, 300 m above sea level, to glacial trenches, 550 m above sea level, to six major mountain ranges (Selkirk, Purcell, Cabinet, Coeur d'Alene, Clearwater, and Bitterroot Mountains) having elevations as high as 2,745 m. Sampling was mainly restricted to a midelevational zone in this region, ranging from 550 to 1,400 m above sea level.

The macroclimatic regime of northern Idaho is an inland expression of the Pacific Coast maritime climate (Ross and Savage 1967). Estimates for precipitation at sample locations range from 500 to 1,270 mm (Pacific Northwest River Basin Commission 1969); the actual values are dependent on elevation, north-south and east-west location, and position relative to orographically influenced precipitation patterns. Generally, precipitation occurs between October and May. The June through September period averages less than 25 mm rainfall per month. The average monthly ambient temperatures for these sites are equally variable. Mean summer temperatures range from 29 to 36 °C and mean winter temperatures range from –2 to –10 °C, with maximum extremes that range from 41 to –50 °C (USDC NOAA 1985). Although the aboveground climatic conditions are extremely variable, the presence of complete snow cover during winter months creates a moderate soil environment in which soil temperature regimes (USDA SCS 1975) are frigid or cryic and soil moisture regimes are generally udic or ustic, with some drier sites having a xeric regime.

## Geology

The study area includes two geological provinces. The Columbia Intermontane Province (Thornbury 1965), from the Seven Devils Mountains northward to Moscow, with interfingering as far north as Coeur d'Alene, is characterized by variable thicknesses of wind-deposited silt (loess) that overlies mid- to late-Tertiary Columbia River Plateau basalts, which, in turn, overlie intrusions of early Tertiary Idaho Batholith granite or Precambrian metasediments.

The Northern Rocky Mountains Province covers the remainder of the study area from the southeast and south-central Nez Perce National Forest to the Canadian border. The Clearwater and Coeur d'Alene Mountain ranges are an undifferentiated mass of Precambrian Belt Supergroup metasediments and Idaho Batholith granodiorites and quartz monzonites. The eastern boundary of the study area is formed by the Bitterroot Range, also quite variable in composition of granite, gneiss, and metasediments. North of Pend Oreille Lake, the Selkirk Mountains and the Cabinet Mountains are both composed of Belt Supergroup metasediments. Tertiary and Quaternary gravel and glacial till deposits occur sporadically throughout the region. Major deposition of till from Pleistocene Epoch continental glaciation occurs at all elevations north of Sandpoint (Buol and others 1980; Ross and Savage 1967). The geologic data collected for habitat type classification in northern Idaho (Cooper and others 1987) identify over two dozen different parent materials.

The region has been subjected to periodic, violent eruptions of volcanos and subsequent deposition of ejecta over wide areas of the Northern Rocky Mountains. Of the three most recent eruptions—Glacier Peak, Mount Mazama, and Mount St. Helens—the most significant was the creation of Crater Lake with the climactic eruption of Mount Mazama about 6,700 years ago. Ash from this event is an important material we now find in both relatively pure and mixed upper soil horizons, as deep as 1 meter, in northern Idaho (Nimlos and Zuuring 1982).

## Vegetation

In this study, habitat type is the taxonomic unit used to decribe plant communities (Daubenmire 1968). Habitat type is defined as follows: All the area that now supports, or within recent time has supported, and is still capable of supporting one plant association. A habitat type may encompass quite variable physical characteristics of topography, climate, and soils, yet the effective environment for plant growth and reproduction remains relatively constant. The diagnostic climax plant community (association) acts as an integrator of climate, relief, and soil through factor compensation, allowing for identification of equivalent environments by means of simple floristic lists of diagnostic species.

In the Northern Rocky Mountains, contiguous stands of mesic maritime forests are unique to northern Idaho (Cooper and others 1987; Daubenmire and Daubenmire 1968). These stands are characterized by the climax dominance of the coastal species *Tsuga heterophylla* (Raf.) Sarg. and *Thuja plicata* Donn. ex D. Don. This interpretation of Pacific maritime climatic influence is supported by numerous studies of coastal disjunct species found sporadically throughout northern Idaho (Johnson 1968; Johnson and Steele 1978; Steele 1971). The six habitat types chosen for this study represent the modal environmental conditions for the three overstory species (*T. heterophylla, T. plicata*, and *Abies grandis* [Dougl. ex D. Don] (Lindl.) most directly associated with this maritime climatic anomaly.

# METHODS

## Sampling Procedures

**Vegetation Data**—A set of 89 sample plots was selected from those sampled by Cooper and others (1987) as the data base for this study. Because similar studies have shown that a large amount of variation can be expected in the data (Base and Fosberg 1971; Monserud and others 1986; Sondheim and Klinka 1983), sample selection was restricted to six similar habitat types: *Abies grandis / Clintonia uniflora* habitat type-*Clintonia uniflora* phase (ABGR/CLUN-CLUN); *Abies grandis / Asarum caudatum* habitat type-*Asarum caudatum* phase (ABGR/ASCA-ASCA); *Thuja plicata / Clintonia uniflora* habitat type-*Clintonia uniflora* phase (THPL/CLUN-CLUN); *Thuja* *plicata / Asarum caudatum* habitat type-*Asarum caudatum* phase (THPL/ASCA-ASCA); *Tsuga heterophylla / Clintonia uniflora* habitat type-*Clintonia uniflora* phase (TSHE/CLUN-CLUN); and *Tsuga heterophylla / Asarum caudatum* habitat type-*Asarum caudatum* phase (TSHE/ASCA-ASCA). Association tables with site data and complete species list with canopy coverage class per species for this study's sample set can be found in Neiman (1986). Site selection technique and rationale for field procedures employed is detailed in Pfister and Arno (1980) and Cooper and others (1987). Hitchcock and Cronquist (1973) was the authority used for all plant nomenclature.

**Soil Data**—One soil pit was dug per plot at an undisturbed point representative of each stand. Minimum data collected were complete horizonation description (UDSA SCS 1981) and assessment of local parent materials. The set of samples utilized for this study contained 18 separately identified parent materials (table 1). Depth of pits was generally to the first or second C horizon. Time and cost constraints did not allow for excavation to bedrock, or for classification on site to soil family (USDA SCS 1975). Approximately a 1-liter sample of each horizon was collected and returned for laboratory analysis. This analysis consisted of: a verification of tactile textural classification for each horizon; assessment of moist and dry colors under ideal conditions; sieving of samples to determine percentage gravel content by weight; and measurement of pH, using a 1:1 ratio soil:water paste. Because the focus of this study was on field-identifiable characteristics of both vegetation and soil, no nutrient analyses were performed.

**Table 1**—Parent materials associated with subset of soil-vegetation samples selected for analysis

| Rock origin | Parent material |
|---|---|
| Sedimentary | Sandstone |
| | Siltstone |
| | Shale |
| Metamorphic | Argillite |
| | Quartzite |
| | Phyllite |
| | Schist |
| | Mica schist |
| | Gneiss |
| | Biotite gneiss |
| Igneous | Basalt |
| | Quartz monzonite |
| | Granite |
| | Biotite granite |
| Miscellaneous | Alluvium, mixed |
| | Glacial till, mixed |
| | Volcanic ash |
| | Sedimentary, mixed |
| | Loess |

## Analytical Procedures

**Vegetation Data**—Analysis of the vegetation data was performed during the original classification study (Cooper and others 1987) using accepted vegetation ordination techniques. But all plots were reassessed as to their original classification to habitat type and phase.

**Soil Data**—The hypothesis tested was that soil taxonomic classifications (USDA SCS 1975) have no ecological meaning when applied to forest soil-forest vegetation relationships. A subset of 50 soils formed from coarse-textured parent materials (for example, glacial drift, granite, gneiss, and sandstone) was classified to family taxonomic level by three soil scientists currently active in classification and mapping of soils within the study area (appendix A). These soil taxonomic units were then used to analyze soil-vegetation relationships.

The numerical pattern analysis concentrated on physical characteristics generally identifiable in the field (per instructions in Fosberg and Falen 1983) by non-soil scientist personnel. Individual soil characteristics were quantified for computer analysis and the data entered in an association table format. The initial data set consisted of the following 27 variables for each soil horizon in the vertical sequum:

1. Sequential horizon number – numbered as 1, 2, 3. .
2. Horizon genetic designation – USDA SCS (1981)
3. Depth – to base of horizon in centimeters
4. Boundary – Soil Survey Staff (1981)
5. Dry color – Hue – Munsell (1975)
6. Dry color – Value – Munsell (1975)
7. Dry color – Chroma – Munsell (1975)
8. Moist color – Hue – Munsell (1975)
9. Moist color – Value – Munsell (1975)
10. Moist color – Chroma – Munsell (1975)
11. Structural Grade – USDA SCS (1981)
12. Structural Size – USDA SCS (1981)
13. Structural Shape – USDA SCS (1981)
14. Texture – Gravel – presence/absence coding
15. Texture – % Clay – percentage from textural triangle
16. Texture – % Silt – percentage from textural triangle
17. Texture – % Sand – percentage from textural triangle
18. Available Water Capacity (AWC) – calculated as a function of textural water holding capacity (USDA SCS 1972), horizon depth, presence of volcanic ash, and percentage of coarse fragments per horizon
19. Root abundance – Size fine (USDA SCS 1981)
20. Root abundance – Size medium (USDA SCS 1981)
21. Root abundance – Size coarse (USDA SCS 1981)
22. Coarse fragments – Percent gravel by weight
23. Coarse fragments – Percent cobble by volumetric estimate
24. Coarse fragments – Percent stone by volumetric estimate
25. pH – 1:1 soil:water paste
26. Parent material 1 – coding for parent material
27. Parent material 2 – coding for parent material.

Five additional pedon summarization or site-specific variables were included in the analysis of soil horizon data: Total depth of organic litter layers; total depth of sequum to C horizon; total effective depth, calculated as the summation of each horizon depth times [(100 – percent coarse fragment)/100] down to but not including the C horizon; and total available water capacity, a summation of all horizon AWC's. Soil temperature, moisture regime, or chemical composition data, such as base saturation or cation exchange capacity, were not available for analysis. A complete set of these data and definitions for variables are presented in Neiman (1986).

**Data Matrix Design**—Since root systems are not generally affected by the minor differences that are significant to soil horizon classification, horizon data was analyzed in a simple sequential order, based on the depth rather than genetic horizon (that is, first, second, third horizon vs. A1, A2, AB, B2, . . .). This design was also dictated by the similarity-dissimilarity index analysis and ordination techniques available, wherein the presence or absence of data for a group of variables is weighted more heavily than are the individual quantitative values. Consider, for example, two pedons identical in all respects except for the presence of a 1-cm-deep A horizon in one of the sequa. Based on the presence-absence relationships in the first set of A horizon variables, ordination techniques would place these two pedons in highly dissimilar positions, whereas the presence of such a shallow A horizon should be subordinate to similarities for variables in the rest of the horizons.

Because categorical names are simply a summarization of horizon characteristics (such as color, texture, . . .), the quantitative data for these characteristics should contain equivalent if not more definitive information. A major problem arises when sequential horizonation rather than genetic horizonation is used for analysis. The problem occurs when one soil description begins with an A horizon and another sample begins with a B horizon. By not using categorical names in the analysis, the ability to differentiate A from B is lost. Forest soils of northern Idaho often do not develop an A horizon, yet when present, it was considered to be potentially significant in analysis of soil-vegetation relationships. Therefore, the first set of 27 horizon characteristics was allotted to only A horizon data, allowing for simplified analysis of presence-absence or quantitative data within only A horizons. For samples having more than one A horizon, a weighted-by-thickness average for all characteristics was used as the single set of A horizon data. The second and subsequent sequential horizon data sets record all other horizonation, and thus are restricted to AB, E, B, C, and R type illuvial and parent material horizons.

**Data Analysis**—Analysis was divided into three separate processes: The first investigated noise and redundancy of variables in the data set of 27 characteristics per horizon; the second attempted to delineate naturally occurring patterns of soil physical characteristics and assess their relationship to the vegetation types that they support; and the third developed discriminant functions based on soils data that are predictive for habitat type classification. Due to a disparity in both size and units of measure, all variables were standardized to a mean of 1 and a standard deviation of 0.1 (SAS 1982b). All data, raw and standardized, were analyzed for normal, skewed, or bimodal distribution (SAS 1982a) across the entire data set and within sets stratified by habitat type.

Noise was considered as variation in one characteristic being not coordinated with variation in another (Gauch 1982). Noise analysis was restricted to use of means and range data, with only those variables which were constant across the data (and therefore contain no useful information) being removed from further analysis. Correlation analysis of all possible pairs (SAS 1982a) and principal components analysis (Gauch 1977) were used to evaluate redundancy within and relationships between variables across the entire data set and for data stratified by either habitat types or parent material groups. The objective of these analyses was to create a reduced data set of as few independent variables as possible without sacrificing meaningful information.

Pattern analysis was conducted using a series of ordination techniques: polar ordination (Bray and Curtis 1957); principal components analysis (Gauch 1977); two-way indicator species analysis (Hill 1979b); and detrended correspondence analysis (Hill 1979a). All of these techniques are described as dimensionality reduction techniques, but each approaches the problem from a slightly different perspective. All four techniques allow for ordination of both variables and samples in the same analysis, which makes them useful for exploring variable reduction within samples, pattern analysis between samples, and delineation of variables related to patterns of samples.

Vegetation-soil relationships were analyzed using a subset of samples stratified by parent material and further stratified by habitat type. Techniques used to identify significant discriminators were: factor analysis (SAS 1982b); stepwise discriminant analysis (Dixon 1981); and canonical discriminant analysis (SAS 1982b). Using the set of significant variables identified by these programs, classification models based on discriminant functions were developed using discriminant analysis (SAS 1982b).

# RESULTS AND DISCUSSION

## Data Reduction

Criteria for retaining a variable in the data were as follows: continuous or a class of continuous values; not related to short-term vegetational changes or person-caused disturbance; suited to accurate assessment in the field; requires minimal subjective interpretation; and not influenced by other characteristics. Based on these criteria, a subset of 11 variables per horizon was selected for use in all further analyses. These were: depth; moist color value; moist color chroma; structural size and shape; percentages of clay, silt, gravel, cobble, and stone; and pH. All variables selected are quantified in terms of continuous or classes of continuous units, except for structural shape, which was quantified into categories whose increasing values denote increasing development through illuviation of fine soil material. Univariate analysis indicated a reasonable normality of distribution for all variables.

Initial ordinations were performed using data for all horizons and all 89 pedons. These ordinations produced groupings, based on the presence or absence of data for a single horizon, within a larger sequence of horizons. The number of pedons having data for a fifth and sixth horizon was too few to allow meaningful analysis with those horizons included in the data set. Analysis was then reduced to using the physical characteristics of the first four horizons only. Ordination groups created from this reduced data set still contained very dissimilar soils except for the presence or absence of a thin A horizon or the presence or absence of a fourth horizon. The fourth horizon, when present, contained genetic horizon data that described highly dissimilar B, C, or R type characteristics. Although stratification of the data by parent material was considered to have future utility, further ordination analysis, based on inclusion of the fourth horizon data, was deemed meaningless.

Ordinations were next performed using data from the upper three horizons and only those samples having an A horizon present. A second set of ordinations was then conducted on this same set of samples using only data from the second and third horizons. Comparison of results of these ordinations indicated that very little information was lost due to removal of the A horizon characteristics. All further analyses use only data from the second and third horizons. Because the data consist of the same 11 variables found in two consecutive horizons, a numerical suffix was added to the name of each of the 22 variables to identify the horizon of origin. Even though an A horizon (that is, the first horizon) did not occur in all pedons analyzed, for consistency the suffixes used were 2 and 3.

Widely differing parent materials produce significantly different textural and structural qualities, coarse fragment contents, and pH values, but often do not create differences in color or depth. Data were stratified into coarse-textured vs. fine-textured parent material groups in an attempt to eliminate these confounding factors. Basalt was grouped separately due to its basic properties, as opposed to the acidic nature of the other parent materials. Three groups were created:

| **Coarse-textured** $n$=55 | **Fine-textured** $n$=31 | **Basalt** $n$=3 |
|---|---|---|
| Alluvium – coarse | Alluvium – fine | Basalt |
| Glacial drift | Argillite | |
| Gneiss | Loess | |
| Granite | Mica schist | |
| Mixed sedimentary | Phyllite | |
| Quartzite | Schist – fine | |
| Quartz monzonite | Siltite | |
| Sandstone | Siltstone | |
| Schist – coarse | | |

In all cases, volcanic ash, where present, is an overlying amendment to the parent materials.

## Pattern Analysis

If a soil-survey-oriented taxonomy can be developed based on a combination of quantifiable and categorical horizon variables, then numerical taxonomic analysis of these variables should assign the same samples to clusters of closely equivalent taxonomic units. One problem created by the monothetic design of the soil taxonomy (USDA SCS 1975) is the emphasis placed on single variables in the delineation of taxonomic units. Two soil sequa similar in all respects except color of the epipedon can vary taxonomically in Order, Suborder, and/or Great Group. The emphasis in this study was not to mimic the currently accepted soil taxonomy, but rather to investigate the classification of polypedons based on multivariate statistical analysis of physical attributes. Because of this approach, the data from individual horizons were not combined into a control section format as used in soil taxonomy (USDA SCS 1975), nor was emphasis in the form of weighting placed on any single variable or set of variables.

As soils are extremely variable and multivariate in character, ordination was selected as the means to summarize and reduce dimensionality of the data (Gauch 1982). Using the four ordination techniques and the 11 variables for each of two horizons as outlined above, no identifiable relationships were discerned between numerically generated soil groupings, soil taxonomic units (using all hierarchical units from Order to Family), and habitat types within the full data set. Further stratification of the data set to reduce internal variation appeared necessary. The coarse-textured parent material group of 55 samples was selected for all further analyses.

Analyses of this reduced data set by three of the ordination techniques ranked samples in similar positions within their respective ordinations (Neiman 1986). Even though the rankings of each technique concurred in a general way, a large amount of variation occurred among the soils. Low eigenvalues of the principal component analysis indicated that only 19 percent of the total variation was explained by the first axis, 62 percent by the first five axes, and 86 percent by the first 10 axes. The so-called "cloud" of sample points in multidimensional space in this case truly lived up to its name. This large amount of unexplained variation in the data indicated that either the selected variables were not suitable for numerical grouping or that identifying soil groups numerically at this level of stratification has no statistical or ecological interpretive power. Yet, the ability to develop consistent rankings of samples by the various analytical techniques indicated a potential to define soil groups. The problem in doing so appears to be the small data set and high variation inherent in soils. Variation could be further reduced by stratifying the coarse-textured parent material group to create a subset containing samples from only granite, quartz monzonite, quartzite, and gneiss. This was not performed due to sample size restrictions.

## Soil-Vegetation Relationships

The second objective was to investigate relationships between soil characteristics and forest habitat types. A lack of correlation between the two taxonomic units can be seen in appendix A. If the work of Jenny (1941, 1958) and Major (1951) is correct, then some relatively discrete relationship between the functional factors for soil and vegetation properties should exist. Because a soil series or series-phase classification was not available for most of the study area, and because the samples had not been chemically analyzed, physical soil characteristics were used to analyze soil-habitat type relationships.

Data were reduced by removing redundant variables. An "inverse" ordination analysis, sometimes called Q-technique (Williams and Lambert 1961), sorts sample-pairs into similarity groups rather than species-pairs. The four "inverse" ordinations of soil characteristics resulted in a high concurrence of rankings of variables (table 2). The assignment of statistical significance to these rankings is meaningless, as the assumptions of linear relationships and independence of terms cannot be met. But almost identical rankings of variables at the extremes of all four ordination techniques identified the same primary group of variables. Structural ped size, ped shape, and coarse fragment content contain variation that appears to be related to internal structure of the data. These relationships were supported by correlation coefficients greater than 0.70 between structural and coarse fragment groups within horizons.

Factor analysis, an eigenvector analysis similar to principal component analysis, describes covariance relationships between two or more variables. If structural ped size and shape, or any other group of variables, are significant covariates, then a single variable is sufficient for analysis. But if a set of variables are not related, then all variables should be retained. Significant covariate relationships were found for seven groups in the first six factors of a varimax rotated factor analysis (SAS 1982b). In Factor 1, the silt and clay content of horizons 2 and 3 were highly related to each other. In Factor 2, structural size and ped shape in horizon 2 and percentage of gravel and cobble content, also in horizon 2, were related, but the two pairs of variables are inversely related to each other. This supports the positioning at the extremes of spatial structure developed by ordination (table 2). The only variables not exhibiting good covariate relationships were chroma and pH of the second horizon and chroma, percentage gravel, percentage cobble, and pH of the third horizon.

**Table 2**—Comparison of first axis ordination selection of coarse-textured parent material soil characteristics by polar ordination (PO), centered principal components analysis (PCA), two-way species indicator analysis (TWINSPAN), and detrended correspondence analysis (DCA). Data set consisted of 22 variables and $n = 55$. Variable suffix indicates associated horizon number

| Axis | PO | PCA | TWINSPAN | DCA |
|---|---|---|---|---|
| 1 | Size2 | Size2 | Shape2 | Size2 |
| 2 | Shape2 | Shape2 | Size2 | Shape2 |
| 3 | Shape3 | Size3 | Shape3 | Shape3 |
| 4 | Size3 | Shape3 | Size3 | Size3 |
| 5 | Depth3 | Depth3 | Chroma3 | Depth3 |
| 6 | Clay2 | Clay2 | Chroma2 | pH3 |
| 7 | pH3 | Depth2 | Value3 | Depth2 |
| 8 | Silt2 | Silt2 | Depth3 | Clay2 |
| 9 | Depth2 | pH3 | pH2 | Clay3 |
| 10 | pH2 | Silt3 | Clay2 | pH2 |
| 11 | Silt3 | Clay3 | Value2 | Silt3 |
| 12 | Clay3 | pH2 | Depth2 | Silt2 |
| 13 | Value3 | Value2 | pH3 | Value2 |
| 14 | Value2 | Value3 | Clay3 | Value3 |
| 15 | %Stone2 | Chroma3 | Silt3 | Chroma3 |
| 16 | Chroma3 | %Cobble3 | Silt2 | %Cobble3 |
| 17 | Chroma2 | %Gravel3 | %Stone3 | Chroma2 |
| 18 | %Cobble3 | Chroma2 | %Stone2 | %Gravel3 |
| 19 | %Stone3 | %Cobble2 | %Cobble2 | %Stone2 |
| 20 | %Cobble2 | %Stone2 | %Cobble3 | %Cobble2 |
| 21 | %Gravel3 | %Stone3 | %Gravel3 | %Stone3 |
| 22 | %Gravel2 | %Gravel2 | %Gravel2 | %Gravel2 |

Stepwise discriminant analysis (Dixon 1981) computes classification functions for subsets of quantitative variables by means of *F* values from an analysis of covariance. Table 3 lists the stratification combinations and selected variables for which *F* values were significant at the 0.90 level or greater. Through this analysis, 14 variables were identified as containing useful information for discriminating between various stratifications of the data. These variables were:

| | | | | |
|---|---|---|---|---|
| Chroma2 | Clay2 | Size3 | Shape3 | %Cobble3 |
| Size2 | %Cobble2 | Depth3 | Silt3 | pH3 |
| Shape2 | pH2 | Value3 | %Gravel3 | |

Canonical discriminant analysis of the coarse-textured parent material samples stratified into six habitat types resulted in the first three canonical components having *F* values significant at the 90 percent probability level or greater. All 22 variables had positive or negative correlation values greater than 0.5 within the first three canonical components. This is not surprising because factor analysis showed all variables, but five, were members of highly related covariate groups. By selecting the two largest positive and negative values within each of the three canonical components, six pairs of soil variables were identified as being good discriminators for habitat types.

Positive canonical coefficient pairs:
Value3 – Chroma2 %Gravel2 – %Gravel3
pH3 - Shape3

Negative canonical coefficient pairs:
Depth3 – %Cobble3 Clay2 – Silt2
Shape2 – Size2

Calculations similar to those of stepwise discriminant analysis were produced by canonical discriminant analysis for each of the 11 other data stratifications. Due to redundancy of results, these analyses are not presented. Based on the results of principal component analysis, factor analysis, and stepwise and canonical discriminant analysis, the following four variables were chosen for use in developing discriminant functions: Size2, Size3, %Cobble2, and %Cobble3.

Discriminant functions are the most valuable when analyzing homogeneous groups in which clusters of samples overlap (Sneath and Sokal 1973). This appears to be the situation among habitat types and soils. Statistical significance can only be ascribed to discriminant functions if the variables are multivariate normal, the variance-covariance matrices are similar, prior probabilities are identifiable, and the relationships between variables are linear (Greig-Smith 1983; Pielou 1977; Williams

Table 3—Variables selected, significant *F* value, and degrees of freedom (numerator and denominator) produced by stepwise discriminant analysis on coarse-textured parent material data

| Stratification of data | Variable | *F* Value Sig. >0.90 | Degrees of freedom | |
|---|---|---|---|---|
| | | | Numerator | Denominator |
| Six habitat types | Size3 | 6.522 | 5 | 49 |
| | %Gravel3 | 3.277 | 5 | 48 |
| | pH3 | 2.902 | 5 | 47 |
| | Size2 | 3.157 | 5 | 46 |
| | %Cobble2 | 2.575 | 5 | 45 |
| Overstory series ABGR-THPL-TSHE | pH2 | 5.421 | 2 | 52 |
| Two overstory series ABGR - TSHE | pH2 | 9.008 | 1 | 41 |
| | Value3 | 4.447 | 1 | 40 |
| | Silt3 | 6.218 | 1 | 39 |
| Understory unions CLUN - ASCA | Size3 | 16.187 | 1 | 53 |
| | Chroma2 | 7.083 | 1 | 52 |
| | %Cobble3 | 4.589 | 1 | 51 |
| ABGR/CLUN - ABGR/ASCA | %Gravel3 | 5.108 | 1 | 16 |
| | %Cobble3 | 6.765 | 1 | 15 |
| | Chroma2 | 7.411 | 1 | 14 |
| | Shape3 | 4.973 | 1 | 13 |
| TSHE/CLUN - TSHE/ASCA | Size3 | 27.547 | 1 | 22 |
| | %Cobble3 | 8.557 | 1 | 21 |
| ABGR/CLUN - ABGR/ASCA - TSHE/CLUN - TSHE/ASCA | Size3 | 13.315 | 3 | 39 |
| | %Gravel3 | 5.534 | 3 | 38 |
| | Value3 | 4.341 | 3 | 3 |
| | pH3 | 3.401 | 3 | 36 |
| | Depth3 | 3.841 | 3 | 35 |
| ABGR/CLUN - TSHE/CLUN | pH2 | 6.429 | 1 | 12 |
| | Clay2 | 10.740 | 1 | 13 |
| | Size3 | 15.882 | 1 | 12 |
| | Shape3 | 11.155 | 1 | 11 |
| ABGR/ASCA - TSHE/ASCA | Size2 | 15.228 | 1 | 25 |
| | %Gravel3 | 6.665 | 1 | 24 |
| | Shape2 | 6.951 | 1 | 23 |
| THPL/CLUN - THPL/ASCA - TSHE/CLUN - TSHE/ASCA | Size3 | 5.787 | 3 | 32 |
| | %Cobble2 | 5.693 | 3 | 31 |

1983). All four of these assumptions were violated to some extent in these analyses, leaving exploratory generalizations about both the data structure and discriminant functions as the result, rather than statistically significant conclusions.

Using four soil characteristics as variables, the probability of correct classification is equal to or greater than 57 percent for the *Abies grandis* and *Tsuga heterophylla* series habitat types, with 33 percent or less accuracy for *Thuja plicata* habitat types (table 4). The probability of simply guessing the correct habitat type is 16.7 percent. Considering the small sample size and the large amount of unexplained variation indicated by principal component analysis, this degree of classification accuracy is quite good. Although it is somewhat circular to test results with data used to develop the classification scheme, it does act as an acceptable initial test of classification accuracy.

In an attempt to increase the sample size per group and reduce apparent variation, the data set was stratified by overstory climax species (that is, *Abies grandis, Thuja plicata, Tsuga heterophylla*). Table 5 presents the classification results of discriminant analysis for the three series groups using the same four variables as above. The probability of properly assigning a sample to the *A. grandis* or*T. heterophylla* series using the discriminant functions developed is roughly twice the probability of guessing (33.3 percent), whereas for *T. plicata* it is one-half. Possible reasons for the poor accuracy in *T. plicata*

**Table 4**—Results of classifying six habitat types by four soil characteristics (Size2, Size3, %Cobble2, %Cobble3) using discriminant analysis. Probability of guessing correct classification group is 16.7 percent

| Habitat type -Phase | Sample size | Predicted group membership | | | | | |
|---|---|---|---|---|---|---|---|
| | | ABGR/CLUN -CLUN | ABGR/ASCA -ASCA | THPL/CLUN -CLUN | THPL/ASCA -ASCA | TSHE/CLUN -CLUN | TSHE/ASCA -ASCA |
| | | *Percent* | | | | | |
| ABGR/CLUN -CLUN | 7 | 57.1 | 0 | 0 | 0 | 28.6 | 14.6 |
| ABGR/ASCA -ASCA | 12 | 16.7 | 66.7 | 0 | 8.3 | 0 | 8.3 |
| THPL/CLUN -CLUN | 6 | 0 | 16.7 | 16.7 | 0 | 33.3 | 33.3 |
| THPL/ASCA -ASCA | 6 | 33.3 | 0 | 0 | 3.3 | 16.7 | 16.7 |
| TSHE/CLUN -CLUN | 9 | 11.1 | 11.1 | 0 | 0 | 77.8 | 0 |
| TSHE/ASCA | 15 | 0 | 13.3 | 0 | 0 | 0 | 86.7 |

**Table 5**—Results of classifying three overstory series by four soil characteristics using discriminant analysis

| Sample series | Group size | Predicted group membership | | |
|---|---|---|---|---|
| | | ABGR | THPL | TSHE |
| | | *Percent* | | |
| ABGR | 19 | 63.2 | 5.3 | 31.5 |
| THPL | 12 | 33.3 | 16.7 | 50.0 |
| TSHE | 24 | 33.3 | 0 | 66.7 |

**Table 6**—Results of classifying two understory unions by four soil characteristics using discriminant analysis

| Sample union | Group size | Predicted group membership | |
|---|---|---|---|
| | | CLUN | ASCA |
| | | *Percent* | |
| CLUN | 22 | 77.3 | 22.7 |
| ASCA | 33 | 18.2 | 81.8 |

classification may be that a different set of variables is required as discriminators for this climax tree species, or there simply is too much noise (for example, small data set) in this midground portion of what appears to be a relatively narrow environmental continuum. This problem also occurred in the stepwise discriminant analysis (table 3), wherein no significant variables could be found for habitat type groupings of *T. plicata* by itself or when combined with samples from the *A. grandis* series.

A much greater accuracy of classification is achieved by stratifying the data based on two understory unions of *Clintonia uniflora* (Schult.) Kunth. and *Asarum caudatum* Lindl. Table 6 presents the results of this discriminant classification showing approximately 77 percent and 82 percent proper classification, respectively. Stratification of the data into subsets of a single overstory species and two different understory unions should further increase classification accuracy.

The analysis conducted with only 55 samples may have produced results that reflect a simple random structure in the data set. If so, statisticians refer to this model as "overfitting the data" and not a true response to the system being modeled. Therefore, stratification of these data beyond the present level precludes further meaningful analysis.

Tables 7, 8, and 9 present the discriminant score formulas produced for classification of unknown samples into one of six habitat types, one of three overstory climax series, or one of two understory unions. Appendix B defines values for field quantification of structural ped size and percentage of cobbles.

Using four soil characteristics, the formulas calculate a discriminant score for each vegetation unit within a stratification group. The formula that produces the highest discriminating score (DS) has the highest probability of being classified correctly. As an example, one of the original sample plots, assigned by vegetation analysis to the ABGR/CLUN-CLUN habitat type, has the following values for the four discriminating soil characteristics:

| | | | | | |
|---|---|---|---|---|---|
| Size2 | = | 4 | %Cobble2 | = | 10 |
| Size3 | = | 4 | %Cobble3 | = | 20 |

Table 7—Discriminant score formulas for six habitat types and phases and four soil characteristics

| Habitat type -phase | Formula |
|---|---|
| ABGR/CLUN -CLUN | DS = (17.3 Size2 + 15.0 Size3 + 4.5 Cobble2 – 0.01 Cobble3 + 227.9) |
| ABGR/ASCA -ASCA | DS = (18.4 Size2 + 12.6 Size3 + 4.4 Cobble2 + 0.01 Cobble3 + 231.6) |
| THPL/CLUN -CLUN | DS = (16.9 Size2 + 13.1 Size3 + 4.3 Cobble2 + 0.04 Cobble3 + 233.7) |
| THPL/ASCA -ASCA | DS = (17.3 Size2 + 13.9 Size3 + 4.6 Cobble2 – 0.01 Cobble3 + 230.3) |
| TSHE/CLUN -CLUN | DS = (18.0 Size2 + 14.0 Size3 + 4.5 Cobble2 – 0.06 Cobble3 + 229.8) |
| TSHE/ASCA -ASCA | DS = (15.9 Size2 + 12.5 Size3 + 4.1 Cobble2 + 0.12 Cobble3 + 236.6) |

Table 8—Discriminant score formulas for three overstory series and four soil characteristics

| Overstory series | Formula |
|---|---|
| ABGR | DS = (13.7 Size2 + 7.4 Size3 + 2.9 Cobble2 + 0.56 Cobble3 + 179.3) |
| THPL | DS = (13.0 Size2 + 7.5 Size3 + 2.9 Cobble2 + 0.56 Cobble3 + 180.4) |
| TSHE | DS = (12.7 Size2 + 7.3 Size3 + 2.8 Cobble2 + 0.57 Cobble3 + 182.3) |

Table 9—Discriminant score formulas for the modal phase of two understory unions and four soil characteristics

| Understory union | Formula |
|---|---|
| CLUN | DS = (10.6 Size2 + 9.2 Size3 + 2.6 Cobble2 + 0.52 Cobble3 + 166.6) |
| ASCA | DS = (10.5 Size2 + 8.2 Size3 + 2.5 Cobble2 + 0.57 Cobble3 + 168.7) |

Using the six formulas in table 7, the discriminant scores (DS) calculated for each of the six habitat types are:

| | |
|---|---|
| ABGR/CLUN-CLUN | DS = 401.9 |
| ABGR/ASCA-ASCA | DS = 399.8 |
| THPL/CLUN-CLUN | DS = 397.5 |
| THPL/ASCA-ASCA | DS = 400.9 |
| TSHE/CLUN-CLUN | DS = 401.6 |
| TSHE/ASCA-ASCA | DS = 393.6 |

The highest discriminant score, calculated by the ABGR/CLUN-CLUN formula is 401.9, indicating this is the best choice for classification based on four soil characteristics. Table 4 shows a 57 percent probability that this is a correct classification. A rank order of scores can be used to identify other potential habitat types for consideration as classified units. In the example, the second best habitat type choice would be TSHE/CLUN-CLUN. With highly similar sites, classification errors can occur due to rounding of significant numbers in the formula. In all cases where discriminating scores are within three-tenths equivalent values (such as 401.9 vs. 401.6), further supporting evidence from investigation of onsite or adjacent vegetation is required for accurate classification.

## Ecological Interpretations

Even though soil-vegetation relationships were identified, the ecological interpretations are extremely hypothetical. The habitat types used to define the study environment are positioned along a continuous moisture-temperature gradient. *Tsuga heterophylla* can maintain viable populations only in the most moderate moisture and temperature regimes found in northern Idaho. Sites adjacent to *T. heterophylla*, but either too dry, too wet, too hot, or too cold for it to successfully reproduce are generally dominated by *Thuja plicata*. The harshest environments within this continuum, sites too hot and dry or too cold for *T. plicata*, are dominated by *Abies grandis*. The two understory unions likewise respond to environmental gradients, which generally can be described as warm-moist sites supporting both climax *Asarum caudatum* and *Clintonia uniflora*, while the colder and/or drier sites support only *C. uniflora*. Within the theorized functions for soil (Jenny 1941) and vegetation properties (Major 1951), these environmental relations are incorporated in the climate, relief, and parent material factors. If a change in vegetation is related to changing environmental factors, then a concurrent, but not necessarily convergent, shift in soil properties should occur.

Within the data used for this study no statistically or ecologically significant correlation could be found between habitat types and taxonomic soil units. Reasons for this failure are probably related to: the restricted amount of available data and its nonconformity to statistical constraints; the relatively narrow environmental gradient encompassed by the habitat types studied; and the broad geographic region included within the data base.

Interpretation of ecological relationships between habitat types and soil characteristics appears to be related directly to and confounded by climatic conditions that control soil genesis and species composition of the plant community. The cooler and wetter climatic regimes affecting northern Idaho are so recent (Mehringer 1985) that most of the vegetation-soil ecosystems are still in a state of flux. Primary successional development of plant communities and soil horizonation are proceeding at different rates. Duchaufour (1982) refers to short-cycle and long-cycle patterns of soil formation, with the dominant functional factors being vegetation and climate, respectively. The vegetation of northern Idaho has responded rapidly to the climatic change, whereas the soils are immature relative to the current conditions of climate and vegetation. This could account for the high variance values for soil characteristics when viewed from the perspective of a narrow vegetational continuum. I hypothesize that the habitat types used in this study are relatively stable in composition given the current climate, but the soils associated with these habitat types have not yet stabilized.

## CONCLUSIONS

For the geographic area studied, there appear to be no universal soil variables or sets of variables that can be used to predict the climax plant communities. The relationships between vegetation and soils are multifactorial and dynamic; the effect upon plant growth or reproduction of any one soil variable changes quantitatively and/or qualitatively with every variation in the complex of environmental factors. Yet, identifiable relationships do exist between a stratified set of soils and vegetation. This study was able to identify soil characteristics usable for differentiating pairs or groups of habitat types occurring on specific groupings of parent materials in northern Idaho. The concepts explored herein should be widely useful. But they should be applied only to northern Idaho ecosystems; only to the typal phase of the six habitat types discussed; and only to soils developed from the group of coarse-textured parent materials previously defined.

The importance of these findings for forest managers is twofold. First, with a large sample size and sufficient insight, a unique set of soils can be correlated with individual habitat types. Within a habitat type each set of functional soil-forming factors will develop a soil specific to that set of environmental conditions. Second, and probably more important, a silvicultural prescription may not produce a uniform vegetational response when applied to a specific habitat type or habitat type-phase occupying more than one type of soil. The use of universal guidelines for prescribed silvicultural treatments, site preparation, selection of regeneration species, stocking levels, and many other management activities has often resulted in failure. Many of these failures were the result of an inappropriate prescription chosen because of insufficient knowledge about these highly complex ecosystems. Effective management requires an individualistic prescription for each stand based on knowledge of its unique features, particularly its soils.

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## APPENDIX A: SOILS CLASSIFIED TO FAMILY LEVEL BASED ON PHYSICAL DATA. INCLUDES HABITAT TYPES ASSOCIATED WITH FAMILY AND PLOT NUMBER OF SAMPLE CLASSIFIED TO THAT FAMILY

| Great Group | Subgroup | Family | Habitat type | Plot No. |
|---|---|---|---|---|
| Eutroboralf | Typic | fine, mixed, frigid | TSHE/CLUN | 92141 |
| | | fine-loamy, mixed, frigid | THPL/ASCA | 92130 |
| Glossoboralf | Eutric | fine-loamy, mixed | ABGR/CLUN | 93110 |
| | | loamy, skeletal, mixed | TSHE/CLUN<br>TSHE/ASCA<br>TSHE/ASCA<br>TSHE/ASCA | 93131<br>93136<br>94009<br>94038 |
| Udifluvent | Typic | sandy, mixed, frigid | TSHE/ASCA | 92161 |
| Udipsamment | Typic | sandy, mixed, frigid | TSHE/ASCA | 92158 |
| Udorthent | Typic | sandy, mixed, frigid | THPL/ASCA | 40559 |
| Cryandept | Entic | medial over sandy or sandy skeletal | THPL/ASCA | 38503 |
| Cryocrept | Andic | coarse-loamy, mixed | ABGR/CLUN | 38314 |
| | Dystric | sandy, mixed | ABGR/ASCA | 38308 |
| | Typic | loamy, skeletal, mixed | ABGR/CLUN<br>ABGR/CLUN | 38305<br>38555 |
| Cryumbrept | Entic | sandy, skeletal, mixed | ABGR/CLUN | 38522 |
| Dystrochrept | Andic | fine loamy, mixed, frigid | ABGR/CLUN | 40740 |
| | | loamy, skeletal, mixed, frigid | THPL/CLUN<br>TSHE/CLUN<br>TSHE/ASCA | 94025<br>92139<br>92113 |
| | Typic | fine-loamy over sandy or sandy-skeletal, mixed, frigid | TSHE/ASCA | 93156 |
| | | loamy over sandy or sandy-skeletal, mixed, frigid | THPL/CLUN | 40560 |
| Dystrochrept | Typic | loamy, skeletal, mixed, frigid | THPL/ASCA | 92118 |
| | | coarse loamy, mixed, frigid | ABGR/ASCA<br>THPL/CLUN<br>TSHE/CLUN | 40553<br>40548<br>92150 |
| | | sandy, skeletal, mixed, frigid | ABGR/ASCA | 38566 |
| | Umbric | sandy, skeletal, mixed, frigid | ABGR/CLUN<br>ABGR/ASCA | 38541<br>38706 |

(con.)

## APPENDIX A. (Con.)

| Great Group | Subgroup | Family | Habitat type | Plot No. |
|---|---|---|---|---|
| Eutrochrept | Typic | sandy, mixed, frigid | ABGR/ASCA | 38707 |
| Haplumbrept | Andic | loamy, skeletal, mixed, frigid | ABGR/ASCA | 40552 |
| Vitrandept | Typic | loamy, skeletal, mixed, frigid | THPL/ASCA | 94011 |
| | | medial over loamy, mixed, frigid | TSHE/CLUN | 92102 |
| | | | TSHE/CLUN | 92134 |
| | | medial over loamy-skeletal, mixed, frigid | ABGR/ASCA | 93116 |
| | | | ABGR/ASCA | 94043 |
| | | | ABGR/ASCA | 94047 |
| | | | THPL/CLUN | 93154 |
| | | | THPL/CLUN | 94060 |
| | | | THPL/ASAC | 94029 |
| | | | TSHE/CLUN | 93106 |
| | | | TSHE/ASCA | 93111 |
| | | | TSHE/ASCA | 93115 |
| | | | TSHE/ASCA | 93125 |
| | | | TSHE/ASCA | 93126 |
| | | | TSHE/ASCA | 93129 |
| | Umbric | loamy-skeletal, mixed, frigid | ABGR/ASCA | 93160 |
| | | medial over loamy-skeletal, mixed, frigid | ABGR/ASCA | 94026 |

# APPENDIX B: DEFINITIONS AND PHYSICAL VALUES FOR FIELD QUANTIFICATION OF %COBBLES AND STRUCTURAL PED SIZE (FROM FOSBERG AND FALEN 1983)

Cobbles – Rock fragments of rounded, subrounded angular or irregular shape. Size range of 7.6 to 25 cm (3 to 10 in) diameter.

%Cobbles – Visual estimate of percent of soil volume occupied by rock fragments of cobble size class.

Structural Ped Size – all ped shapes should be measured by the size classes for angular and sub-angular blocky structure.

| Size Class | Diameter |
|---|---|
| 1 | <5 mm  |
| 2 | 5 to 10 mm  |
| 3 | 10 to 20 mm  |

| Size Class | Diameter |
|---|---|
| 4 | 20 to 50 mm  |

Neiman, Kenneth E., Jr. 1988. Soil characteristics as an aid to identifying forest habitat types in Northern Idaho. Res. Pap. INT-390. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 16 p.

Vegetation and soil physical characteristics were analyzed to identify numerical patterns within the soils data, relationships between soils and habitat types, and soil characteristics related to specific habitat types. Ordination and discriminant analysis techniques were used to identify four soil characteristics useful in identifying soils variation between six highly similar habitat types in northern Idaho. Improved classification techniques will allow for greater accuracy in predicting site capabilities and response of vegetation to disturbance.

KEYWORDS: soil-vegetation relationships, numerical soil taxonomy, multivariate soil-vegetation analysis

# INTERMOUNTAIN RESEARCH STATION

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