AN ABSTRACT OF THE THESIS OF

Rodrick D. Lentz for the degree of Master of Science

in Soil Science presented on November 9, 1984

Title: Correspondence of Soil Properties and Classification Units with Sagebrush Communities in Southeastern Oregon

Abstract approved: Redacted for privacy

Gerald H. Simonson

This research employed multivariate analytical techniques to statistically examine the relationship between individual soil-landscape units (SLUs) in Southeastern Oregon and their associated sagebrush communities. The objective was to determine if soil properties between SLUs differed, describe the variation, and verify that these differences were reflected in the taxonomic class of soils representing each SLU.

Several strategies for developing a profile concept which accurately summarized and typified morphological data collected from each SLU were compared. Statistical evaluations of soil profiles exhibiting diverse horizonation were accomplished by grouping profile subhorizons into aggregate strata, termed super-horizon-categories, which were defined to be common to all profiles.

Two procedures were utilized to appraise soil variability between SLUs: 1) Principal component analysis and hierarchical analysis of variance examined components of variance at each level in the sampling design. 2) Discriminant analysis, multivariate analysis of variance,

and Bonferroni's simultaneous confidence intervals were employed to select relevant soil parameters, test equality of group mean vectors, and construct specific between-group comparisons, respectively.

In Part one, geographically separate mono-taxa SLUs that supported different Artemisia habitat types were compared. Those factors which varied most highly between SLUs included elevation, aspect, presence of E or BA subhorizons, clay content of Bt horizon, and sand content of surface strata. In Part two, polypedons within a multi-taxa SLU that supported different phases of an Artemisia arbuscula/ Festuca idahoensis habitat type were compared. In this case, soil parameters which best distinguished between polypedons included depth of mollic epipedon, surface rock fragment cover, and thickness and average dry consistence of the Bt horizon.

In both studies, series separations between soil bodies supporting different plant communities were justified. Differentia included family or class distinctions of higher categories or differences in horizon composition and range of soil properties. Differences between soils which were not detected at family or higher class levels included 1) presence or absence of transitional AB and BCt subhorizons, 2) volumetric rock fragment content of A and Bt horizons, 3) thickness of mollic epipedon, 4) structure of BAt subhorizon, 5) thickness, and 6) average dry consistence of Bt horizon. Structure type of subhorizons, positions of subhorizons in soil profiles relative to the soil surface, and nutrient content are properties of soils which are often neglected by soil surveyors, yet these characteristics may provide important discrimination between soils possessing different range potentials.

CORRESPONDENCE OF SOIL PROPERTIES AND CLASSIFICATION UNITS WITH SAGEBRUSH COMMUNITIES IN SOUTHEASTERN OREGON

by

Rodrick David Lentz

A THESIS

Submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree

Master of Science

Completed November 9, 1984

Commencement June 1985

APPROVED:

Redacted for privacy

Professor of Soil Science in charge of major

Redacted for privacy

Head, Department of Soil Science

Redacted for privacy

Dean of Graduate School

Date thesis is presented November 9, 1984

Typed by Kimberly A. Spady Lentz for Rodrick D. Lentz

ACKNOWLEDGEMENTS

I sincerely thank the Soils Science Department and Eastern Oregon Agricultural Research Center for supporting this study.

Assistance and guidance provided by the following individuals is gratefully appreciated: Dr. G. H. Simonson, for giving me "a free rein to choose my own course and goal" and for his counsel "during the journey"; Dr. Huddleston, Dr. R. Miller, and Dr. N. Goetze, for their suggestions and constructive criticism of this thesis; and Dr. D. Thomas for helpful insights into statistical problems.

Special thanks are extended to Jack Istok for his helpful direction during my return to fortran programming. I also thank all the faculty, staff, and graduate students in the Soils Department for their assistance and comradery during my stay. Thanks also go to Dr. Bob Raliegh and many others at Section Five for their generous assistance, and to Gil and Marci Enniberg and Shand and Kate Cunningham, for helping to make my two summers at Squaw Butte Range Station exceptionally pleasant and memorable.

For their love, patience, support and encouragement, especially during those critical times when needed the most, I acknowledge my Lord Jesus Christ and those he has given me: my wife, Kimberly, mother and father, brother and sister, and their families. Warmest thanks go to Kimberly who typed the thesis and for many reasons deserves an important partnership in this accomplishment.

TABLE OF CONTENTS

Table of contents, continued

LIST OF FIGURES

List of Figures, continued

LIST OF TABLES

List of Tables, continued

CORRESPONDENCE OF SOIL PROPERTIES AND CLASSIFICATION UNITS WITH SAGEBRUSH COMMUNITIES IN SOUTHEASTERN OREGON

INTRODUCTION

In their quest to understand and map soil landscapes, soil scientists rely heavily upon soil profile observations collected in the field. Because obtaining such information requires large expenditures of time and labor, other more easily observed landscape features such as landform or vegetation are often employed as indicators of soil conditions. That soils vary as a result of changes in vegetation is an unquestioned axiom of Soil Science. Similarly, soil differences are a recognized cause of vegetation changes. The surveyor assumes that changes occurring in landform or natural vegetation across a landscape imply concomitant variation in soils. Under this assumption, a soil scientist can be selective in locating soil observations, restricting their number to relatively few representative locations after the general relationships between soils and vegetation are identified. However, inherent variability of soils, combined with a paucity of soil profile observations obtained using this procedure, preclude testing the validity of the assumed vegetation relationships. For example, using vegetation difference as the basis for making a small number of soil observations, a soil scientist may ascertain that two polypedons are alike; yet, because each support a different plant community the surveyor might conclude that there is a difference between polypedons, even though the soil profile observations did not confirm this judgement.

A scientist in the field ordinarily lacks time to fully investigate and verify plant-soil relationships; therefore, by assigning the polypedons to different map units, the phenomenon at least will have been recorded for future reference and interpretation. In this case, it is essential to further investigate the vegetation-soil relationships so that assumptions concerning their correspondence may be verified or disproved, and any potential interpretive differences between soils supporting different vegetation can be evaluated.

The purpose of this paper is 1) to objectively compare groups of contiguous soil pedons which are similar in morphology yet support contrasting plant communities, and 2) determine if properties or classification of soils in these groups exhibit consistent differences. Examinations of soil-pedon groups, or soil-landscape units (SLUs), were conducted at two field scales. In chapter one, comparisons were made between geographically separate large mono-taxa SLUs, such as those delineated by map unit consociations in a detailed soil survey. In chapter two, soil comparisons were made between smaller, proximate soil pedon groups located within a multi-taxa SLU. The multi-taxa SLU corresponds to a single delineation of a map unit defined as a soil complex in a detailed soil survey. In this case, two or more soils are distributed in an intricate pattern throughout the unit and intermesh so intimately that they cannot be separated at the usual scale of mapping (1:24,000). The two scales of soil comparisons are illustrated in Figure 1.

Comparisons of plant communities also differed in the two studies. Chapter one examines correspondence of soils with vegetation that varied most strikingly in regard to composition of dominant species.

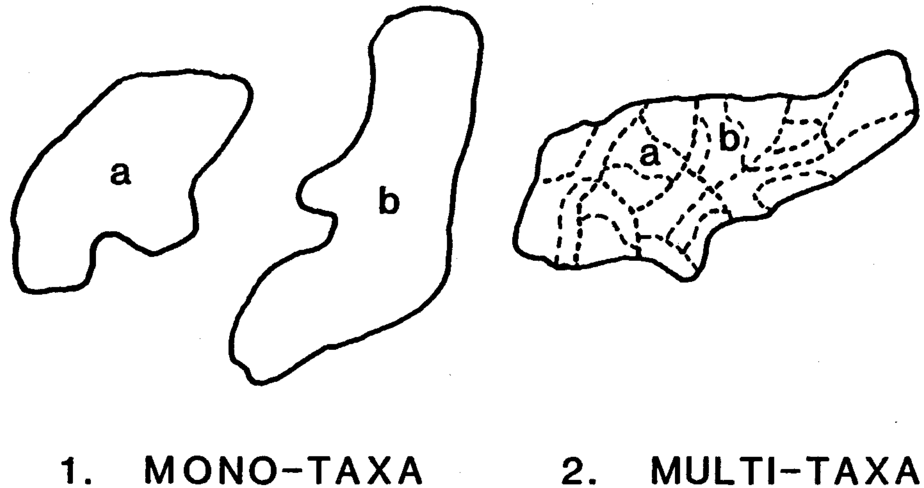


FIGURE 1. Scale of soil-landscape unit. Soils of "a" are examined with respect to those of "b".

In these plant communities, either dominant shrub or dominant grass species, or both, differed between SLUs. Chapter two examines correlation of soils with plant communities that varied less with respect to composition and more with regard to proportion of species present. The same plant species were present in nearly all assemblages studied in part two, but cover values for shrubs, grasses and herbs diverged significantly between them.

LITERATURE REVIEW

It is generally recognized that soil character affects the distribution of vegetation over its surface (Daubenmire, 1974). Factors responsible for soil development, including parent material, climate, time and topography (Jenny, 1958), simultaneously determine to a large degree the type of vegetation and organisms which can inhabit the site (Clements, 1905; Daubenmire, 1974). Local interaction of plants and organisms within a given habitat (e.g. competition, allelopathy, mycorrhiza etc.) defines plant community relationships (Kleiner and Harper, 1977). Further modification may be made through other environmental influences such as fire and human activity (Daubenmire, 1974). Relatively stable plant communities resulting from these processes at the site may subsequently and predictably influence the character of the soil (Birkeland, 1974; Buol et al., 1973; Jenny, 1980). Tueller (1962) demonstrated that range condition and trend within a habitat type may also be influenced by soil character. Many workers have observed that different vegetation types are associated with soils having different characteristics (Barkham and Norris, 1970; Finny et al., 1962; Gauch and Stone, 1979; Kleiner and Harper, 1977; Mahall and Park, 1976; Mitchell et al., 1966; Stein and Ludwig, 1979; Zedler et al., 1969).

Soil Conservation Service soil mapping policy reflects this premise. Within Major Land Resource Areas (MLRAs), phases of soil series are associated with a single vegetation type or range site. The Soil Conservation Service (1976) defines range site as:

"...a distinctive kind of rangeland that differs from other kinds of rangeland in its ability to produce a characteristic natural plant community. A range site is the product of all environmental factors responsible for its development. It is capable of supporting a native plant community typified by an association of species that differs from that of other range sites in the kind or proportion of species or in total production."

Therefore, different range site potentials result from dissimilar environments, and since soil is an important environmental factor, then the edaphic condition should be closely associated with range site.

This concept has an important impact on soil mapping procedure. Soil scientists working in the field ostensibly must map vegetation as well as soils. This is advantageous in that soil maps made this way may be less variable and more useful (Spurr and Barnes, 1980). However, soil surveyors have observed that correlation between soil morphology and vegetation potential is inconsistent. In some instances, obvious differences in morphological properties between soils are accompanied by a change in the type of plant community each soil supports. In other cases, morphologically contrasting soils may appear to support identical plant communities, and conversely, soils that appear to be morphologically identical are observed to support contrasting vegetation types.

There are several plausible explanations which may account for this apparent variability:

1. Soil scientists rely mainly on field observations of profiles to place the soil into its proper taxonomic class. However, use of specific morphological criteria for classification of pedons does not necessarily result in accurate discrimination between soils at the series level (Crosson and Protz, 1974; Henderson and Ragg, 1980;

Mausbach et al., 1980).

2. Field observations may not be precise enough to distinguish between soils that are similar. For example, Munsell color determinations cannot conclusively identify a mollic epipedon if the organic matter content of the horizon is slightly greater than one percent. Such horizons commonly produce dry color values ranging on either side of 5.5, making definite identification impossible in the field.

3. Soil mapping procedures and many sampling schemes employed in related scientific investigations do not provide the number of soil observations needed to quantitatively describe the character of soil landscapes. Soil properties of mono-taxa soil-landscape units can vary significantly and proper sampling is required for valid statistical comparisons (Crosson and Protz, 1974; Hammond et al. 1958; Reynolds 1975).

4. Field observations of the plant community inhabiting the soilscape may be too meager to permit valid comparisons with vegetation at other sites. Few quantitative data about plant cover are collected during soil surveys; commonly, only dominant species are noted for each field location. Some range sites are easily distinguished based on species composition. Other plant communities, containing similar groupings of species, can be discerned only by quantitatively comparing parameters such as cover, species, plant vigor or site production (USDA, Soil Conservation Service, 1976).

5. Variation within a plant community is at least as great as within mono-taxa SLUs; again, adequate sampling is required to define the association (Eckert, 1957). This is not accomplished during a soil

survey.

6. Present vegetation may not reflect the climax potential for the site. Influences such as drought, biotic infestations, grazing, fire and physical disturbances may have modified the plant community (Daubenmire, 1974). The response of species to these factors may be dependent upon the reaction of other species in their association, so each range site may respond differently to the same stress (USDA, Soil Conservation Service, 1976). Over larger geographic areas the effects of these influences become more variable and difficult to ascertain.

7. The scale of investigation may affect the perception of plant-soil relationships. First, the number of soil observations collected in the field during a small-scale soil survey which encompasses a large geographic area may be too few and widely spaced to reveal more subtle correlations. Second, in small scale soil surveys which cover large land areas, comparison of geographically distant plant communities may confuse plant-soil relationships. For example, geographically separated plants of the same species may represent different provenances and as such may have different physiological tolerance ranges (Mahall and Park, 1976). As a result, identical environmental conditions in different locations may support contrasting plant communties. In large soil surveys it is possible that both of these problems occur; however, use of carefully defined MLRAs may lessen the influence of the latter.

A single factor or combination of those mentioned above may obscure a soil scientist's perception of plant-soil relationships. The correlations between plant communities and the morphologic and taxonomic features of soils are not always vindicated under soil survey conditions. An understanding of this relationship is desirable as it would define factors pertinent to proper management of present vegetation and maximize interpretive and predictive capabilities of soil surveys, especially in regard to potential new uses of the soil resource.

STUDY AREA

Research was conducted at the Eastern Oregon Agricultural Research Center--Squaw Butte Range. Squaw Butte Experimental Range is located in the northwestern corner of Harney County, Oregon approximately 72 km (45 mi) west-southwest of Burns (Fig. 2). Its squared boundaries are 8 km (5 mi) on each side and encompass an area of 6,480 ha (16,600 ac).

Climate

The climate of Squaw Butte Experiment Station is characterized by a paucity of precipitation, especially during summer months, and large annual and diurnal ranges in air temperature. Mean annual precipitation is 277 mm (10.9 in), of which 31 percent falls as snow (National Climatic Center, NOAA, 1983). Precipitation maxima occur during early winter and late spring months (November, December, January, and May), while minima occur in mid and late summer (July, August and September). Mean annual variation in precipitation is 22 percent, indicating the moisture supply here is more dependable than in most regions having dry climates. This may be due to cool season cyclonic storm systems which provide a dominant portion of the region's precipitation (Brisbois, 1959). Local convectional storms are most common in summer; such thunderstorms occur on 5 to 20 days each year.

The mean annual temperature is 7.6 degrees C (45.7 F); average annual minimum temperature is 0.3 degrees C (32.5 F); and the average annual maximum temperature is 14.9 degrees C (58.9 F). In winter the mean temperature is -0.6 degrees C (30.8 F) and the average daily minimum is -4.8 degrees C (23.4 F). In summer the mean temperature is

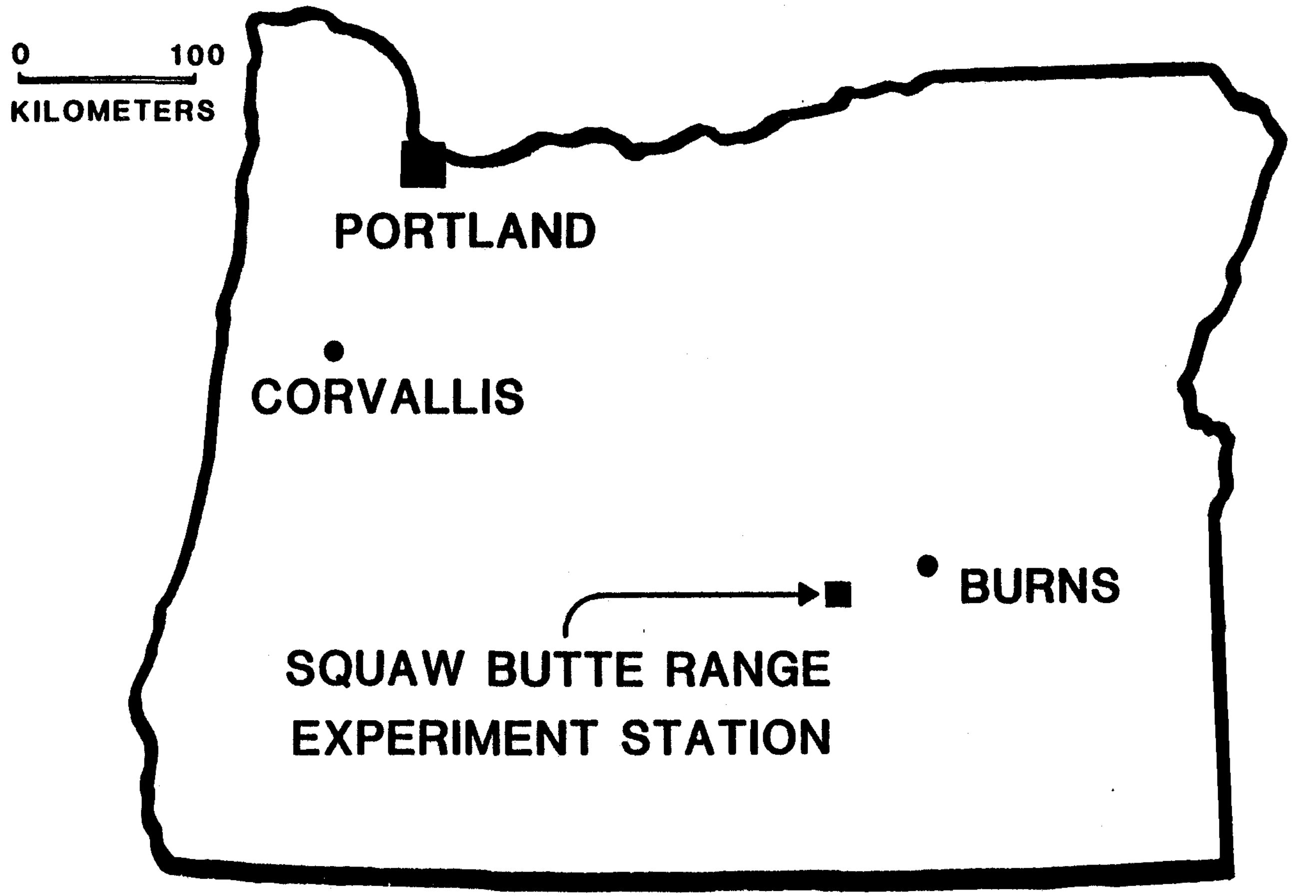


FIGURE 2. Location of study area.

17.6 degrees C (63.6 F) and the average daily maximum is 26.8 degrees C (80.3 F) (National Climatic Center, NOAA, 1983). Frost-free season is approximately 80 days, but killing frosts can occur in any month (Brisbois, 1959).

Physiography, Geology and Soils

Squaw Butte Station is located in the High Lava Plains physiographic province of Oregon. This somewhat fractured and faulted plateau was created by a series of four voluminous basalt flows spanning a 13 million year period and ending 12 million years ago. Active faulting and numerous smaller volcanic events have continued into recent times. Volcanic episodes producing locally extensive lava extrusions in and around Central and Southeastern Oregon were common during the Pliocene but ceased 2 million years ago (McKee, 1972). More recent volcanic activity (Newberry Volcano) has occurred along the Brothers fault zone within the last 2 to 4 thousand years (Higgens and Waters, 1967).

Local physiography is dominated by a sequence of several gently to moderately sloping lava plateau steps which ascend from a basalt plain at 1,350 m (4,500 ft) in the south portion of the station, to a dissected olivine andesite plateau, and finally, to a fault riddled and deeply dissected rhyolite and rhyodacite plateau remnant. This last landform comprises the northern quarter of the survey area and attains an elevation of 1,560m (5,200 ft). The lower elevation plains are composed of tertiary and quaternary aged flows of olivine-bearing basalt which feature both vescicular and dense platy forms. The top strata of the oldest flow was determined to be 2.4 million years old (Greene, Walker and Corcoran, 1972). The olivine andesite flow was estimated to be of early or middle Pliocene age while the rhyolite and rhyodacite rocks of higher elevation plateau remnants are considered to be of late Miocene or early Pliocene age (Greene et al., 1972). Soils of plateau uplands formed in cobbly residual or colluvial material, feature strongly developed argillic horizons, and commonly are shallow to bedrock or duripan. Dominant soil subgroups on low elevation lava plains include shallow Xerollic Durargids and Lithic Xerollic Haplarigids. Those on uplands at mid- and higher elevations include Lithic Argixerolls and Aridic Argixerolls.

The namesake, Squaw Butte, is an early Pleistocene volcanic cone composed of basalt and andesite scoria, cinders and agglomerate (Baldwin, 1976). Its conspicuous summit rises to an elevation of 1,650 m (5,500 ft.), the highest point on the experiment station. Several small cinder cones dot the eastern portion of the area as well; they are composed mostly of unconsolidated scoriaceous basaltic ejecta and other pyroclastic rocks (Greene et al., 1972). Soils on these steep volcanic slopes form in very cobbly coarse textured parent material; profiles are 30 or more inches deep and exhibit moderate horizon development. The majority of soils on these cinder cone slopes are classified as Aridic Haploxerolls.

Alluvial terraces occur at lower elevations, along an ancient stream floodplain which extends from the center of the survey area in a broad swath toward the southeast border. There are no active streams present within the station boundaries, though low pockets on some plateau surfaces contain small Pleistocene lakebeds which periodically hold water. Orthidic Durixerolls and Aridic Durixerolls are the common soil subgroups occupying terrace landforms; Xerollic Paleargids and

Typic Ochraqualfs occupy lakebeds in plateau depressions. Soils of alluvial terraces formed in loamy or sandy alluvium derived from surrounding volcanic rocks. Profiles are 30 to 40 inches deep to a silica or silica and calcium carbonate cemented duripan, and exhibit relatively weak solum development. These morphological characteristics suggest that the origin of terrace soils is polygenetic. The presence of an indurated duripan implies that the soil is in an advanced stage of development; yet this maturity is not reflected in the character of overlying horizons. The discontinuity indicates that the solum of an original paleosol had been stripped away and subsequently replaced with alluvial and possibly eolian material. Succeeding horizon differentiation of these deposits formed the solum observed presently. At some locations on terrace postions the paleosol remains intact, and these soils exhibit a strongly developed argillic horizon above the duripan.

A similar process has occurred on the basalt plains, though to a more limited extent. The presence of buried argillic horizons and partial or complete removal of such horizons from the solum above a duripan suggests that the surface has been subject to at least one other apparently selective erosive or depositional process. Fosberg (1963) concluded that buried paleosols of Southwestern Idaho represent the effect of climate, vegetation and parent material of a former more humid period he called the periglacial period. He attributed the stripping away of the buried Bt horizon to the erosive power of solifluction and of running water. The occurrence of stone stripes and Y-forms on higher plateaus at the station is evidence of a time of severe freezing and thawing. Thus it is possible that solifluction may have been an important factor influencing formation of soils at Squaw Butte.

Vegetation

The cool, semi-arid climate at this location supports a sagebrush-bunchgrass vegetation that includes a sparse juniper overstory on elevated plateau remnants and buttes. The climax or near climax plant community associated with lower elevation basalt plains and south exposures on higher upland slopes is represented by the Artemisia tridentata ssp. wyomingensis/Agropyron spicatum (ARTRW/AGSP) habitat type (HT). This community was described by Eckert (1957) on the experiment station, Culver (1964) on the Owyhee Uplands to the southeast, Hironaka, Fosberg and Winward (1983) in Southern Idaho, and Passey and others (1982) in Northern Nevada. Eckert (1957) and Sheehy (1975) identified and described an A. t. ssp. wyomingensis/Stipa thurberiana (ARTRW/STTH) plant community in the vicinity of Squaw Butte. This community is closely associated with the ARTRW/AGSP HT on lower elevation basalt plains. Eckert (1957) believed the ARTRW/STTH community to be a phase of the ARTRW/AGSP habitat type. More recently, Hironaka and others (1983) have identified the ARTRW/STTH plant community as a separate HT in Southern Idaho.

Mid-elevation plateaus with gentle to moderate slopes are associated with a Festuca idahoensis phase of the A. tridenta ssp. wyomingensis/Agropyron spicatum habitat type (ARTRW/AGSP(FEID). An additional seral grass species, F. idahoensis, is present in this plant community in subdominant amounts. Culver (1964) described this habitat type on the Owyhee Uplands.

Vegetation types associated with higher plateau summits and lower elevation positions subject to cold air drainage are dominated by the A. tridentata ssp. vaseyana/ F. idahoensis-A. spicatum

(ARTRV/FEID-AGSP) habitat type. This community was described by Sheehy (1975) at Squaw Butte and in the vicinity of Baker and Silver Lake, Oregon. Higher elevation north facing hill slopes are associated with the A. t. ssp. vaseyana/F. idahoensis (ARTRV/FEID) habitat type. This HT has been described at Squaw Butte (Eckert, 1957) and in Southern Idaho (Hironaka et al., 1983).

Shallow soils derived from rhyolite and andesite on mid- and high elevation plateaus and gentle to strongly sloping convex hillsides often suppport an A. arbuscula/F. idahoensis (ARAR/FEID) plant community. Eckert (1957), Teuller (1962) and Sheehy (1975) described this HT at several locations within the experiment station and other workers have documented its presence in Central Oregon (Hall, 1967), Southern Idaho (Hironaka et al., 1983), Northern Nevada (Zamora and Tueller, 1973) and Northwestern Utah (Passey et al., 1982). In some areas of the preceding three HTs, Juniperus occidentalis has formed a sparse but well established overstory. Usually such stands are restricted to escarpments, rocky crests and stringers, and steep north hillslopes at higher elevations. Eckert (1957) suggested that its relatively high moisture requirement and incidence of fire were two major factors affecting the distribution of J. occidentalis in the study area.

Less extensive upland plant communities occur in the area: 1) The A. rigida/ Poa sandbergii (ARRI/POSA) HT is associated with very shallow soils on higher hill and plateau crests and summits; this HT has been described by Hall (1967) in Central Oregon, Culver (1964) on the Owyhee Uplands, and Hironaka and others (1983) in Southern Idaho. 2) The A. longiloba/F. idahoensis (ARLO/FEID) HT is associated with shallow soils on mid-elevation basalt plateaus and rhyolitic hill summits; it was recognized by Eckert (1957) at Squaw Butte, who found it very similar to the ARAR/FEID HT except for the shrub substitution. This HT has been reported and described in Northern Nevada (Zamora and Teuller, 1973) and in Southern Idaho (Hugie, Passey and Williams, 1964). 3) The A. longiloba/A. spicatum (ARLO/AGSP) HT is associated with shallow soils on moderate, south-facing basalt plateau slopes at lower elevations. Robertson, Nielsen and Bare (1966) described a similar plant community in Colorado. On the experiment station, major shrub and grass species present in this HT include: A. longiloba, Chrysothamnus visidiflorus ssp. visidiflorus, A. spicatum, Poa sandbergii, Stipa thurberiana, and Bromus tectorum.

Well drained alluvial soils of terraces and floodplains support two dominant plant communities. Loamy soils of stream channels and floodplains support an A. tridentata ssp. tridentata/Elymus cinereus (ARTRT/ELCI) HT. On the experiment station this plant assemblage also includes C. v. ssp. visidiflorus, S. thurberiana, P. sandbergii, Sitanion hystrix, P. canbyi and B. tectorum. Swanson (1983) and Hironaka et al. (1983) have identified this HT at Squaw Butte. Alluvial soils on stream and basin terraces that feature moderately coarse to coarse textured surface horizons are associated with an A. tridentada ssp. wyomingensis/C. visidiflorus ssp. visidiflorus/S. thurberiana plant community. Other common species in this plant grouping include, F. idahoensis, P. sandbergii, S. histrix, Agropyron smithii, A. spicatum, Stipa comata, B. tectorum and Carex spp. A similar community, though in very poor condition due to heavy grazing pressure, was described by Culver (1964) on the Owyhee Uplands.

Fine-textured, imperfectly drained soils in plateau depressions support two vegetation types. _Artemisia cana_ ssp. _bolanderi_ and a sparse understory of _S. histrix_, _Muhlenbergia richardsonis_ and _Carex_ spp. occupy the relatively dryer old lakebed positions. Sheehy (1975) described this plant community at Squaw Butte and in shrub-steppe rangeland near Silver Lake and Baker, Oregon. In wetter depression positions, where water remains ponded on the surface throughout much of the summer, vegetation is dominated by _M. richardsonis_, _Eleocharis_ spp., _Juncus_ spp. and _S. histrix_.

Historic Use and Management Factors

Historic use and management of rangeland in the study area was described by Sneva and others (1984). Squaw Butte Range Experiment Station was established in 1934. The area it encompasses is known to have been part of a wild horse range prior to the early 1920's, but from the early 1920's up to 1935 it was utilized as a sheep lambing area. The station therefore inherited rangeland that had been degraded primarily by sheep grazing during early spring months.

Programs implemented during the period of 1936 to 1949 were unable to provide adequate management returns and simultaneously improve range production. Consequently research goals were altered to emphasize range improvement programs. The cow herd was culled, the grazing period shortened, and several other improvements were made which significantly reduced range forage use on the station. Additional improvements included seeding 486 ha to crested wheatgrass, expansion of road and fencing systems, and intensifying a system for watering by truck. Since 1949 the grazing program has endeavered to apply good range management but follows no prescribed system of use. In the years which followed, potential range production at Squaw Butte increased, allowing total range use to return to pre-1950 levels. Since 1960, a balanced program of range utilization and beef production has prevented range deterioration; range use has continued at a level of about 2,000 AUMs, and duration of grazing has varied from a date in early April to about November 1.

Specific management factors relevant to vegetation of study areas used in chapter one have primarily resulted in a change in proportion of dominant species components rather than an alteration in species composition. Larkspur (Delphinimum megacarpum), death camus (Zyadenus paniculatus) and lupine (Lupinus caudatus and L. wyethii) were grubbed from some areas in 1936 and two study sites were subjected to chemical treatment for brush control, one in the 1950's and another in 1966. It appears reasonable to assume that potential habitat types for study areas may be correctly inferred from an examination of present vegetation composition.

The soil-landform element selected for study in chapter two was located in a range that has not been exposed to specific range improvements like those mentioned above. From 1939 to 1949 it was utilized as a season-long pasture in a deferred rotation vs. season long study. In all study areas it was assumed that grazing pressure has been relatively uniform, particularly in view of the station's intensive management strategy and well developed watering program.

CHAPTER I

CORRESPONDENCE OF SOIL PROPERTIES AND CLASSIFICATION UNITS WITH SAGEBRUSH COMMUNITIES IN SOUTHEASTERN OREGON: I. COMPARISONS BETWEEN MONO-TAXA SOIL-LANDSCAPE UNITS

Rodrick D. Lentz

Gerald H. Simonson

CORRESPONDENCE OF SOIL PROPERTIES AND CLASSIFICATION UNITS WITH SAGEBRUSH COMMUNITIES IN SOUTHEASTERN OREGON: I. COMPARISONS BETWEEN MONO-TAXA SOIL-LANDSCAPE UNITS

ABSTRACT

Six similar but geographically separate mono-taxa soil-landscape units (shallow upland soils containing Bt horizons) which support contrasting sagebrush communities were examined to objectively determine if soil properties and classification differed between soil groups. Soil-landscape units (SLUs) supported six different *Artemisia* habitat types: *A. longiloba*/ *Agropyron spicatum*, *A. longiloba*/*Festuca idahoensis*, *A. arbuscula*/*F. idahoensis*, *A. tridentata* ssp. *wyomingensis*/*A. spicatum*, *A. t.* ssp. *wyomingensis*/*A. spicatum*(*F. idahoensis*), and *A. t.* ssp. *vaseyana*/*F. idahoensis*--*A. spicatum*. Morphological properties of 16 profile samples per SLU were compared by averaging values within common aggregate horizons termed super horizon categories (SHCs).

From 227 parameters described for each profile, stepwise discriminant analysis selected elevation, aspect, presence of E or BA horizons, clay content of the Bt horizon and sand content of surface strata as those which best distinguished between SLUs. Evidence suggests that series separations are justified based on family and class distinctions of higher categories or differences in range of soil properties, including variations in horizon composition, volumetric rock fragment content of A and Bt horizons, and structure of BAt horizons. Phase separation criteria suggested include aspect, parent

material, slope and surface texture. Structure type of subhorizons, positions of subhorizons in soil profiles relative to the soil surface, and nutrient content are properties of soils which are often neglected by soil surveyors, yet these characteristics may provide important discrimination between soils possessing different range potentials.

CORRESPONDENCE OF SOIL PROPERTIES AND CLASSIFICATION UNITS WITH SAGEBRUSH COMMUNITIES IN SOUTHEASTERN OREGON: I. COMPARISONS BETWEEN MONO-TAXA SOIL-LANDSCAPE UNITS

INTRODUCTION

Considerable research documenting the correspondence of soil properties with associated plant communities is found in the literature; yet few studies have evaluated this correspondence with regard to soil classification.

Heerwagen and Aandahl (1961) concluded that the most meaningful correlation between kind of soil and kind of native plant community occurs at the soil type and soil phase level of differentiation. Passey, Hugie, Williams and Ball (1982) conducted a ten year study examining soil, climate and vegetation characteristics of little disturbed climax plant communities in 32 relict areas of Utah, Idaho, Nevada and Wyoming. These authors reported that soil subgroups provided the most meaningful level of soil classification for correlation with broad plant associations, and that, when additional information becomes available, it may be feasible to group soils at their family, series or phase level for correlation with vegetation.

Munn, Nielson and Mueggler (1978) classified soils to the family level at 23 sites representing eight mountain and range habitat types in Western Montana. They found no perfect (one-to-one) relationship between habitat types and soil taxonomic units, but detected a general relationship between habitat types and soil taxonomic units with respect to soil moisture and soil development gradients. In a similar study, Zamora and Tueller (1973), identified soils to the family level at 39 sites representing eight low sagebrush habitat types in Northern Nevada. Their results indicated that no perfect relationship between habitat type and soil subgroup was apparent. (Comparisons to family level were unobtainable because family classification of soils were not published.)

Experimental designs of the above papers contained these similarities: 1) a single soil profile was utilized to characterize the edaphic condition at each sample site, 2) sites were distributed over a wide geographic area, 3) sites were located in several different major land resource areas, and 4) sites occurred in a variety of topographic positions. Because these researchers collected so few soil observations, they could compare soils only at the family level or at levels of higher taxonomic classes. Soils associated with different plant communites were not fully distinguishable at these levels of taxonomic description in spite of great variation in soils encountered due to geographic and topographic differences between sites.

The evidence presented by Passey et al. (1982), Munn et al. (1978), and Zamora and Teuller (1973) suggests that soils and associated plant communities need to be examined with greater precision if a more meaningful correlation between class of soil and class of native plant community is to be discerned. Observations of these natural systems must be made at a more detailed level of classification, namely, at the series or phase level for soils, and at the level of habitat type (Tisdale and Hironaka, 1981) or phase of habitat type for plant communities.

The objective of this paper is to explore the relationship between like groups of contiguous soil pedons (mono-taxa soil-landscape units) and their associated sagebrush plant communities on rangeland in southeastern Oregon. This study examines apparently similar but geographically separate soil pedon groups which support contrasting plant communities in order to objectively determine if soil properties and classification differ between groups. Plant communities in this study correspond to habitat types and phases of habitat types. Comparisons of soil classification were made at all levels of taxonomy. Emphasis was placed on determining the validity of series and phase separations between soils of different soil-landscape units.

STUDY AREA

The research was conducted at Squaw Butte Experimental Range Station in Southeastern Oregon. Located within the northernmost extremity of the Great Basin Province, station physiography consists of a sequence of lava plateau steps and elevated buttes. The cool, semi-arid climate, supports a sagebrush-bunchgrass vegetation that includes a sparse juniper overstory at higher elevations. Mean annual precipitation is 277 mm (10.9 in); maxima occur during early winter and late spring months. Approximately 31 percent of the annual precipitation falls as snow. The mean annual temperature is 7.6 degrees C (45.7 F). Frost-free season is approximately 80 days, but hard frosts can occur in any month.

Before selecting specific study sites the author conducted a detailed second-order soil and vegetation survey of the 6,480 ha experiment station in order to delineate and document soil and vegetation units. The predominantly upland soils are generally shallow (less than 50 cm deep) to bedrock or duripan and contain well developed argillic horizons. The profiles of these upland soils appear quite similar, yet support a wide range of sagebrush communities (Winward, 1980).

In a study of vegetation and soil relationships at Squaw Butte, Eckert (1957) found a single upland soil (his uncorrelated Series No. 1) associated with four habitat types, including *Artemisia tridentata/ Festuca idahoensis*, *A. tridentata/Agropyron spicatum*, *Artemisia arbuscula/F. idahoensis* and *A. arbuscula/A. spicatum*. His sample of 1 or 2 soil profiles from each plant community was insufficient to differentiate between pedons of Series

No. 1 which supported contrasting habitat types. Eckert recognized the need for additional study of soil-vegetation relationships and further soils correlation work.

Classification of sagebrush-grass habitat types has subsequently been greatly improved with the recognition of subspecies within _A. tridentata_ (Tisdale and Hironaka, 1981). Refinement in soil comparisons has been achieved by 1) restricting investigation to discrete geomorphic units, 2) increasing sample scheme size and extent (Reynolds, 1975), 3) comprehensive utilization of soil profile sample information (see Methodology) and 4) application of multivariate statistical techniques (Henderson and Ragg, 1980).

Six mono-taxa soil-landscape units were selected for study using the following criteria: 1) Each mono-taxa SLU represented a discrete repeating soil landscape element. 2) Each SLU supported a contrasting plant community of local significance and extent, and, in most cases, one in good range condition. 3) Dominant soils of SLUs featured well developed argillic horizons and were shallow to bedrock. 4) SLUs offered adequate accessibility.

Mono-taxa SLUs were labeled with reference to the plant communities each supported. Frequency of high seral grass species and density of dominant shrub species in each plant community were measured using thirty 0.3 m by 0.6 m frequency plots and three 1.2 m by 30.0 m density plots. (Plant community data is listed in Appendix A.) Names of plant communities identify the sagebrush subspecies and perennial grasses which characterize each site. Plant communities associated with each SLU represent different habitat types or phases of habitat types. These were identified as _Artemisia longiloba_/_Agropyron_ *spicatum* (ARLO/AGSP), *A. longiloba*/*Festuca idahoensis* (ARLO/FEID), *Artemisia tridentata* ssp. *wyomingensis*/ *A. spicatum* (ARTRW/AGSP), *Artemisia tridentata* ssp. *vaseyana*/*F. idahoensis-A. spicatum* (ARTRV/FEID-AGSP), *Artemisia arbuscula*/*F. idahoensis* (ARAR/FEID), and *Artemisia tridentata* ssp. *wyomingensis*/*A. spicatum* (*F. idahoensis* phase) [ARTRW/AGSP(FEID)]. Hironaka *et al*. (1983) have described ARLO/FEID, ARTRW/AGSP and ARAR/FEID habitat types; Sheehy (Sheehy, D. 1975. Relative palatability of seven *Artemisia* taxa to mule deer and sheep. M.S. Thesis, Oregon State Univ., Corvallis.), and Culver (Culver, R. N. 1964. An ecological reconnaissance of the *Artemisia* steppe on the East-Central Owyhee Uplands of Oregon. M.S. Thesis, Oregon State Univ., Corvallis) have documented and described ARTRV/FEID-AGSP, and ARTRW/AGSP(FEID) plant communities, respectively. Robertson *et al*. (1966) recognized the ARLO/AGSP habitat type as a distinct community. The Squaw Butte ARLO/AGSP plant community was in poor range condition relative to other areas examined in this study. The low frequency values observed for *A. spicatum* at this site were expected since this species tends to decrease under grazing pressure. In spite of low occurence, *A. spicatum* was considered a climax dominant at this location.

General site characteristics for each SLU are listed in Table 1.1

TABLE 1.1. General site characteristics of soil-landscape units.

SOIL-LANDSCAPE UNIT	LANDFORM	MEAN ELEV. (m)	SLOPE (%)	ASPECT	SHAPE	PARENT MATERIAL
ARLO/AGSP	Plateau slope	1392	2-5	SE	Convex	Basalt
ARLO/FEID	Plateau slope	1400	4-7	NNE	Concave	Basalt
ARTRV/FEID-AGSP	Hill summit	1520	2-9	SE	Convex	Ryolite
ARTRW/AGSP	Plateau slope	1388	2-5	ESE	Convex	Basalt
ARAR/FEID	Plateau slope	1491	2-9	ESE	Convex	Andesite
ARTRW/AGSP(FEID)	Plateau summit	1432	1-3	SSW	Convex	Basalt

METHODOLOGY

Statistical comparison of soils with respect to taxonomic properties is problematic. Soil classification, especially at the series level, is largely dependent upon profile horizonation for class differentia, and profile samples must be described on this basis. Statistical evaluations of horizon by horizon comparisons for numerous samples become impossible since kind or sequence of horizons vary between profiles. This variation also hampers efforts to develop a conceptual profile which comprehends horizon character of each multisampled soil-landscape unit.

The first problem is avoided if subhorizons are grouped into aggregate strata, termed super-horizon-categories (SHCs), which are defined to be common to all profiles. For this research, seven SHCs were constructed in an effort to examine different aspects of soil character. Twenty-eight morphological parameters describing each SHC were derived using weighted averages from identical variables of component subhorizons. Four SHCs proved most useful for soil comparisons: 1) AS-SHC groups A and AB subhorizons only, 2) AT-SHC groups all surface subhorizons down to, but excluding, an argillic horizon, 3) BI-SHC describes a subhorizon which forms the transition horizon between surface strata and subsoil, and 4) AR-SHC groups all argillic subhorizons. In addition to SHC variable sets, each sample profile was described by a group of general soil and site descripters. Parameters included site elevation, slope, aspect and configuration, soil depth and restrictive layer features, percent structural components per whole soil, depth to strata of specific structure type, surface rock fragment cover, total available water capacity (estimated), 0-18 cm mean moist and dry color value and chroma, mollic epipedon depth, and several binary variables indicating presence/absence of subhorizons. Thus, SLUs were statistically evaluated using an initial data file which included seven sets of SHC parameters and 36 general soil and site descriptors for each sample profile. A fortran program was developed to construct SHC and general site parameter files from original coded data containing an entire list of sample profile descriptions.

A conceptual profile (CP) in this paper refers to a specific soil horizon group and sequence which summarizes and typifies sample profiles observed in each SLU. Horizonation of soil groups was examined by comparing their respective conceptual profiles. Such profiles are not easily defined due to great variability in horizonation among sample profiles. Three procedures for constructing CPs were compared: A) Depth increment: Sample profiles were divided into 25 mm strata; and morphological parameters from strata at common depths were averaged over all samples within SLUs. Each SLU was then represented by an average profile composed of 25 mm incremental units. Strata from each mean profile were grouped into horizons based upon similarities in morphological properties, and horizons were identified based on averaged properties. Grouping was objectively accomplished using cluster analysis, a multivariate analytical technique, which employed an agglomerative hierarchical and flexible clustering strategy (Boesch, 1977). B) Full Sample: Frequency analysis of an entire SLU sample allowed selection of a dominant profile type designated as the CP. C) Representative sample: A subset of all SLU samples which best exemplified the taxonomic character of each soil-landscape unit was chosen. As in part B, the dominant profile type from this sample subset was equivalent to the CP.

MATERIALS AND METHODS

Sixteen profile descriptions were collected within each SLU using a hierarchical multistage random sampling design modified from Nortcliff (1978). Soil-landscape units, which form the highest strata in this design, were subdivided into 100 m by 100 m squares. Four squares were randomly selected for sampling. In each, a point was chosen using random grid coordinates; profile samples were collected here and at a location 20 m distant, along a random azimuth. Another sample was taken 5 m distant from each of these, also along randomly selected azimuths. The structure of this design makes it possible to evaluate soil variability at different scales in the landscape, involving sites 5 m apart to groups of sites (SLUs) several kilometers apart.

Each profile sample was described using standard U.S.D.A. Soil Conservation Service procedures (Soil Survey Staff, 1975) and converted to a computer format. Eleven coded variables identified and described general site and soil characteristics, while 28 identified and described each horizon. Available waterholding capacity for each horizon was estimated based on texture and rock fragment content and included with horizon parameters.

Five pedons were randomly selected from those sample profiles which best represented each SLU. Horizons of these pedons were sampled during a five day period in late September, 1983. Samples were consistently taken from locations between shrub canopies. Doescher _et al_. (1984) demonstrated that the most significant variation in soil chemical properties within these sagebrush communities occurs between inter-shrub and beneath-shrub locations. Surface organic debris was scraped away prior to collection.

Analysis for extractable P and K was performed by the O.S.U. Soils Testing Laboratory. Unlike other analyses, those for nutrients examined only two samples from each pedon, a surface representative (10 cm depth) and a subsoil specimen (10 cm above bedrock). Percent soil separates were determined from mechanical analysis utilizing a pipette procedure. Air dried, sieved samples were treated with hydrogen peroxide to remove organic matter and dispersed using sodium pyrophosphate and air jetting prior to pipetting. The following chemical analyses were performed: organic matter was estimated using Walkley and Black's (1934) wet oxidation-titration procedure; extractable P was quantified using a method outlined by Olsen and Dean (1965) and; a modified technique described by Pratt (1965) was employed to determine extractable K. (A single equilibration of the sample was employed instead of a multiple extraction procedure suggested by Pratt). Total soluble salts were assessed using electrical conductivity of a saturated paste extract and pH was measured utilizing a 1:2 soil/solution ratio and glass electrode.

One or two of the five sampled profiles in each SLU were selected for soil moisture observations. Upper and lower portions of the soil moisture control section (defined by Soil Survey Staff, 1975) in each pedon were sampled at quarterly intervals from October 15, 1983 to July 15, 1984. The upper and lower boundaries of the moisture control section ranged from 10 to 14 cm and 35 cm to bedrock contact, respectively. The control section was deepest in soils with coarser textures and greater rock fragment contents. Duplicate soil cores were collected from horizons of these profiles for determination of bulk density and soil moisture content at -0.01 MPa (.1 bar) and -1.5 MPa (15 bar) soil-water potentials. Soil moisture observations were collected to provide preliminary documentation of soil moisture regime. Available waterholding capacity for each sample was calculated (water held between soil-water potentials of -0.01 MPa and -1.5 MPa) and compared to previously estimated values. Tension plate and pressure membrane apparatus were employed in high and low pressure procedures, respectively. Moisture content was determined gravimetrically.

Two to five locations within each SLU were selected at random as soil temperature study sites. Calibrated thermistor probes were installed at 25 cm depth at all locations. One site in each SLU contained an additional thermister probe installed at 50 cm depth, or bedrock contact if this occurred at a depth greater than or equal to 45 cm. A 50 cm measurement in the ARLO/AGSP SLU was excluded because soils were too shallow. A YSI Model 425 C Tele-thermometer was employed to record readings from probes. Initially, temperatures were observed diurnally to establish daily timing of minima and maxima. Thereafter minimum and maximum soil temperatures were recorded quarterly, from October 15, 1983 to July 15, 1984. Mean annual soil temperatures (MAST) for each SLU were estimated by averaging quarterly 50 cm observations; soil temperature regimes were determined using these values. Shallow temperature observations provided data for estimating the MAST of ARLO/AGSP soils and for making SLU comparisons.

STATISTICAL ANALYSIS

Group comparisons involving SHC soil descriptions, soil temperature, laboratory and nutrient data were performed separately since sampling procedures for each were not equivalent. The scope of statisical inference varied between data groups because of these differences in sampling procedure. Soil profile description and temperature samples were selected from the entire population of soils in each SLU. Due to time and cost considerations, soil samples were collected only from representative pedons in each soil-landscape unit. As a result, laboratory and nutrient data describe variation within a dominant soil only, not the entire SLU, as in the former two data groups.

The 227 variable SHC data set was reduced using a stepwise Discriminant Analysis computer program, BMDP-P7M (Jennrich and Sampson, 1983), which selected a subset of parameters by examining between-group/within group variance ratios. An overall one-way multivariate analysis of variance examined equality of group means for selected variables, and simultaneous post hoc comparisons using Bonferroni's inequalities were performed to investigate between-group differences for each variable (Srivastava and Carter, 1983). Simultaneous Bonferroni confidence limits control type 1 error familywise, over the entire set of variable-group comparisons concurrently. Nonordered variables (eg. landform shape, structure type, etc.) were examined using frequency analysis provided by the SPSS-Aggregate computer program (Nie <u>et al.</u>, 1975).

Because laboratory data were derived from horizon samples, comparisons between soil groups were accomplished using SHCs. The statistical procedure performed was identical to that described for soil description samples but excluded frequency analysis. Nutrient and temperature data sets contained fewer variables so an overall MANOVA was conducted first, followed by construction of simultaneous confidence intervals. Nutrient variables representing surface and subsoil quantities were expressed in terms of weight of nutrient per unit volume of soil. Temperature variables included mean annual, average annual minimum and average annual maximum soil temperature as measured at 25 cm depth.

Variation in morphological characteristics of soil profiles within and between SLUs was further investigated by comparing components of variance from each level in the hierarchical sampling design (Nortcliff, 1978). Because examination of variance patterns for all parameters in the SHC data set would be prohibitively time consuming, only AT-SHC variables were considered. The AT-SHC data set was further reduced using Principal Component Analysis (PCA). Its solution results in a smaller number of new variables that are linear functions of original parameters. These functions (principal components) are uncorrelated and each account for a maximum amount of the variance of variables. The new variables may be interpreted in relation to original parameters by reference to their associated eigenvectors. Statistical analysis of principal components retains and efficiently utilizes useful information present in the initial data set (Srivastava and Carter, 1983), and is a viable alternative to analysis of the entire data set.

Principal components were analyzed using an analysis of variance model of nested or hierarchical design (Kelly and McManus, 1970). Components of variance or scale components at each level in the sampling design were derived, converted to a cumulative series expressed as a percentage of the sum of scale components, and plotted against separation distance represented at the appropriate sampling level. Principal component and nested ANOVA analyses were performed using SPSS-Factor (Nie et al., 1975) and SPSS-Manova (Hull and Nie, 1981) computer programs. Since units of measurement for variables were dissimilar, principal factors were derived using the correlation matrix (Srivastava and Carter, 1983).

RESULTS AND DISCUSSION

Scale Component Analysis

The first seven principal components derived from AT-SHC parameters accounted for 77 percent of the total variance (Table 1.2). Variables highly correlated with individual components and their loading values are listed in Table 1.3. It is apparent from Table 1.3 that the first principal component (PC1) is strongly correlated with variables which describe AT-SHC soil texture. Similarly, the second (PC2) through seventh (PC7) components may be interpreted as representing the following AT-SHC qualities: subhorizon sequence, rock fragment content, color, thickness, ped size, and stucture type.

Scale component configuration for each principal component is shown in Figure 1.1. Note PC4 has been omitted for simplicity; its pattern is nearly identical to that of PC5. The graph of PC1 indicates that 31 percent of variance for AT-SHC texture occurred at level 0 or at 5 m separation; 20 percent was contributed at level 1 or at 20 m separation, 29 percent occurred at level 2 or at approximately 600 m separation (average distance between 100 m square sample units); and 20 percent of the total variance resulted at level 3, between SLUs separated by an average distance of approximately 3000 m. This pattern suggests the greatest variability in surface soil texture occurred within each SLU rather than between them. It is apparent from examination of remaining scale component configurations that only three factors, PC2, PC3, and PC7, contribute a maximum variance at the SLU level. The AT-SHC qualities represented by these three principal components, subhorizon sequence, rock fragment content and structure

TABLE 1.2. Eigenvalues for the first seven principal components.

Principal Component	Eigenvalue	% Total variance	Cumulative % total variance
PC1	6.322	24.3	24.3
PC2	4.314	16.6	40.9
PC3	3.154	12.1	53.0
PC4	2.225	8.6	61.6
PC5	1.794	6.9	68.5
PC6	1.212	4.7	73.5
PC7	1.045	4.0	77.2

TABLE 1.3. Component loadings for variables with greatest correlation to each of the first seven principal components (PCs).

PC1	PC2	PC3	PC4	PC5	PC6	PC7
Sand -0.55	Subhorizon sequence 0.83	Coarse fragment content 0.96	Dry color value -0.44	Horizon thickness 0.89	Structure size 0.87	Stone content -0.53
Clay 0.90	Horizon identification 0.92	Stone content 0.69	Dry color chroma 0.75		Dry consistence 0.78	Pebble content 0.44
Stickiness 0.92		Cobble content 0.89	Moist color value -0.73		Moist consistence 0.48	Dry color chroma -0.56
Plasticity 0.89		Available water capacity -0.58	Moist color chroma 0.84			Structure type 0.70

FIGURE 1.1. Cumulative plots of scale components. PC1 = principal component one; PC2 = principal component two; PC3 = principal component three; PC4 was omitted for clarity--it is closely approximated by PC1; PC5 = principal component five; PC6 = principal component six; PC7 = principal component seven.

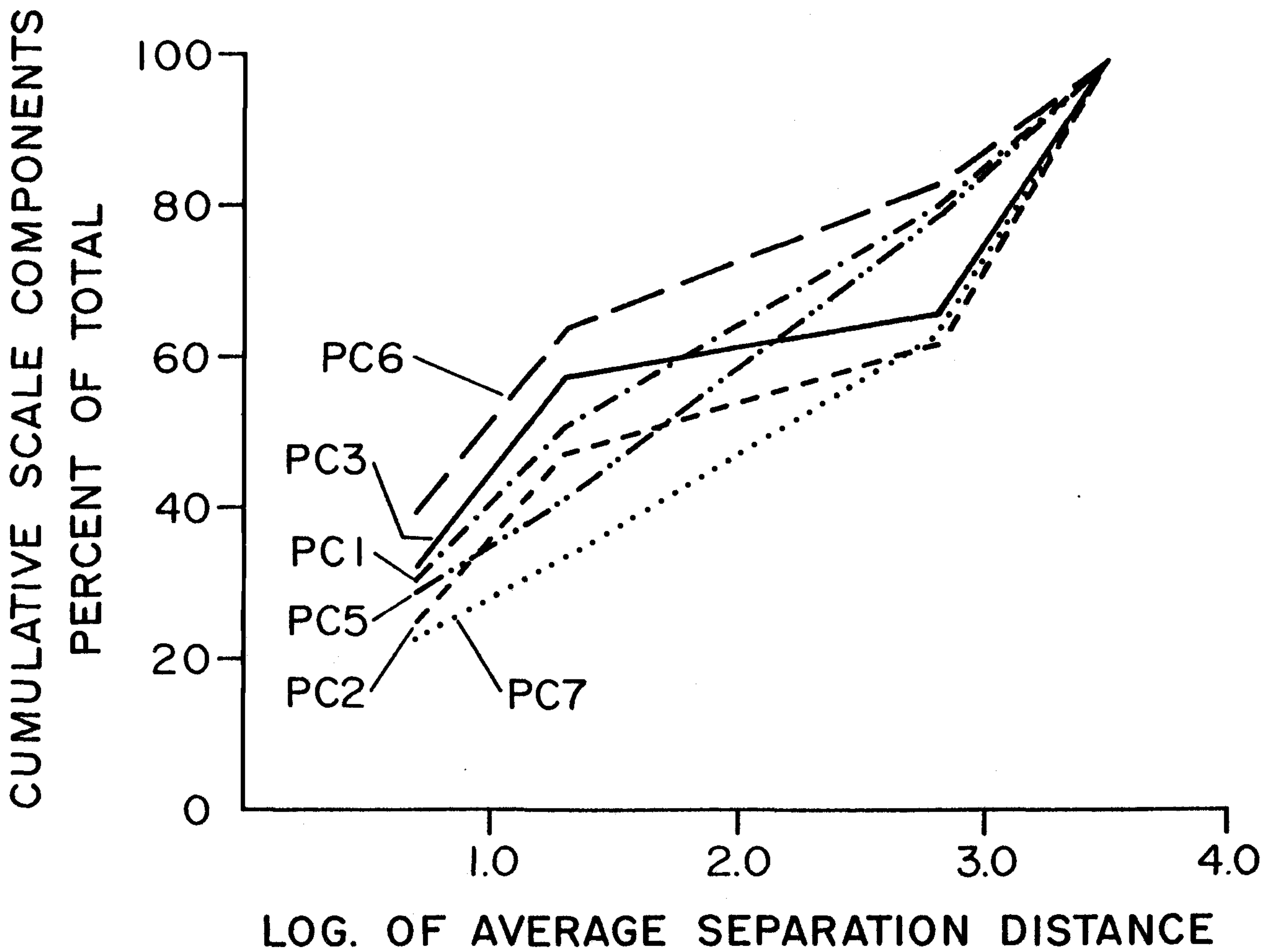

CUMULATIVE SCALE COMPONENTS
PERCENT OF TOTAL
100
80
60
40
20
0
PC6
PC3
PC1
PC5
PC2
PC7
1.0
2.0
3.0
4.0
LOG. OF AVERAGE SEPARATION DISTANCE

FIGURE 1.1

type vary most widely between soil-landscape units and may provide important criteria by which SLU soils may be distinguished.

Conceptual Profiles

Conceptual profiles representing each SLU and developed using three different strategies are illustrated in Figure 1.2. Soil horizon structure was excluded from part A profiles since the procedure employed prohibited determination of this characteristic. Note that strategies A) Depth increment, B) Full sample, and C) Representative sample produced nearly identical conceptual profiles for ARLO/FEID, ARTRV/FEID-AGSP and ARTRW/AGSP(FEID) sites. Each of these SLUs contained relatively homogeneous soil populations. In contrast, ARLO/AGSP, ARTRW/AGSP and ARAR/FEID soil populations were more variable, each comprising two or three co-dominant taxonomic units plus a smattering of fringing classes.

Use of depth increment strategy with nonuniform SLUs fully utilized sample data but its averaging procedure tended to obscure morphologic detail; therefore, identification of horizons was often inaccurate. For example, conceptual profiles derived for the ARLO/AGSP unit using full and representative sample strategies included an E-Bt-BCt horizon sequence whereas the depth increment method proposed an E-BAt-Bt subhorizon series. Field documentation indicated that the presence of a transitional horizon beneath an eluvial E in soil profiles was rare; more commonly, an E horizon would abruptly overlie a fully expressed prismatic Bt.

Of the remaining two strategies, full and representative sample, the former utilized a broader data base and provided a more general interpretation of soil profile characteristics within each SLU.

FIGURE 1.2. Diagrams depicting conceptual profiles for each soil-landscape unit (SLU) developed using three strategies: (A) Depth increment; (B) Full sample; and (C) Representative sample. Plant communities associated with SLUs are symbolized for each. Patterns in subhorizons of profiles correspond to structure type.

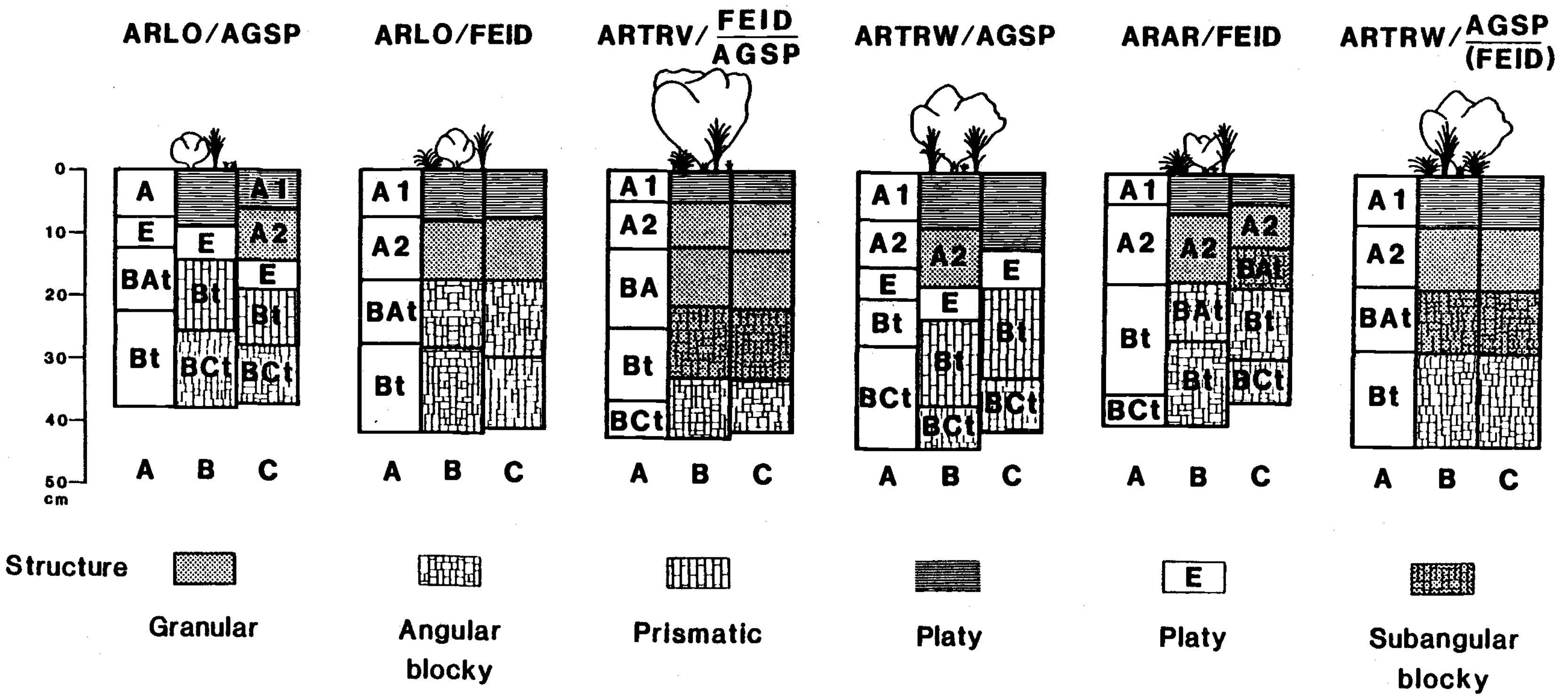

ARLO/AGSP
ARLO/FEID
ARTRV/FEID/AGSP
ARTRW/AGSP
ARAR/FEID
ARTRW/AGSP/(FEID)
0
10
20
30
40
50
cm
A
E
BAt
Bt
A1
A2
BA
BCt
A B C
Structure
Granular
Angular blocky
Prismatic
Platy
E
Platy
Subangular blocky

FIGURE 1.2

This broad perspective was attained using the latter procedure only when homogeneous SLUs were examined since the number of "representative" sample profiles analized under these circumstances would be maximized. When the representative sample strategy was used to analyze heterogeneous SLUs, the resulting data sets were more restricted. In these cases, a considerable amount of soil information that could otherwise contribute to the perception of soil-vegetation relationships within the soil-landform unit is lost. Conceptual pedons defined utilizing the full sample strategy (Fig. 1.2B) were considered the most legitimate form for use in comparing SLUs in this study.

Discriminant Analysis

From 227 SHC parameters described for each profile, stepwise discriminant analysis selected elevation, aspect, presence of E or BA horizons, clay content of Bt horizon (AR-SHC) and sand content of surface strata (AT-SHC) as those which best distinguished between SLUs. Selection of elevation and aspect was predictable since these variables obviously differed more between soil-landscape units than within them. Variables indicating presence/absence of E or BA horizons are strongly influenced by the AT-SHC subhorizon sequence, a quality of the soil identified by scale component analysis as one which varied most highly between SLUs (Fig. 1.1). Sand content of AT-SHC was the final parameter selected during discriminant analysis; it produced the smallest partial F-test-value and was least discriminating of the variables selected. Still, AT-SHC sand content was correlated with PC1, (Fig. 1.1) which was shown to vary relatively little between SLUs. Principal component one refers to AT-SHC soil texture but is more specifically correlated with clay content, stickiness and plasticity, as indicated by high loading of these variables on PC1 (Table 1.3). High variance contributed by PC1 to level 0 is most likely the result of variation in clay content and highly correlated stickiness and plasticity parameters rather than sand content. This illustrates the ambiguity which may result when principal components are interpreted relative to original variables.

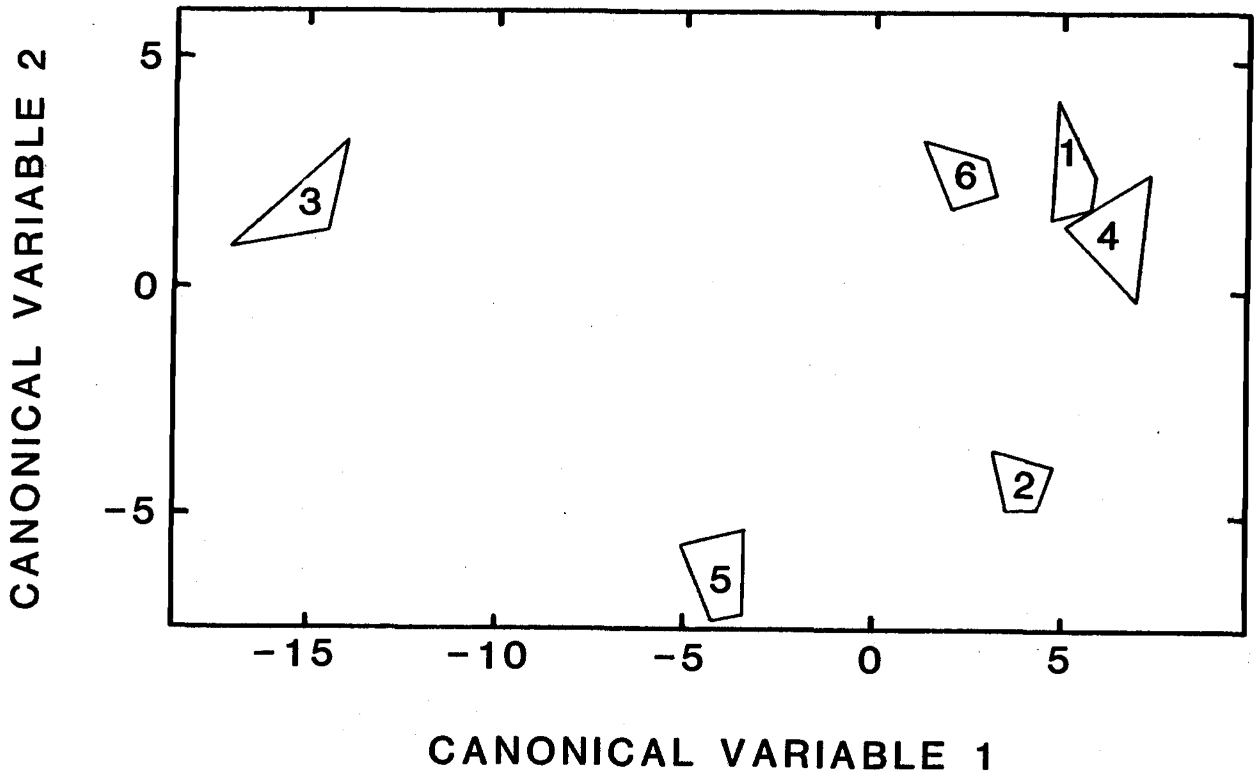
Separation achieved using selected discriminating variables is presented in Figure 1.3. Two new canonical variables were derived from linear combinations of the selected parameters such that the first best discriminates between SLUs and the second is the next best discriminating linear combination uncorrelated with the first. Standardized canonical variables were evaluated at group means and transformed values plotted for each new variable. Proximity of SLU means shown in the scatter plot implies relative similarity of soils. Figure 1.3 suggests that ARTRV/FEID-AGSP (3) soils are most dissimilar though one may argue that ARAR/FEID (5) pedons demonstrate at least an equal disparity since their mean diverges from the main group in two canonical dimensions not one, as is the case for ARTRV/FEID-AGSP. The ARLO/AGSP (1), ARLO/FEID (2), ARTRW/AGSP (4), and ARTRW/AGSP(FEID) (6) SLUs form a loose association of more closely related soils. Of these, ARLO/FEID (2) and ARTRW/AGSP(FEID) (6) groups are clearly separated from ARLO/AGSP (1) and ARTRW/AGSP (4) soils; the latter pair being more closely affiliated morphologically than any other SLUs.

Laboratory data from horizon samples were converted to a SHC format. The 49 parameters created could then be utilized to statistically compare dominant soils from each SLU. Stepwise discriminant analysis selected three variables which most effectively

FIGURE 1.3. Plot of canonical variables one and two. These are first and second best discriminating linear combinations of selected SHC variables, 1) elevation, 2) aspect, 3) presence of E and 4) BA subhorizons, 5) clay content of Bt horizon, and 6) sand content of surface strata. Numbers represent canonical variable means for each soil-landscape unit and field plots encompass sample values for each.

1 = ARLO/AGSP 2 = ARLO/FEID 3 = ARTRV/FEID-AGSP;

4 = ARTRW/AGSP 5 = ARAR/FEID 6 = ARTRW/AGSP(FEID)



CANONICAL VARIABLE 2
5
0
-5
-15
-10
-5
0
5
CANONICAL VARIABLE 1
1
2
3
4
5
6

FIGURE 1.3

distinguished between soil groups: organic matter content of surface strata (AT-SHC), clay content of surface-subsoil transitional subhorizon (BI-SHC), and pH of surface strata (AT-SHC). Of these three parameters, organic matter content of AT-SHC was the best discriminator and produced the largest partial F-test value while pH of AT-SHC was least effective for differentiating between SLU soils. Success of the BI-SHC parameter in discerning between groups is contributable to its sensitivity toward changes in subhorizon sequence of the upper soil. Statistical comparisons of particle size class data confirmed results obtained from analysis of field estimated parameters. Results of one-way multivariate analysis of variance tests examining overall equality of SLU mean vectors are presented in Table 1.4. In each category of soil information the null hypothesis was rejected and we conclude not all mean vectors are equal.

Family Classification

Mean values for soil characteristics of SLUs and those of representative soils from SLUs are presented in Tables 1.5 and 1.6, respectively. Moisture and temperature regime data were inconclusive due to the brevity of the observation period. The Soil Conservation Service (SCS) has correlated all Squaw Butte soils into series with aridic moisture and frigid temperature regimes (Lentz and Simonson, 198xa). Soil temperature observations collected for this study were taken during a year that was both cooler and wetter than normal. Yet, mean annual soil temperatures for all SLUs were warmer than 8 degrees C, implying that they properly belong in the mesic family. Assuming measurement accuracy of 1 degree C, only the ARTRV/FEID-AGSP group could be considered as frigid. Similarly, soil moisture observations

TABLE 1.4. One-way multivariate analysis of variance (MANOVA) for each data set.

ONE-WAY MULTIVARIATE ANALYSIS OF VARIANCE (MANOVA)			
Origin of Analyzed Data	Wilks Lambda	df	Approx. F (P-Value)*
SHC Description parameters	0.000004	60,32	6.993 (0.000)
Soil Temperature (25 cm depth)	0.08422	15,28	2.708 (0.011)
Horizon sample: laboratory data	0.23308	25,80	5.568 (0.000)
Surface/subsoil nutrient data	0.04973	20,74	5.439 (0.000)

* Null Hypothesis: Group mean vectors are equal.

TABLE 1.5. Mean values of selected soil characteristics and super-horizon-category (SHC) parameters for each soil-landscape unit.

SOIL CHARACTERISTICS	MEANS FOR SOIL-LANDSCAPE UNITS					
	ARLO/AGSP	ARLO/FEID	ARTRV/FEID-AGSP	ARTRW/AGSP	ARAR/FEID	ARTRW/AGSP(FEID)
MAST-Mean annual soil temp. (Deg. C.)	10.8	10.1	8.6	10.3	9.3	9.9
Mean annual soil temp. @ 25 cm (Deg. C.)	11.2[d*]	10.2[bc]	8.8[a]	10.7[cd]	10.1[b]	10.3[bc]
Elevation (m)	1392[a]	1400[b]	1520[c]	1388[a]	1491[d]	1432[e]
Slope (%)	4.5[bc]	5.6[c]	5.0[c]	3.6[b]	5.5[c]	2.0[a]
Soil Depth (cm)	37.5	43.0	42.5	43.8	41.5	43.0
Depth to angular blocky strata (cm)	16.8[a]	17.0[a]	37.8[c]	22.4[b]	16.8[a]	21.8[b]
E subhorizon (present = 1.0/absent = 0.0)	1.0[d]	0.1[a]	0.0[a]	0.6[c]	0.3[b]	0.0[a]
AB subhorizon (same)	0.4[a]	1.0[b]	1.0[b]	0.8[b]	0.8[b]	1.0[b]
BA subhorizon (same)	0.0	0.1	0.9	0.2	0.0	0.1
Proportion subangular blocky structure in soil profile	1.3[a]	11.1[bc]	40.3[e]	5.9[ab]	12.3[c]	19.9[d]
Munsell mean dry color value of 0-18 cm layer	5.80[c]	5.45[a]	5.30[a]	5.68[bc]	5.27[a]	5.45[ab]
AT-SHC thickness (cm)	16.5[a]	17.2[a]	22.2[b]	21.6[b]	16.6[a]	18.0[a]
AT-SHC rock fragment content (% by vol.)	10.1[a]	19.3[d]	11.2[a]	15.7[c]	13.7[bc]	9.2[a]
AT-SHC est. sand (%)	53.6[c]	48.4[b]	43.7[a]	48.6[b]	47.1[b]	41.3[a]
AT-SHC est. clay (%)	12.6	17.2	15.8	15.4	17.9	19.2
AR-SHC rock fragment content (% by vol.)	16.4[a]	34.3[d]	28.4[c]	22.9[b]	34.8[d]	23.2[bc]
AR-SHC est. clay (%)	41.6[b]	44.1[c]	30.1[a]	48.0[d]	44.2[c]	39.6[b]

* Variables selected for statistical analysis. Similar letters indicate nonsignificant differences ($\alpha = 0.05$) for soil-landscape unit comparisons.

TABLE 1.6. Mean values of selected super-horizon-category (SHC) parameters and soil chemical characteristics for dominant soils from each soil-landscape unit.

SOIL CHARACTERISTICS	MEANS FOR DOMINANT SOIL FROM EACH SOIL-LANDSCAPE UNIT					
	ARLO / AGSP	ARLO / FEID	ARTRV / FEID-AGSP	ARTRW / AGSP	ARAR / FEID	ARTRW / AGSP(FEID)
Mean organic matter 0-18 cm (% D.W.)	1.12^{b*}	0.98^{ab}	2.36^{d}	0.90^{a}	1.16^{b}	1.48^{c}
AT-SHC pH	7.6^{d}	7.3^{b}	7.1^{a}	7.4^{c}	7.4^{c}	7.3^{bc}
AT-SHC sand (%)	52.9^{c}	46.1^{b}	41.6^{a}	46.9^{b}	39.1^{a}	37.9^{a}
BI-SHC clay (%)	12.5^{a}	38.1^{c}	25.6^{b}	13.8^{a}	33.4^{c}	30.3^{bc}
AR-SHC clay (%)	38.7^{bc}	47.4^{d}	26.6^{a}	43.0^{cd}	41.5^{c}	35.1^{b}
Surface P (mg l^{-1})	3.0^{a}	4.5^{abc}	4.6^{bc}	7.8^{d}	3.3^{ab}	5.7^{c}
Surface K (mg l^{-1})	457.2^{b}	319.6^{a}	777.0^{c}	481.0^{b}	517.7^{b}	820.3^{c}
Subsoil P (mg l^{-1})	1.9^{b}	1.2^{a}	2.1^{b}	2.2^{b}	1.1^{a}	1.8^{b}
Subsoil K (mg l^{-1})	243.1^{ab}	223.4^{a}	715.3^{d}	316.7^{b}	273.6^{ab}	449.0^{c}

* Variables selected for statistical analysis. Similar letters indicate nonsignificant differences ($\alpha = 0.05$) for soil-landscape unit comparisons.

suggest the moisture regime of sampled soils is xeric not aridic; though these results may only reflect temporary climatic conditions. Further study is needed, but one may conclude that soil climatic regimes are at the least marginal in character. For purposes of soil classification SCS determinations were assumed to be adequate.

Soil temperature observations collected at 25 cm depth were useful for comparing soil groups. The ARLO/AGSP site was significantly warmer and ARTRV/FEID-AGSP significantly cooler than other soil-landscape units. The mean annual 25 cm soil temperatures for the remaining SLUs, ARLO/FEID, ARAR/FEID and ARTRW/AGSP(FEID) and ARTRW/AGSP were similar. However, soils of ARLO/FEID were significantly cooler than those of the ARTRW/AGSP site. Only simple comparisons of SLU soil moisture were possible because of the meager data base collected. One measure of soil aridity is described by the consecutive number of days that the soil moisture control section is completely dry during four months following summer solstice. These data suggest that profiles sampled in ARLO/AGSP, ARTRV/FEID-AGSP, ARAR/FEID and ARTRW/AGSP(FEID) SLUs were dry for approximately 83 consecutive days after summer solstice while the ARLO/FEID profile was dry for only 65 days during the same period. Unexpectedly, the lower moisture control section in both pedons sampled from the ARTRW/AGSP soil-landscape unit failed to dry completely during the 120 day time span. Sample profiles were located near the base of a gentle plateau slope which comprises the ARTRW/AGSP unit. Water moving from upper slopes in the subsoil above lithic contact may account for the presence of continuing soil moisture supplies in the absence of significant additional precipitation. This occurence may also be a temporary phenomenon related to unusual climatic conditions.

The average depth of soils from all SLUs ranged from 38 to 44 cm. Determination for presence of mollic epipedon in these shallow soils was primarily dependent upon mean soil color and organic matter content of the 0 to 18 cm surface layer. Mean organic matter contents (% dry wieght) in dominant soils of ARLO/AGSP, ARLO/FEID, ARTRW/AGSP and ARAR/FEID SLUs were marginally mollic, ranging from 0.9 to 1.2 percent, and differences were nonsignificant. Mean soil colors were sufficiently dark to make all but ARLO/AGSP and ARTRW/AGSP soil-landscape units mollic; surface dry color values of these two soil groups were above 5.5 and were significantly different from soils of all SLUs except ARTRW/AGSP(FEID). However, organic matter contents of surface soils from the ARTRV/AGSP(FEID) unit were significantly greater than those observed in soils of either ARLO/AGSP or ARTRW/AGSP sites. This provided justification for taxonomic separation of ARLO/AGSP and ARTRW/AGSP SLUs from others based on mollic criteria.

Soils of all groups contained argillic horizons. Family particle size class was clayey for all soils except those from ARTRV/FEID-AGSP. The family texture control section (i.e. the argillic horizon for soils of all SLUs) of typical ARTRV/FEID-AGSP soils contained an average of 30 percent clay compared to a range of 40 to 48 percent found in soils of other SLUs (field estimation). Mean rock fragment content in argillic horizons of soils from the six groups ranged from 16 to 35 percent.

Soils of each SLU were classified to family level based on the above information and assumptions concerning SCS determinations of soil moisture and temperature regimes, and family mineralogy class. Soils of ARLO/AGSP and ARTRW/AGSP groups were identified as clayey, montmorillonitic, frigid Lithic Xerollic Haplargids; soils of ARLO/FEID, ARAR/FEID and ARTRW/AGSP(FEID) are clayey, montmorillonitic, frigid Lithic Argixerolls; and soils from the ARTRV/FEID-AGSP SLU are loamy, mixed, frigid Lithic Argixerolls.

Series Classification

Evidence suggests that series level separation of soils from the different SLUs is justified considering family and class distinctions of higher categories or differences in range of soil properties. Soils of the ARTRV/FEID-AGSP SLU belong to a unique family in comparison to other soils and must be assigned to a separate soil series. Soils of ARLO/AGSP and ARTRW/AGSP groups are of the same family but differ in horizons present (Fig. 1.2). Binary variables representing presence/absence of specific profile subhorizons indicate 1) the occurrence of an eluvial E (mean value of binary variable is greater than 0.5) in profiles of both groups, 2) the occurrence of an A2 horizon in soils of the ARTRW/AGSP group and 3) that ARLO/AGSP site soils are significantly different from those of ARTRW/AGSP in regard to status of the A2 subhorizon (Table 1.5). An increase in thickness of the AT-SHC strata in soils from ARTRW/AGSP groups relative to those of ARLO/AGSP sites also suggests the presence of another subhorizon. Typically, profiles from the ARLO/AGSP soil-landscape unit possess an ochric epipedon which includes an A-E subhorizon sequence. Epipedons of ARTRW/AGSP soils contain a supplemental transitional A2 subhorizon, resulting in an A1-A2-E profile sequence. Series level separation of ARLO/AGSP and ARTRW/AGSP soil concepts is tenable in view of these differences in horizon composition.

Soils of ARLO/FEID, ARAR/FEID and ARTRW/AGSP(FEID) groups are distinguished from series defining other SLUs on the basis of family or class distinctions in higher taxonomic categories. An examination of conceptual pedons (Fig. 1.2) and horizon parameters (Table 1.5) indicates that soils of ARLO/FEID, ARAR/FEID and ARTRW/AGSP(FEID) groups exhibit identical horizon composition; however, evidence obtained from frequency analysis and simultaneous comparisons of select soil properties suggest that variation in 1) range of mean volumetric rock content of A and Bt horizons and 2) characteristic structure of the BAt horizon provides a basis for valid series level segregation of soils from these SLUs. Significant differences in volumetric rock fragment content were observed between soils of the three SLUs; profiles from ARTRW/AGSP(FEID) sites included the least and those of ARLO/FEID contained the greatest volume of coarse fragments (Table 1.5). Soils of the ARTRW/AGSP(FEID) site also differed from those of ARLO/FEID and ARAR/FEID in respect to structure type of BAt horizon. Results from post-hoc between-group comparisons suggest that soils of the ARTRW/AGSP(FEID) SLU contain a significantly greater relative proportion of subangular blocky structure in comparison to pedons from ARLO/FEID and ARAR/FEID sites. The source of this discrepancy appears to be the BAt horizon. Frequency analysis for structure type (grouped by SLU and horizon) indicates that BAt horizons in ARTRW/AGSP(FEID) soils typically possess subangular blocky structure while angular blocky structure is dominant in BAt horizons of ARLO/FEID and ARAR/FEID soils. To specify separate series concepts for ARLO/FEID, ARAR/FEID and ARTRW/AGSP(FEID) soil groups, series descriptions must include carefully defined range-in-characteristic-statements. Such statements, for series represented by ARLO/FEID, ARAR/FEID and ARTRW/AGSP(FEID) SLUs, respectively, would define 1) A horizon volumetric rock content as 15 to 25 percent, 5 to 15 percent and 5 to 15 percent, 2) Bt horizon volumetric rock content as 27 to 35 percent, 27 to 35 percent and 15 to 27 percent, and 3) structure of BAt horizon as prismatic or angular blocky for ARLO/FEID and ARAR/FEID series concepts, and subangular blocky for ARTRW/AGSP(FEID).

Phase Level Criteria

Under certain circumstances it may not be feasible to construct specific series concepts capable of discriminating between soils of these SLUs. This would be the case if a previously defined series already occupied the series "window" into which the present concepts were to be placed. Evidence from between-group variable comparisons suggests that, in the absence of specific series assignments, soils of ARLO/FEID, ARAR/FEID and ARTRW/AGSP(FEID) SLUs may be differentiated at phase level using these criteria--aspect, parent material, slope and surface texture. Application of two phase criteria to map units containing these soils could produce valid separations. Names of phases for soils from ARLO/FEID, ARAR/FEID and ARTRW/AGSP(FEID) SLUs, respectively, are: 1) aspect - north, south, south; 2) parent material - basalt, andesite and basalt; 3) slope - 4 to 8 percent, 4 to 8 percent and 0 to 4 percent; 4) surface texture - cobbly loam, loam and loam.

Results from statistical analysis of soil data suggests that soil properties besides those normally considered as taxonomic criteria in range soils may provide important means of soil differentiation. For example, of ARLO/FEID, ARAR/FEID and ARTRW/AGSP(FEID) SLUs, profiles of the ARTRW/AGSP(FEID) site contain nearly twice the concentration of extractable P and K as soils of ARLO/FEID or ARAR/FEID groups (Table 1.6). The differences between ARTRW/AGSP(FEID) profiles and those of ARLO/FEID and ARAR/FEID were significant in all but one nutrient category. Another soil property that clearly discriminates between pedons of ARTRW/AGSP(FEID) and those of ARLO/FEID and ARAR/FEID is depth to a subhorizon exhibiting angular blocky or prismatic structure. In these soils such ped types are associated with subhorizons that contain relatively high mean clay contents (37.6 to 48.7% by field estimate). The angular blocky or prismatic strata wholly or partially comprises the argillic horizon in each profile; however, the argillic horizon may feature subangular blocky structure in an upper, transitional BAt subhorizon. Results suggest that depth to angular blocky strata is significantly shallower in soil-landscape units supporting low sagebrush (A. arbuscula and A. longiloba) than in those which support big sagebrush (A. tridentata) plant communities. Mean depth to an angular blocky horizon in profiles from SLUs supporting low sagebrush range from 16.8 to 17.0 cm compared to a range of 21.8 to 37.8 cm for SLU soils supporting big sagebrush (Table 1.5). Lentz and Simonson (198x) reported a similar relationship for closely associated soils occurring within a multi-taxa soil-landscape unit. Summerfield and Peterson (1971) concluded that this same characteristic was the only consistent morphological difference between soils supporting A. arbuscula and A. tridentata communities in northwestern Nevada. Depth to compound prismatic-blocky strata occurred from 7 to 30 cm under A. arbuscula communities and 30 to 53 cm beneath A. tridentata communities. Zamora and Tueller (1973) examined soils supporting A. arbuscula and A. longiloba in northern Nevada. Depth to dense clay horizons, when present, ranged from 7 to 36 cm and averaged 19 cm. It is apparent that this morphological feature is to some degree an indicator of soil potential, and should be included in soil description and characterization. In the soil profile, depth to angular blocky strata is not necessarily related to the thickness of a specific horizon; therefore, when defining series concepts for soils containing argillic horizons, and especially those which support sagebrush communities, it may be beneficial to include a specific statement describing range in depth to angular blocky strata. The importance of horizon structure is emphasized here as a morphological parameter worthy of a soil scientist's watchful attention.

Structure type and nutrient content of subhorizons, and positions of subhorizons in the soil profile relative to the soil surface, are properties often ignored or neglected when classifying range soils. This research emphasizes the importance of these parameters, as well as more commonly observed properties such as rock fragment content, texture, horizon composition, elevation and aspect, for distinguishing between soils possessing different range potentials.

REFERENCES

Boesch, D. F. 1977. Application of numerical classification in ecological investigations of water pollution. U.S. Environmental Protection Agency. Ecological Res. Series EPA-600/3-77-033.

Doescher, P. S., R. F. Miller and A. H. Winward. 1984. Soil Chemical patterns under Eastern Oregon plant communities dominated by big sagebrush. Soil Sci. Soc. Am. J. 48: 659-663.

Eckert, Richard. 1957. Vegetation-soil relationships in some Artemesia types in northern Harney and Lake Counties, Oregon. Ph.D Thesis, Oregon State Univ., Corvallis. Univ. Microfilms, Ann Arbor, MI (Diss. Abstr. 00:24633).

Heerwagen, A. and A. R. Aandahl. 1961. Utility of soil classification units in characterizing native grassland plant communities in the Southern Plains. J. Range Manage. 14: 207-213.

Henderson, R. and J. M. Ragg. 1980. A reappraisal of soil mapping in an area of southern Scotland. Part II The usefulness of some morphological properties and of a discriminant analysis in distinguishing between the dominant taxa of four mapping units. J. Soil Sci. 31: 573-580.

Hironaka, M., M. A. Fosberg and A. H. Winward. 1983. Sagebrush-grass habitats of Southern Idaho. Forest, Wildlife and Range Exp. Stn., Univ. of Idaho, Moscow, Bull. No. 35.

Hull, D. H. and N. H. Nie. 1981. SPSS update 7-9: New procedures and facilities for releases 7-9. McGraw-Hill, Inc. New York.

Jennrich, R. and P. Sampson. 1983. P7M: Stepwise Discriminat Analysis IN Dixon, W.J. (ed.) BMDP statistical software. University California Press, Berkeley.

Kelley, J. C. and D. A. McManus. 1970. Hierarchical analysis of variance of shelf sediment texture. J. Sed. Petr. 40: 1335-1366.

Lentz, R. D. and G. H. Simonson. 198x. Correspondence of soil properties and classification units with sagebrush communities of Southeastern Oregon: II. Comparisons within a multi-taxa soil-landscape unit. Soil Sci. Soc. Am. J. (To be submitted)

Lentz, R.D. and G. H. Simonson. 198xa. A detailed soil inventory of Squaw Butte Experimental Range. Agric. Exp. Stn., Oregon State Univ., Corvallis, Spec. Pub. No. x.

Munn, L. C., G. A. Nielsen and W. F. Mueggler. 1978. Relationships of soils to mountain and foothill range habitat types and production in Western Montana. Soil Sci. Soc. Am. J. 42:135-139.

Nie, N. H., D. H. Hull, J. G. Jenkins, K. Steinbrenner and D. H. Bent. 1975. SPSS: Statistical package for the social sciences. McGraw-Hill, Inc. New York.

Nortcliff, S. 1978. Soil variability and reconnaissance soil mapping: a statistical study in Norfolk. J. Soil Sci. 29: 403-418.

Olsen, S. R. and L. A. Dean. 1965. Phosphorus. IN C. A. Black et al. (ed.) Methods of soil analysis, part 2. Agromomy 9: 1035-1048. Am. Soc. of Agron., Madison, Wisconsin.

Passey, H.B., V. K. Hugie, E. W. Williams and D. E. Ball. 1982. Relationships between soil, plant community, and climate on rangelands of the Intermountain West. USDA-SCS Tech. Bull. no. 1669.

Pratt, P. G. 1965. Potassium. IN C. A. Black et al. (ed) Methods of soil analysis, part 2. Agronomy 9: 1022-1030. Am. Soc. of Agron., Madison, Wisconsin.

Reynolds, S. G. 1975. Soil property variability in slope studies: suggested sampling schemes and typical required sample sizes. Z. Geomorph. N. F. 19: 191-208.

Robertson, D. R., J. L. Nielsen and N. G. Bare. 1966. Vegetation and Soils of alkali sagebrush and adjacent big sagebrush ranges in North Park, Colorado. J. Range Manage. 19: 17-20.

Soil Survey Staff. 1975. Soil taxonomy, a basic system of soil classification for making and interpreting soil surveys. Agric. Handb. 436.

Srivastava, M. S. and E. M. Carter. 1983. An Introduction to applied multivariate statistics. North Holland, New York.

Summerfield, H. B. and F. F. Peterson. 1971. Soil properties related to occurrence of big and low sagebrush in northwestern Nevada. Abst. of Pap., 24 Annual Meeting, Soc. for Range Manage., Reno, Nevada.

Tisdale, E. W. and A. Hironaka. 1981. The sagebrush-grass region: A review of the ecological literature. For., Wildl. and Range Sci. Exp. Stn., Univ. of Idaho, Moscow, Bull. no. 33.

Walkley, A. and I. A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci. 37: 29-38.

Winward, A. H. 1980. Taxonomy and ecology of sagebrush in Oregon. Agric. Exp. Stn., Oregon State Univ., Corvallis, Bull. no. 642.

Zamora, B. and P.T. Tueller. 1973. Artemisia arbuscula, A. longiloba and A. nova habitat types in Northern Nevada. Great Basin Nat. 33: 225-242.

CHAPTER II

CORRESPONDENCE OF SOIL PROPERTIES AND CLASSIFICATION UNITS WITH SAGEBRUSH COMMUNITIES IN SOUTHEASTERN OREGON: II. COMPARISONS WITHIN A MULTI-TAXA SOIL-LANDSCAPE UNIT

Rodrick D. Lentz

Gerald H. Simonson

CORRESPONDENCE OF SOIL PROPERTIES AND CLASSIFICATION UNITS WITH SAGEBRUSH COMMUNITIES IN SOUTHEASTERN OREGON: II. COMPARISONS WITHIN A MULTI-TAXA SOIL-LANDSCAPE UNIT

ABSTRACT

A multi-taxa soil-landscape unit composed of two dominant soil components supporting a range of heterogeneous sagebrush communities was examined in order to determine if soil properties and classification differed between plant community types. Twenty-seven site and species-cover parameters were measured for 64 vegetation sample sites within the complex. Cluster analysis of these data identified six recurring plant groupings (RPGs). Soil profile descriptions were collected from a proportionate number of randomly selected vegetation sample sites for each RPG. Morphological properties of sample profiles were compared by averaging values within aggregate horizons, termed super horizon categories (SHCs) , which were common to all profiles.

Recurring plant groupings were characterized by relative canopy cover of *Artemisia arbuscula*, *Artemisia tridentata* ssp. *wyomingensis*, *Festuca idahoensis*, *Agropyron spicatum*, total grasses, and total herbs. From all SHC parameters described for each profile, stepwise discriminant analysis selected depth of mollic epipedon, surface rock fragment cover, and thickness and average dry consistence of the argillic horizon as those which best distinguished between RPG associated soils. Evidence suggests that series separations are justified based on family and class distinctions of higher categories or differences in range of one or more soil

properties, including 1) horizon composition, 2) mollic epipedon thickness, 3) structure of BAt subhorizon, 4) thickness and 5) mean dry consistence of the argillic horizon. Phase level separations of RPG associated soils from identical families are feasible if both physiographic and surface criteria are utilized together.

CORRESPONDENCE OF SOIL PROPERTIES AND CLASSIFICATION UNITS WITH SAGEBRUSH COMMUNITIES IN SOUTHEASTERN OREGON: II. COMPARISONS WITHIN A MULTI-TAXA SOIL-LANDSCAPE UNIT

INTRODUCTION

In an earlier paper (Lentz and Simonson, 198x), soil classification units were shown to correspond with discrete soil-landscape elements which support different monolithic sagebrush communities. These researchers found considerable variation in soil character within several soil-vegetation mono-taxa units they examined in southeastern Oregon. Analysis of scale component patterns derived using data from each soil-landscape unit (SLU) indicated the surface strata components--soil texture, color, thickness and ped size contributed relatively greater variance at scale levels within SLUs than between them. Do changes in plant community consistently accompany this intra-SLU soil variation? If so, can soil taxonomic units (Soil Survey Staff, 1975) distinguish between soils exhibiting different range potentials? This study examines large scale soil- plant community relationships within a multi-taxa soil landscape delineation composed of two dominant soil components which support a number of transitional and heterogeneous sagebrush communities. The purpose of this study is 1) to identify the major recurring plant communities which inhabit this soil-landscape unit and 2) objectively determine if soils supporting these plant communities co-vary consistently in respect to their morphological properties or classification.

STUDY AREA

The research was conducted at Squaw Butte Range Experiment Station in southeastern Oregon. The station was previously described by Lentz and Simonson (198x). A multi-taxa soil-landscape unit was selected for study considering the following desired features: a) the soil-land-scape unit was complex relative to both soil and vegetation, b) range was in good condition, c) the unit was of adequate size, and d) accessible. The multi-taxa SLU chosen occupies an east-southeast facing sideslope of a moderately dissected lava plateau and includes an area of approximately 30 hectares. Its slope ranges from 2 to 9 percent and averages 5.5 percent. The soil-landscape unit is composed of several smaller landform subelements; the most distinctive of these form what appear to be a series of shallow inactive drainageways and interfluves that align themselves perpendicular to the slope gradient. Maximum microrelief between the two landform surfaces is approximately 60 cm. A third major subelement is a smooth slightly convex shaped slope conspicuously lacking in surface drainage features. In a recent soil survey of the Experimental Station, Lentz and Simonson (198xa) reported the study area to contain a complex of two soils classified as clayey, montmorillonitic, frigid Lithic Argixerolls and clayey, montmorillonitic, frigid Aridic Argixerolls. Vegetation is dominated by an <u>Artemisia arbuscula</u>/<u>Festuca idahoensis</u> plant community which has been previously described by Eckert (1957) and Tueller (Teuller, Paul. 1962. Plant Succession on two <u>Artemesia</u> habitat types in Southwestern Oregon. Ph.D. Thesis, Oregon State Univ., Corvallis.). This community is well established on smooth slightly convex and slightly concave plateau slope landform subelements. Subtle changes in soil and, or environmental conditions associated with different minor landform subelements produce a number of transitional communities in which A. tridentata ssp. wyomingensis increasingly displaces A. arbuscula as dominant shrub species. Complete substitution results in an A. tridentata ssp. wyomingensis/F. idahoensis plant community similar to one described by Doescher (1983).

MATERIALS AND METHODS

Vegetation sampling was conducted in late June, 1983. A cool, moist spring slightly delayed maturation of ephemeral annuals, assuring that most plant species were readily identifiable at this date. Floristic composition of polypedon vegetation was sampled at 64 sites using a multistage random sampling design. A 100 m^2 circular plot for measuring vegetation was selected as the largest size plot fitting the scale of vegetative units characterizing the soil-landscape unit. Canopy cover estimates for each plant species and surface rock fragments were measured with the line intercept method across the diameter of each sample plot, and by systematic visual inspection of the entire sample area. Location of baseline within each plot was confined to areas of vegetation representative of the plot as a whole. Variables recorded for each sample plot included a) cover and type of surface rock fragments, b) slope, c) aspect, d) landform type, f) vascular plant species and canopy cover, and g) mean size of sagebrush shrubs. Herbaceous species data were combined and indexed by total diversity and total cover. These characteristics became the attributes which describe each sample plot or entity.

Recurring plant groupings (RPGs) were identified using cluster analysis. This multivariate analytical technique objectively classified each sample plot into hierarchical groups of greater dissimilarity. Cluster analysis employed an agglomerative hierarchical (Boesch, 1977) and flexible clustering strategy (Lance and Williams, 1967), and utilized a percent standardized Bray-Curtis coefficient (Clifford and Stephenson, 1975) as a dissimilarity measure. Resulting hierarchical groups were cleaved at a dissimilarity level which produced the largest number of clusters while simultaneously avoiding excessive fragmentation of entities. Recurring plant groupings so identified were inspected for obvious misclassifications and adjusted accordingly.

A proportionate number of entities from identified RPGs were randomly selected for soil observations. Soil pits were excavated and described in representative locations within each of the selected vegetation sample plots using standard USDA Soil Conservation Service (Soil Survey Staff, 1975) procedures. Soil profiles were then defined in terms of super-horizon-categories (SHCs) (Lentz and Simonson, 198x) in order to facilitate statistical comparisons between soils associated with RPGs. Statistical procedures described previously by Lentz and Simonson (198x) for polypedon comparisons involving SHC soil descriptions were employed: 1) discriminant analysis aided in data reduction, 2) multivariate analysis of variance (MANOVA) evaluated equality of RPG soil mean vectors, and 3) Bonferroni confidence intervals examined between-group relationships for specific variables. Soil data from RPGs 1, 2 and 3 were subjected to further analysis in an attempt to obtain more precise group comparisons. A second MANOVA evaluated equality of mean vectors between the three soil groups, and Bonferroni confidence intervals were constructed to test for group differences for specific variables. Conceptual profiles for each RPG were defined using a full sample strategy (Lentz and Simonson, 198x). Nonordered variables (eg. landform shape, structure type, etc.) were examined using frequency analysis.

RESULTS AND DISCUSSION

Recurring Plant Groupings

Hierarchical cluster analysis developed the dendrogram illustrated in Figure 2.1. Six clusters of sample plots are delineated at a dissimilarity level of 0.3; characteristics of these recurring plant groupings (RPGs) are listed in Table 2.1. After careful examination of individual samples relative to RPG qualities, three misclassified entities were placed into more representative groups. Recurring plant groupings appear to be closely related to landform position, each occupying a different subelement.

The influence of microtopography on the distribution of vegetation has been previously documented in a New York mesophytic forest (Gauch and Stone, 1979), Wisconsin prairie-marsh ectone (Zedler and Zedler, 1969) and Utah sagebrush-grass steppe (Walker and Brotherson, 1982). One may infer from these reports that when other factors are constant, the integrity of large scale plant community classification is enhanced if it is also correlated with the associated topography. Thus, the correspondence of RPGs to landform subelements found in this study provided added credibility to the classification procedure employed.

Artemisia arbuscula dominated plant communities were represented by all RPGs except number four, in which *A. tridentata* spp. *wyomingensis* was the prevalent shrub (Table 2.1). Those RPGs featuring the least shrub cover included vegetation sites 1, 5 and 6 (12.2, 15.8 and 7.0%). These occupied convex positions on rocky crests, plateau slopes, and low interfluve areas between drainageways.

FIGURE 2.1. Dendrogram showing vegetation sample plots (entities) linked into groups of greater and greater dissimilarity. Six recurring plant groupings (RPGs) were formed by cleaving the hierarchy at a dissimilarity level of 0.3.

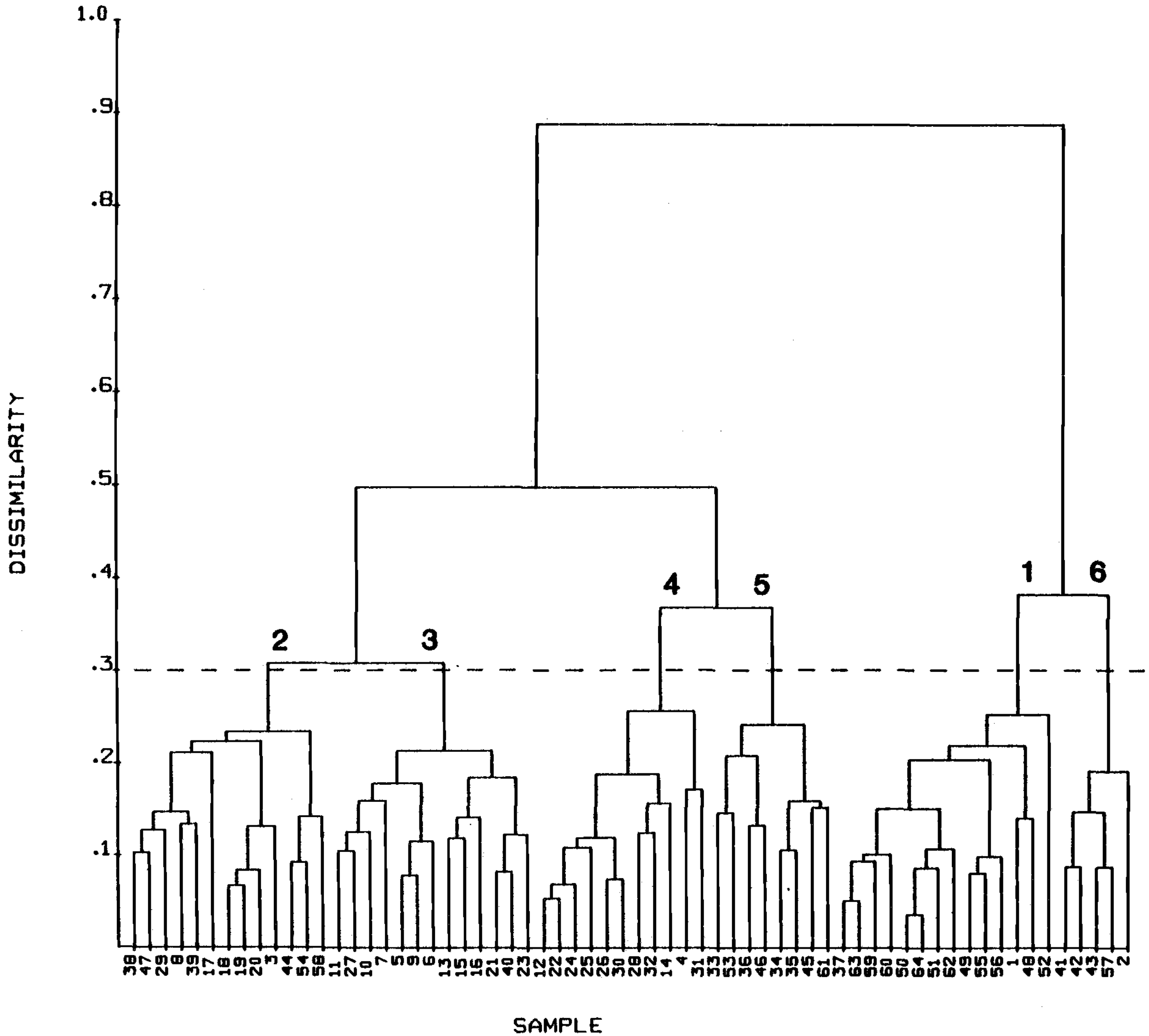

DISSIMILARITY
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
1
2
3
4
5
6
38 47 29 8 39 17 18 19 20 3 44 54 58 11 27 10 7 5 9 6 13 15 16 21 40 23 12 22 24 25 26 30 28 32 14 4 31 33 53 36 46 34 35 45 61 37 63 59 60 50 64 51 62 49 55 56 1 48 52 41 42 43 57 2
SAMPLE

FIGURE 2.1

Table 2.1. Landform and plant community characteristics of repeating plant groupings. ARAR8 = Artemisia arbuscula; ARTRW = Artemisia tridenta ssp. wyomingensis; FEID = Festuca idahoensis; AGSP = Agropyron spicatum.

REPEATING PLANT GROUPINGS	LANDFORM		PLANT COMMUNITY				
	SHAPE	SUBELEMENT	ARAR8	ARTRW	FEID/AGSP	TOTAL GRASSES	TOTAL HERBS
One	Sl. Convex	Smooth Slope	**		*	***	*
Two	Sl. Concave	Smooth Slope	****	+	*	**	*
Three	Sl. Concave	Inactive drainageways	***	*	**	****	+
Four	Sl. Convex	Interfluve Hummocks	**	****	*	***	+
Five	Sl. Convex	Low Interfluve/Slope	**	+	*	***	+
Six	Sl. Convex	Rocky Crests	*		+	**	+

Cover classes (% canopy cover):
blank = 0-0.5 + = 0.5-3.5 * = 3.5-8.0 ** = 8.0-13.5 *** = 13.5-16.0 **** = >16.0

The vegetation sites which exhibited the greatest sagebrush cover were RPGs 3 and 4 (21.1 and 26.8%); they occurred in concave drainageways and on convex interfluve hummocks, respectively. Grass and herbaceous cover was lowest in RPGs 2 and 6 (17.1 and 13.6%), and relatively greatest in RPGs 1 and 3 (19.2 and 22.5%). While most plant communities accommodated several codominant grass species, grass cover in RPG 6 consisted almost exclusively of _Poa sandbergii_ and _Sitanion hystrix_. Cover of herbaceous plants in RPGs 1 and 2 (4.1 and 3.7%) was relatively higher than the others; herb cover was lowest in groups 6 and 4 (2.6 and 2.7). Recurring plant groupings were clearly differentiated based on topographic position and relative cover values for dominant sagebrush, _Festuca idahoensis_ and _Agropyron spicatum_ grasses, total grasses, and total herbaceous species. (Site and vegetation data for sample plots comprising each RPG are listed in Appendix B.)

Discriminant Analysis of Soil Data

From SHC parameters describing each soil profile the stepwise discriminant procedure selected depth of mollic epipedon and surface rock fragment cover as those which best distinguished between RPG-associated soils. Separation achieved using selected discriminating variables is presented in Figure 2.2. Two new canonical variables were derived from linear combinations of the selected parameters such that the first best discriminated between polypedons and the second was the next best discriminating linear combination uncorrelated with the first. Standardized canonical variables were evaluated at group means and transformed values plotted for each new variable. Proximity of group means shown in the scatter plot implies relative similarity

FIGURE 2.2. Plot of canonical variables one and two. These are first and second best discriminating linear combinations of SHC parameters, depth of mollic epipedon and surface rock fragments. These variables were selected in a discriminant analysis of all parameters and have the highest partial F-test values with respect to the six groups. Numbers and field plots represent transformed means of recurring plant groupings (RPGs) and areas encompassing transformed RPG sample values, respectively.

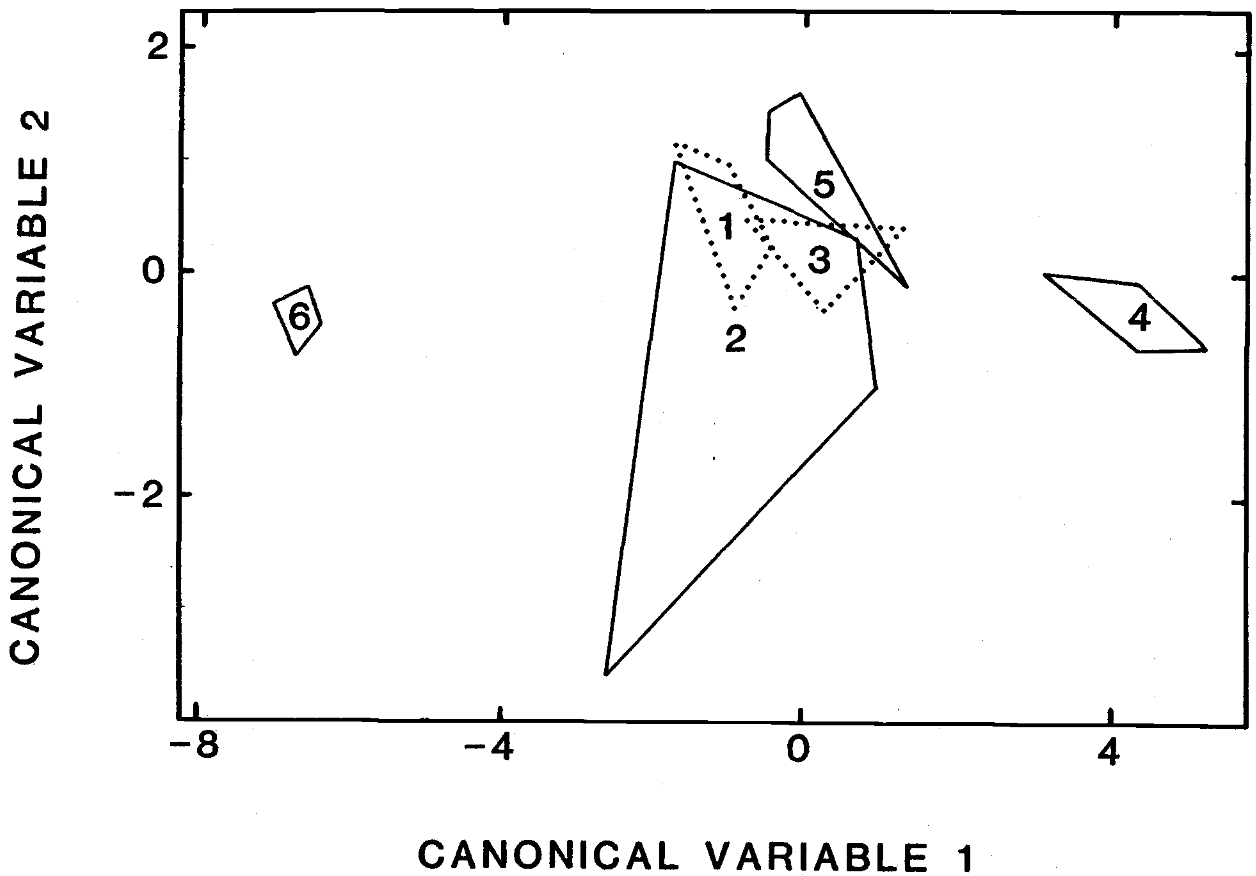


FIGURE 2.2

of soils. Figure 2.2 suggests that soils from RPGs 4 and 6 exhibited the greatest contrast in morphological character. Similarly, vegetation supported by these soil groups represented two extremes; RPG 6 sites sustain only A. arbuscula and a meager population of grasses and forbs while RPG 4 plots sustain A. tridentata ssp. wyomingensis as the dominant shrub, and a relatively large population of grasses and herbs. The remaining four groups are closely associated, but RPG 5 is separated slightly from the strongly overlapping sample fields of RPGs 1, 2 and 3. Obviously, the parameters selected during an overall discriminant analysis of the six groups were not capable of clearly differentiating between RPGs 1, 2 and 3. To improve group separation two additional variables were selected for their high between-group variance/within-group variance ratios with respect to RPGs 1, 2 and 3. Added parameters described thickness of argillic horizon and average dry consistence of soils in the argillic horizon. A new set of canonical variables was derived using all four parameters. The resulting plot of mean values and sample fields for the first and second new canonical variables (Fig. 2.3) suggests that variation in these four soil characteristics provides important evidence justifying separation of groups.

These four selected soil parameters, along with several others, comprised variable vectors which characterized soils from each RPG. Results of the one-way multivariate analysis of variance (MANOVA) test which examined overall equality of RPG soil mean vectors are presented in Table 2.2. The null hypothesis was rejected at a significance level less than 0.01. We conclude that all RPG soil mean vectors are not equal. Mean values for selected variables and between-group

FIGURE 2.3. Plot of canonical variables one and two. These are first and second best discriminating linear combinations of SHC parameters, 1) depth of mollic epipedon, 2) surface rock fragments, 3) thickness of argillic horizon, and 4) mean dry consistence of argillic horizon. The latter two were added because they produced the highest between-group/within-group variance ratios for groups one, two and three. Numbers and field plots represent transformed means of recurrimg plant groupings (RPGs) and areas encompassing transformed RPG sample values, respectively.

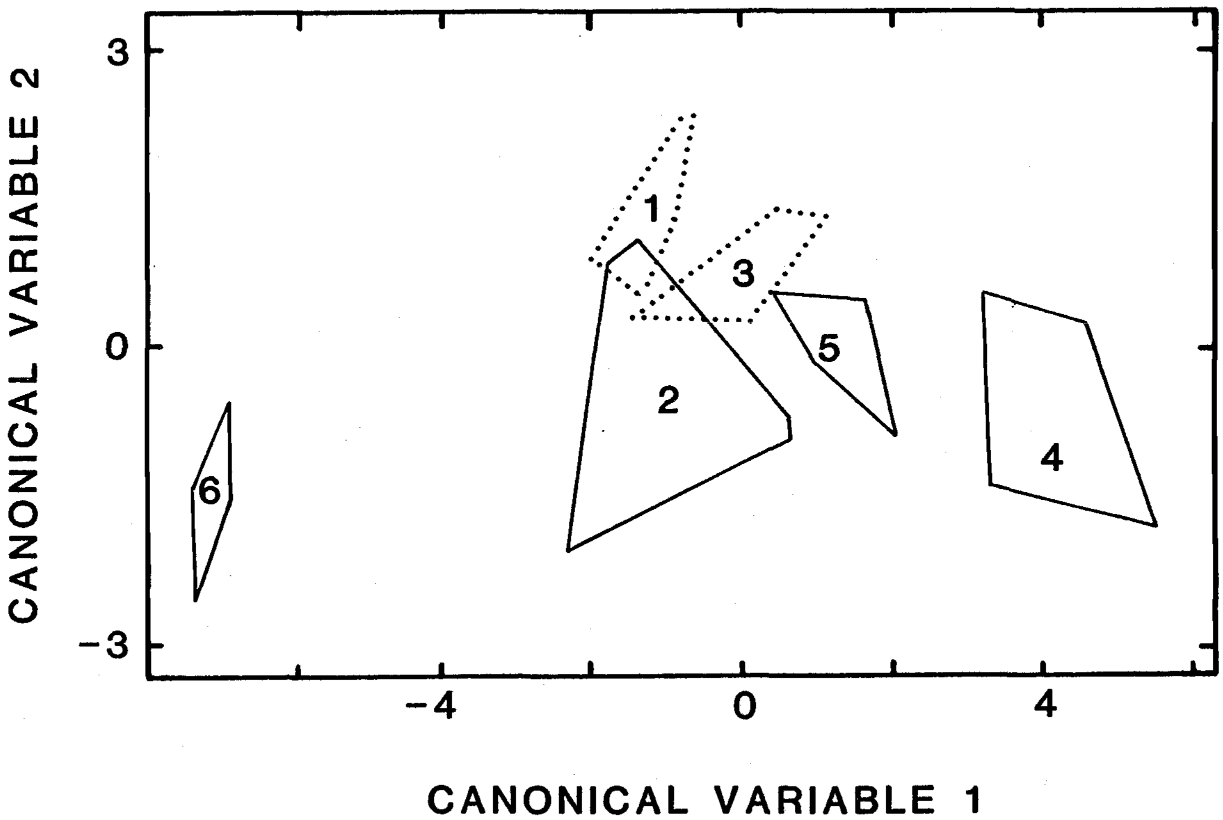


FIGURE 2.3

TABLE 2.2. Results of overall one-way multivariate analysis of variance (MANOVA) tests comparing equality of mean vectors for selected soil parameters. Comparisons between all six recurring plant groupings, and groups one, two and three were conducted.

ONE-WAY MULTIVARIATE ANALYSIS OF VARIANCE (MANOVA)*			
Recurring Plant Groupings Compared	Wilks Lambda	df	Approx. F (P-Value)
One through Six	0.03102	35,57	2.094 (0.006)
One, Two, Three	0.42467	4,22	2.940 (0.043)

* Null Hypothesis: Group mean vectors are equal.

comparisons for variables included in the MANOVA are reported in Table 2.3.

Conceptual profiles for soils representing each RPG are presented in Figure 2.4. This diagram also depicts major landform and vegetation characteristics for repeating plant groupings from which profiles were derived. Note the similarity in profile horizonation exhibited by all groups; only soil profiles from RPGs 4 and 6 differ slightly in horizon identity and sequence from other profiles. Structure featured in common horizons is also nearly constant. Two conspicuous exceptions are BAt horizons in soil profiles from RPG 3 and 4; these exhibit subangular blocky structure while those of other RPG profiles contain angular blocky structure.

Family Classification

Availability of soil temperature and moisture data for the study area is extremely limited. The Soil Conservation Service (SCS) correlated all soils in a recently completed soil survey of the Experiment Station (Lentz and Simonson, 198xa) into series with aridic moisture and frigid temperature regimes. Preliminary data collected by Lentz and Simonson, (198x) suggest that soils of the station may be warmer and more moist than previously anticipated, having characteristics at least marginally representative of xeric moisture and mesic temperature conditions. For purposes of soil classification in this research, SCS determinations of soil climatic regimes were assumed to be adequate.

Mean solum thickness of soils across the soil-landform element range from 25 cm for profiles from RPG 6, to 67 cm for those of RPG 5 (Table 2.3). Mean soil depth for soils from RPGs 4 and 5 were 60 and

TABLE 2.3. Mean values for selected variables and between-group comparisons for variables included in MANOVA tests.

SOIL CHARACTERISTICS	MEANS OF RECURRING PLANT GROUPINGS (RPGs)					
	ONE	TWO	THREE	FOUR	FIVE	SIX
Depth to Bedrock (cm)	38.3^{c*}	45.5^{b}	43.1^{bc}	59.7^{d}	67.1^{e}	25.0^{a}
Surface Rock fragment Cover (%)	14.4	22.0	13.4	3.9	7.3	40.0
Surface Stone Cover (%)	1.2^{bc}	4.5^{d}	3.8^{d}	0.1^{a}	2.5^{cd}	10.0^{e}
Depth to angular blocky strata (cm)	19.0^{bc}	17.8^{b}	20.5^{c}	25.0^{d}	17.8^{b}	14.0^{a}
BCt subhorizon (Present: > 0.5) (Absent: < 0.5)	0.6^{b}	0.7^{b}	0.7^{b}	0.3^{b}	0.8^{c}	0.0^{a}
Munsell mean dry color value (0-18 cm)	5.2^{a}	5.2^{a}	5.3^{a}	5.3^{a}	5.3^{a}	6.1^{b}
Munsell mean dry color Chroma (0-18 cm)	2.7	2.6	2.8	2.8	2.7	2.9
Munsell mean moist color value (0-18 cm)	3.1	3.2	3.1	3.1	3.2	3.7
Munsell mean moist color chroma (0-18 cm)	2.7	2.6	2.8	3.0	2.7	3.1
Thickness of Mollic Epipedon (cm)	19.5^{b}	22.9^{c}	22.5^{c}	30.7^{d}	22.5^{c}	13.8^{a}
Family Control Sec. Est. Clay (% by dw.)	43.5	41.8	44.4	38.7	40.2	40.5
Family Control Sec. Est. Rock fragments (% by vol.)	29.2^{b}	32.6^{bc}	23.9^{a}	23.6^{a}	23.9^{a}	37.5^{c}
Thickness of Argillic horizon (cm)	8.6^{A**}	11.8^{B}	11.0^{B}	15.7	15.7	7.0
Mean Dry Consistence of Argillic horizon	3.7^{B}	3.1^{A}	3.5^{B}	2.9	3.2	2.5

* Variables selected for overall MANOVA of soils from RPGs one through six. Similar lower case letters indicate nonsignificant differences ($\alpha = 0.05$) between group means.

** Variables selected for MANOVA of soils from RPGs one, two and three only. Similar upper case letters indicate nonsignificant differences ($\alpha = 0.05$) between group means.

FIGURE 2.4. Diagrams depict the conceptual profile, landform subelement, and plant community associated with each recurring plant grouping (RPG). Dashed shrub outlines indicate very low cover for those plants. Grass cover in illustrations is proportional to that in RPGs. Patterns in conceptual profiles correspond to horizon structure type, as defined in the legend below.

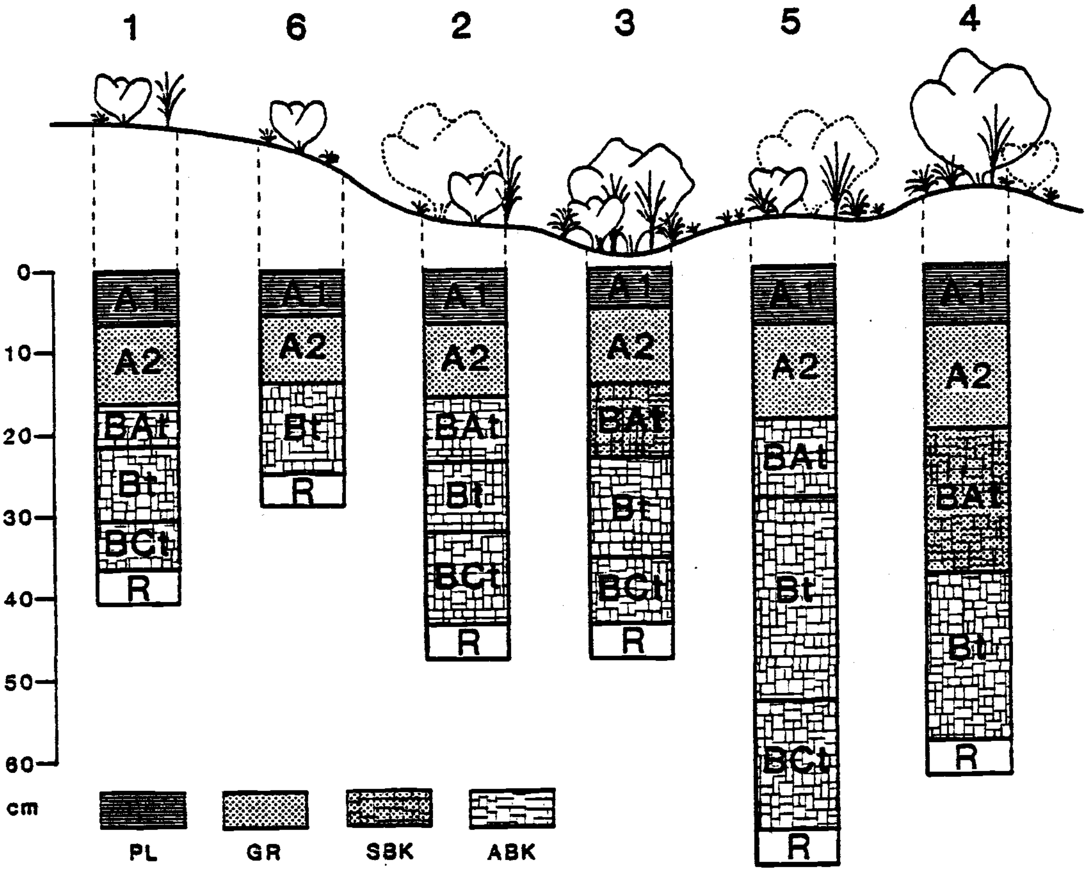


FIGURE 2.4

67 cm respectively; these pedons were significantly deeper than those from other RPGs, which averaged less than 50 cm deep to bedrock. Profiles from RPG 6 were significantly more shallow than other groups; their mean soil depth differed by at least 13 cm from that of the remaining soils. Determination of the presence of a mollic epipedon in shallow soils (50 cm or less) is dependent primarily upon the nature of the 0 to 18 cm surface layer. For deeper soils (50 to 75 cm) in the study area, the mollic epipedon is required to be at least 18 cm thick and more than one-third the depth from soil surface to the base of the argillic horizon (Soil Survey Staff, 1975). For shallow soils representative of RPGs 1, 2, 3 and 6, mean soil colors of the 0 to 18 cm surface layer indicate that only RPG 6 soils are too light to meet mollic criteria (Table 2.3). A significant difference in mean dry color value (MDCV) of this layer was detected between soils of RPG 6 (MDCV = 6.1) and those of the first three groups (MDCV = 5.2 or 5.3). Lentz and Simonson (198x) sampled many soils within the experiment station; their results suggest that surface horizons exhibiting mollic coloration do contain at least one percent organic matter. It was assumed that soils from RPGs 1, 2 and 3 had similar organic matter contents and so were considered mollic. In moderately deep soils from RPGs 4 and 5, mean thickness of the dark surface epipedon exceeded 18 cm and was thicker than one-third the mean depth from soil surface to the base of the argillic horizon (Table 2.3). Epipedons of these soil groups also were assumed to satisfy organic matter content requirements and were determined to be mollic.

Soils of all groups contained argillic horizons. Family particle size class was clayey for soils from RPGs 1 through 5, but clayey-skeletal for those from RPG 6. Mean clay content (field estimate) for the family texture control section of each soil group ranged from 39 to 44 percent; mean volumetric rock fragment content (field estimate) ranged from 24 to 33 percent for soils from RPGs 1 through 5 and 38 percent for those of RPG 6. Typically, the upper boundaries of argillic horizons were clear (2.5 to 5.0 cm in thickness) and, in moderately deep soils, an increase in clay content along the boundary was less than 20 percent within 7.5 cm depth. Swanson (1983) sampled a range of soils in and near Squaw Butte Experimental Station and reported that base saturation in soil profiles varied from 89 to 97 percent. There was no indication that base saturation of soils examined in this study should differ significantly from those pedons examined by Swanson.

Soils of each polypedon were classified to family level based on the above information and assumptions concerning SCS determinations of soil moisture and temperature regimes, and family mineralogy class. Soils of RPGs 1, 2 and 3 were identified as clayey, montmorillonitic, frigid Lithic Argixerolls; soils of RPGs 4 and 5 are members of fine, montmorillonitic, frigid Aridic Argixerolls; and soils from RPG 6 were identified as clayey, montmorillonitic, frigid Lithic Xerollic Haplargids.

Series Classification

Evidence suggests that soils from each RPG may be classified into a separate series based on family and class distinctions of higher categories, or differences in range of soil properties. Soils of RPG 6 belong to a unique family in comparison to other soils and must be assigned to a separate soil series.

Pedons of RPGs 4 and 5 are members of a distinct family and are separated from other soils on this basis. Though of the same family, soils of RPG 4 and 5 may be assigned to different soil series based on differences in horizonation. Between-group comparisons for a binary variable measuring presence/absence of the BCt subhorizon indicate that this subhorizon is dominantly present (mean value of variable is greater than 0.5) in profiles of RPG 5 but typically absent in soils from RPG 4 (Table 2.3). Other variable comparisons between soils of RPGs 4 and 5 revealed significant differences involving thickness of the mollic epipedon. In RPG 4 soils, mean thickness of the mollic epipedon is 30.7 cm and ranged from 27.5 to 32.5 cm; the same epipedon in soils from RPG 5 had a mean thickness of 22.5 cm and ranged from 17.5 to 25.0 cm.

Results from frequency analysis of nonordered variables suggested that structure of the BAt subhorizon also differed between these soil groups. The dominant structure comprising this subhorizon in RPG 4 soils was subangular blocky while its counterpart in RPG 5 soils was angular blocky (Figure 2.4). This contrast in structure type is also implied by a change in the parameter which measures depth to a horizon exhibiting angular blocky or prismatic structure in the soil profile. Mean depth to angular blocky strata was found to be significantly greater in soils from RPG 4 than in those of RPG 5 (Table 2.3). Since thickness of the A horizon in both groups was nearly identical, one may infer that structural differences in the upper argillic horizon, or BAt subhorizon, were primarily responsible for changes in this parameter. Series level separation of soils from RPG 4 and 5 appears justifiable in view of contrasts in 1) horizonation, 2) mollic epipedon thickness and 3) structure type of transitional BAt subhorizon.

Soils of RPGs 1, 2 and 3 are distinguished from series representing those of other soil groups on the basis of Family or class distinctions in higher taxonomic categories. Soils of these three groups are members of the same family and, as an examination of their conceptual profiles (Fig. 2.4) indicates, exhibit identical horizonation. However, results from a frequency analysis for structure type (grouped by polypedon and horizon) suggest that BAt subhorizons in soils of RPG 3 typically possess subangular blocky structure, whereas an angular blocky construction is more common in BAt subhorizons of soils from RPGs 1 and 2.

Soils from RPGs 1, 2 and 3 were compared in a separate MANOVA analysis. For this procedure, soils were defined using two variables which individually produced the largest univariate F-test-values between the three groups. Results indicated that mean vectors were not equal (Table 2.2); significant differences were observed between soils of these groups when two parameters of the argillic horizon, 1) thickness and 2) average dry consistence of soil, were considered together. Between-group comparisons for these parameters are presented in Table 2.3. The data suggest that soils from RPGs 1, 2 and 3 may be separated at the series level utilizing the criteria discussed above; however, diagnostic properties of each soil group must be carefully specified in range-in-characteristics-statements for each series concept. Definitions of those properties which provide critical differentiation between series are listed in Table 2.4.

Table 2.4. Definitions of soil properties which provide critical series level differentiation between soils of repeating plant groupings one, two and three.

Soil Property	Soil Source--Repeating Plant Groupings (RPGs)		
	One	Two	Three
Structure of BAt Horizon	Angular blocky or Prismatic	Angular blocky or Prismatic	Subangular blocky
Thickness of Argillic Horizon	12 to 22 cm	22 to 30 cm	22 to 30 cm
Mean Dry Consistence of Argillic Horizon	Very Hard or Extremely Hard	Hard	Dominantly Hard, but ranges to Very Hard

Phase Level Criteria

Under some circumstances it may not be feasible to correlate RPG soils into several distinct series even though differences in soil characteristics justify the separation. This situation would more commonly occur among soil groups that are members of the same family. If soils from RPGs 1, 2 and 3 were correlated into one series, evidence from between-group variable comparisons imply that soils still may be differentiated utilizing common phase critieria. The same is true for soils of RPGs 4 and 5, within their family class. In the case of the former three groups, application of two phase criteria describing soil physiographic and surface characteristics (Table 2.3) could be utilized to distinguish between soils (USDA, Soil Conservation Service, 1983). Names of phases for soils of RPGs 1, 2 and 3, should they be represented by a single series, are presented in Table 2.5. In the latter groups, RPGs 4 and 5, application of a single phase criteria describing surface characteristics could distinguish between soil groups. Soils from RPGs 4 and 5 would be designated as stony and extremely stony surface phases, respectively. If series distinctions between these groups were not feasible, separations based on phase criteria would still be justified.

Table 2.5. Phase designations for soils from repeating plant groupings one, two and three. These phases are capable of distinguishing between groups if soils are not first differentiated at the series level.

Soil Source (Repeating Plant Groupings)	Phase Criteria			
	Texture	Physiographic	Slope	Surface
One	loam,	*	4 to 8 percent	very stony
Two	loam,	*	4 to 8 percent	extremely stony
Three	loam,	depressional,	4 to 8 percent	extremely stony

* The usual physiographic phase is not named (USDA-SCS, 1983).

REFERENCES

Boesch, D. F. 1977. Application of numerical classification in ecological investigations of water pollution. U.S. Environmental Protection Agency. Ecological Res. Series EPA-600/3-77-033.

Clifford, H. T. and W. Stephenson. 1975. An introduction to numerical classification. Academic Press, New York.

Doescher, P. W. 1983. Phyto-edaphic relationships and ecotypic development of Festuca idahoensis in eastern Oregon habitat types of Artemisia tridentata. Ph.D. Thesis, Oregon State Univ., Corvallis. Univ. Microfilms, Ann Arbor, MI (Diss. Abstr. 8227577).

Eckert, Richard. 1957. Vegetation-soil relationships in some Artemesia types in northern Harney and Lake Counties, Oregon. PhD Thesis, Oregon State Univ., Corvallis. Univ. Microfilms, Ann Arbor, MI (Diss. Abstr. 00:24633).

Gauch, H. G. and E. L. Stone. 1979. Vegetation and soil pattern in a mesophytic forest at Ithaca, New York. Am. Midl. Nat. 102: 332-345.

Lance, G. N. and W. T. Williams. 1967. A general theory of classificatory sorting strategies. I. Hierarchical systems. Comput. J. 1:15-20.

Lentz, R. D. and G. H. Simonson. 198x. Correspondence of soil properties and classification units with sagebrush communities of Southeastern Oregon: I. Comparisons between simple polypedons. Soil Sci. Soc. Am. J. (To be submitted)

Lentz, R.D. and G. H. Simonson. 198xa. A detailed soil inventory of Squaw Butte Experimental Range. Agric. Exp. Sta. Spec. Pub. No. X, Oregon State Univ., Corvallis.

Soil Survey Staff. 1975. Soil taxonomy, a basic system of soil classification for making and interpreting soils surveys. U.S. Agric. Handb. 436.

Swanson, S. R. 1983. Infiltration, soil erosion, nitrogen loss, and soil profile characteristics of Oregon lands occupied by three subspecies of Artemisia tridentata. Ph.D. Thesis. Oregon State Univ., Corvallis. Univ. Microfilms, Ann Arbor, MI (Diss. Abstr. 8308814).

USDA, Soil Conservation Service. 1976. National Range Handbook. U.S. Government, Washington D.C.

USDA, Soil Conservation Service. 1983. National Soils Handbook. U.S. Government, Washington D.C.

Walker, G. R. and J. D. Brotherson. 1982. Habitat relationships of basin wildrye in high mountain valleys of Central Utah. J. Range Manage. 35:628-632.

Zedler, S. B. and P. H. Zedler. 1969. Association of species and their relationship to microtopography within old fields. Ecol. 50: 432-442.

SUMMARY AND CONCLUSIONS

This research applies multivariate statistical analyses to problems involving soil classification and discrimination. Soil groups supporting different sagebrush communities at different scales of association were compared with respect to conceptual profiles and two separate statistical procedures. Results from the three procedures were highly complementary. Soil groups supporting plant assemblages of different habitat types or phases of habitat types were assigned to unique series concepts based on family and class distinctions of higher categories, or differences in range of soil properties.

A strong, fairly precise relationship exists between properties or classification of these Eastern Oregon soils and their associated natural plant communities; but, this correspondence is fully precise only at lower levels of categorization (eg. at series and phase level for soils, and habitat type or phase of habitat type for plant communities). Some soil properties, such as nutrient content, subhorizon structure, and a parameter which described depth to a clayey and blocky subhorizon, are not commonly utilized to distinguish between soil taxa. Yet this study emphasizes the importance of these parameters, as well as more commonly observed soil characteristics such as rock fragment content, texture, horizon composition, elevation and aspect, for distinguishing between soils possessing different range potentials.

Soil-Vegetation Relationships

Some clear associations between soil properties and inhabiting plant species have been outlined during the course of this study; however, no direct evidence is presented herein which attributes these associations to cause/effect mechanisms. It is not always obvious whether vegetation is responding to the climatic environment and subsequently alters soil properties, or is responding directly to edaphic conditions.

An interaction exists between climate and soils; the influence of climate on the distribution of plants as individuals and as members of communities may be modified by the soil factor, and vice versa (Passey et al., 1982). A similar interaction occurs between individual properties of soils. For example, in Chapter two the recurring plant groupings 4 and 5 were located on similar landform subelements, under nearly identical climatic condition. Mean solum thickness for both soil groups was greater than 59 cm, adequate to supply enough water and nutrients to support an ARTRW community. Yet soils of RPGs 4 and 5 support different plant communities; RPG 4 is dominated by ARTRW while RPG 5 is dominated by ARAR. Soil properties of RPG 5 differ from RPG 4 soils in these respects: 1) clayey and angular blocky strata occur at a shallower depth in the profile, 2) the mollic epipedon is thinner and, 3) a transitional BCt subhorizon is absent. The effect of solum depth on plant distribution was apparently modified by changes in the aforementioned soil properties. Those changes effectively decreased the soil's total water supplying capacity and inhibited movement of soil gases through the profile. The latter effect is most pronounced in winter and spring when the soils are wettest.

The manner in which soils correspond to their associated natural plant communities is a function of climatic or environmental conditions, biotic factors, and the summary effects resulting from a complex interaction of numerous soil parameters. Therefore, it is unlikely that the plant-soil correspondence observed here at Squaw Butte will be precisely the same as that found in the next state, county, or even ten miles distant. At another location, if environmental, biological and soil circumstances are generally similar to that of Squaw Butte, one may expect to observe similar but perhaps differently calibrated plant-soil relationships. For instance, a parameter measuring depth to clayey and angular blocky horizons, if present, is often an indicator of a soils potential to support ARLO and ARAR, communities. In Northern Nevada soils, the average depth to this horizon is 19 cm (Zamora and Teuller, 1973), 2 cm greater than the mean for Squaw Butte soils (16.9 cm). The difference may result from a cooler and slightly wetter climate associated with the more northerly location.

In general, soil properties that distinguish between soil groups supporting different habitat types are those which 1) reflect differences in soil temperature, moisture, aeration and nutrient conditions between sites or, 2) are themselves capable of influencing the expression of these factors in the soil profile. Soil properties utilized to differentiate between soil groups supporting different plant communities are listed in Appendix C. Possible effects of these soil properties on factors influencing plant distribution are described there as well. Relative levels of these factors in soils of soil-landscape units (SLUs) which supported different monolithic sagebrush communities are listed in Table 1.

TABLE 1. Comparisons between monolithic sagebrush communities-relative levels of four important soil factors. Increasing values represent 1) increasing soil temperature, 2) increasing moisture availability, 3) better soil aeration and 4) increasing nutrient supply.

	PLANT COMMUNITIES ASSOCIATED WITH MONO-TAXA SLUs					
SOIL FACTORS	ARLO/AGSP	ARLO/FEID	ARAR/FEID	ARTRW/AGSP	ARTRW/AGSP (FEID)	ARTRV/FEID-AGSP
TEMPERATURE	4	2	2	3	2	1
MOISTURE	1	3	4	2	4	5
AERATION	1	1	1	2	2	3
NUTRIENTS	1	1	1	2	2	3

Several relationships are evident: First, ARTRV soils were relatively cooler, more moist, better aerated and higher in nutrients than others. Second, big sagebrush (ARTRW, ARTRV) soils exhibited better aeration and nutrient supply relative to low sagebrush (ARLO, ARAR) soils. Third, soils supporting FEID were cooler and featured a greater available water capacity relative to soils supporting AGSP. Finally, the available water capacity of ARLO soils was less than that of ARAR soils, due to the comparatively larger volume of rock fragments present in ARLO profiles.

Implications for Soil Inventories

Results of this research suggest that soil scientists working in the field can expect to observe a good correspondence between soil taxons and their associated natural plant communities. Obviously, soil surveyors cannot examine the landscape as thoroughly as was done here. Yet, a better understanding of the manner in which changing soil properties influence plant distribution will enable field workers to make more meaningful series and phase level separations between soils. Presently, conceptual separations between soils possessing conspicuously different range potentials are often based on superficial profile or site characteristics which may or may not 1) represent valid differences between soils and, or 2) be properly indicative of the soil's range potential. Information linking properties of soils to their range potential and productivity provides an important means of improving the accuracy of both the soil mapping process and the interpretations and predictions derived from the completed soil inventory.

In Chapter two, a real correspondence between recurring plant groupings (RPGs) and their associated soils was observed. Though differences in soils and associated plant communities exist between RPGs, it does not necessarily follow that these soil bodies should be recognized separately in a soil survey. Soil inventories on rangeland delineate the soil resource as it relates to both range potential, and use and management. Since use and management of rangeland is not intensive, differences between some precisely defined RPGs become insignificant. Recognizing such similar soil groups under these circumstances would unnecessarily complicate the content and utility of the inventory.

LITERATURE CITED

Baldwin, E. M. 1976. Geology of Oregon. Edward Brothers, Inc., Ann Arbor, Michigan.

Barkham, J. P. and J. M. Norris. 1970. Multivariate procedures in an investigation of vegetation and soil relations of two Beech woodlands, Cotswold Hills, England. Ecol. 51: 630-639.

Birkeland, P. W. 1974. Pedology, weathering and geomorphological research. Oxford University Press, Inc., New York.

Boesch, D. F. 1977. Application of numerical classification in ecological investigations of water pollution. U.S. Environmental Protection Agency. Ecological Res. Series EPA-600/3-77-033.

Brisbois, A. 1959. Dry climates of Central and Eastern Oregon. M.S. Thesis, Oregon State Univ., Corvallis.

Buol, S. W., F. D. Hole and R. J. McCracken. 1973. Soil genesis and classification. The Iowa State University Press, Ames.

Clements, F. E. 1905. Research methods in ecology. The University Publishing Company, Lincoln, Nebraska.

Clifford, H. T. and W. Stephenson. 1975. An introduction to numerical classification. Academic Press, New York.

Crosson, L. S. and R. Protz. 1974. Quantitative comparison of two closely related soil mapping units. Can. J. Soil Sci. 54: 7-14.

Culver, R. N. 1964. An ecological reconnaissance of the *Artemisia* steppe on the East-Central Owyhee Uplands of Oregon. M.S. Thesis, Oregon State Univ., Corvallis.

Daubenmire, R. F. 1974. Plants and environment. John Wiley and Sons, New York.

Doescher, P. W. 1983. Phyto-edaphic relationships and ecotypic development of *Festuca idahoensis* in eastern Oregon habitat types of *Artemisia tridentata*. Ph.D. Thesis, Oregon State Univ., Corvallis. Univ. Microfilms, Ann Arbor, MI (Diss. Abstr. 8227577).

Doescher, P. S., R. F. Miller and A. H. Winward. 1984. Soil Chemical patterns under Eastern Oregon plant communities dominated by big sagebrush. Soil Sci. Soc. Am. J. 48: 659-663.

Eckert, Richard. 1957. Vegetation-soil relationships in some Artemesia types in northern Harney and Lake Counties, Oregon. Ph.D Thesis, Oregon State Univ., Corvallis. Univ. Microfilms, Ann Arbor, MI (Diss. Abstr. 00:24633).

Finny, H. R., N. Holowaychuk and M. R. Heddleson. 1962. The influence of microclimate on the morphology of certain soils of the Allegheny Plateau of Ohio. Soil Sci. Soc. Am. Proc. 26: 287-292.

Fosberg, M. A. 1963. Genesis of some soils associated with low and big sagebrush complexes in the Brown, Chestnut, and Chernozem-Prairie soils in South-Central and Southwestern Idaho. Ph.D. Thesis, Univ. of Wisconsin, Madison. Univ. Microfilms, Ann Arbor, MI (Diss. Abstr. 63:07607).

Gauch, H. G. and E. L. Stone. 1979. Vegetation and soil pattern in a mesophytic forest at Ithaca, New York. Am. Midl. Nat. 102: 332-345.

Greene, R. C., G. W. Walker and R. E. Corcoran. 1972. Geologic map of the Burns quadrangle, Oregon. USGS Misc. Geologic Investigations, Map I-446.

Hall, F. C. 1966. Vegetation-soil relations as a basis for resource management on the Ochoco National Forest of Central Oregon. Ph.D. Thesis, Oregon State University, Corvallis. Univ. Microfilms, Ann Arbor, MI (Diss. Abstr. 67:11806).

Hammond, L. C., W. L. Pritchett and V. Chew. 1958. Soil sampling in relation to soil heterogeneity. Soil Sci. Soc. Am. J. 22: 548-552.

Heerwagen, A. and A. R. Aandahl. 1961. Utility of soil classification units in characterizing native grassland plant communities in the Southern Plains. J. Range Manage. 14: 207-213.

Henderson, R. and J. M. Ragg. 1980. A reappraisal of soil mapping in an area of southern Scotland. Part II The usefulness of some morphological properties and of a discriminant analysis in distinguishing between the dominant taxa of four mapping units. J. Soil Sci. 31: 573-580.

Higgens, M. W. and A. C. Waters. 1967. Newberry caldera, Oregon: A preliminary report. Oregon Geology 29: 37-60.

Hironaka, M., M. A. Fosberg and A. H. Winward. 1983. Sagebrush-grass habitats of Southern Idaho. Forest, Wildlife and Range Exp. Sta., Univ. of Idaho, Moscow, Bull. No. 35.

Hugie, V. K., H. B. Passey and E. W. Williams. 1964. Soil taxonomic units and potential plant community relationships in a pristine range area of Southern Idaho. Am. Soc. Agron. Spec. Publ. 5: 206-211.

Hull, D. H. and N. H. Nie. 1981. SPSS update 7-9: New procedures and facilities for releases 7-9. McGraw-Hill, Inc. New York.

Jennrich, R. and P. Sampson. 1983. P7M: Stepwise Discriminat Analysis IN Dixon, W.J. (ed.) BMDP statistical software. University California Press, Berkeley.

Jenny, H. 1958. Role of the plant factor in pedogenic functions. Ecol. 39: 5-16.

Jenny, H. 1980. The soil resource: origin and behavior. Springer Verlag, New York.

Kelley, J. C. and D. A. McManus. 1970. Hierarchical analysis of variance of shelf sediment texture. J. Sed. Petr. 40: 1335-1366.

Kleiner, E. F. and K. T. Harper. 1977. Occurrence of four major perennial grasses in relation to edaphic factors in a pristine community. J. Range Manage. 30:286-289.

Kooijman, S. A. L. M. 1979. Inference about dispersal patterns. Acta Bioth. 3: 149-189.

Lance, G. N. and W. T. Williams. 1967. A general theory of classificatory sorting strategies. I. Hierarchical systems. Comput. J. 1: 15-20.

Lavender, D. P. 1981. Environment and shoot growth of woody plants. Forest Research Laboratory, Oregon State Univ., Corvallis. Res. Pap. 45.

Lentz, R. D. and G. H. Simonson. 198x. Correspondence of soil properties and classification units with sagebrush communities of Southeastern Oregon: I. Comparisons between mono-taxa soil-landscape units. Soil Sci. Soc. Am. J. (To be submitted)

Lentz, R. D. and G. H. Simonson. 198xa. Correspondence of soil properties and classification units with sagebrush communities of Southeastern Oregon: II. Comparisons within a multi-taxa soil-landscape unit. Soil Sci. Soc. Am. J. (To be submitted)

Lentz, R.D. and G. H. Simonson. 198xb. A detailed soil inventory of Squaw Butte Experimental Range. Agric. Exp. Stn., Oregon State Univ., Corvallis, Spec. Pub. No. X.

Mahall, B. E. and R. B. Park. 1976. Ecotone between Spartina foliosa Trin. and Salicornia virginica L. in salt marshes of northern San Fransico Bay: I. biomass and production. J. Ecol. 64: 793-809.

Mausbach, M. J., B. R. Brasher, R. D. Yeck and W. D. Nettleton. 1980. Variability of measured properties in morphologically matched pedons. Soil Sci. Soc. Am. J. 44: 358-363.

McKee, B. 1972. Cascadia; the geologic evolution of the Pacific Northwest. McGraw-Hill, Inc., New York.

Mitchell, J. E., N. E. West and R. W. Miller. 1966. Soil physical properties in relation to plant community patterns in the shadscale zone of Northwestern Utah. Ecol. 47: 627-630.

Munn, L. C., G. A. Nielsen and W. F. Mueggler. 1978. Relationships of soils to mountain and foothill range habitat types and production in Western Montana. Soil Sci. Soc. Am. J. 42:135-139.

National Climatic Center, NOAA. 1983. Climate normals for the U.S. (base: 1951-80). Gate Research Co., Detroit, Michigan.

Nie, N. H., D. H. Hull, J. G. Jenkins, K. Steinbrenner and D. H. Bent. 1975. SPSS: Statistical package for the social sciences. McGraw-Hill, Inc. New York.

Nortcliff, S. 1978. Soil variability and reconnaissance soil mapping: a statistical study in Norfolk. J. Soil Sci. 29: 403-418.

Olsen, S. R. and L. A. Dean. 1965. Phosphorus. IN C. A. Black et al. (ed.) Methods of soil analysis, part 2. Agromomy 9: 1035-1048. Am. Soc. of Agron., Madison, Wisconsin.

Passey, H.B., V. K. Hugie, E. W. Williams and D. E. Ball. 1982. Relationships between soil, plant community, and climate on rangelands of the Intermountain West. USDA-SCS Tech. Bull. no. 1669.

Pratt, P. G. 1965. Potassium. IN C. A. Black et al. (ed) Methods of soil analysis, part 2. Agronomy 9: 1022-1030. Am. Soc. of Agron., Madison, Wisconsin.

Reynolds, S. G. 1975. Soil property variability in slope studies: suggested sampling schemes and typical required sample sizes. Z. Geomorph. N. F. 19: 191-208.

Robertson, D. R., J. L. Nielsen and N. G. Bare. 1966. Vegetation and Soils of alkali sagebrush and adjacent big sagebrush ranges in North Park, Colorado. J. Range Manage. 19: 17-20.

Sheehy, D. 1975. Relative palatability of seven Artemisia taxa to mule deer and sheep. M.S. Thesis. Oregon State Univ., Corvallis.

Soil Survey Staff. 1975. Soil taxonomy, a basic system of soil classification for making and interpreting soil surveys. U.S. Dep. Agric. Handb. 436.

Sneva, F. A., L. R. Rittenhouse, P. T. Teuller and P. Reese. 1984. Changes in protected and grazed sagebrush-grass in Eastern Oregon, 1937 to 1974. Agric. Exp. Stn., Oregon State Univ., Corvallis, Bull. 663.

Spurr, S. H. and B. V. Barnes. 1980. Forest ecology. John Wiley and Sons, New York.

Srivastava, M. S. and E. M. Carter. 1983. An Introduction to applied multivariate statistics. North Holland, New York.

Stein, R. A. and J. A. Ludwig. 1979. Vegetation and soil patterns on a Chihuahuan Desert Bajada. Am. Midl. Nat. 101: 28-37.

Summerfield, H. B. and F. F. Peterson. 1971. Soil properties related to occurrence of big and low sagebrush in northwestern Nevada. Abst. of Pap., 24 Annual Meeting, Soc. for Range Manage., Reno, Nevada.

Swanson, S. R. 1983. Infiltration, soil erosion, nitrogen loss, and soil profile characteristics of Oregon lands occupied by three subspecies of Artemisia tridentata. Ph.D. Thesis. Oregon State Univ., Corvallis. Univ. Microfilms, Ann Arbor, MI (Diss. Abstr. 8308814).

Teuller, Paul. 1962. Plant Succession on two Artemesia habitat types in Southwestern Oregon. PhD Thesis, Oregon State Univ., Corvallis.

Tisdale, E. W. and A. Hironaka. 1981. The sagebrush-grass region: A review of the ecological literature. For., Wildl. and Range Sci. Exp. Stn., Univ. of Idaho, Moscow, Bull. no. 33.

USDA, Soil Conservation Service. 1976. National Range Handbook. U.S. Government, Washington D. C.

USDA, Soil Conservation Service. 1983. National Soils Handbook. U.S. Government, Washington D.C.

Walker, G.R. and J.D. Brotherson. 1982. Habitat relationships of basin wildrye in high mountain valleys of Central Utah. J. Range Manage. 35: 628-632.

Walkley, A. and I. A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci. 37: 29-38.

Winward, A. H. 1980. Taxonomy and ecology of sagebrush in Oregon. Agric. Exp. Stn., Oregon State Univ., Corvallis, Bull. no. 642.

Zamora, B. and P.T. Tueller. 1973. Artemisia arbuscula, A. longiloba and A. nova habitat types in Northern Nevada. Great Basin Nat. 33: 225-242.

Zedler, S. B. and P. H. Zedler. 1969. Association of species and their relationship to microtopography within old fields. Ecol. 50: 432-442.

APPENDICES

APPENDIX A

Plant community data for mono-taxa soil-landscape units. Frequency of high seral grass species and density of dominant shrub species.

FREQUENCY OF HIGH SERAL GRASS SPECIES AND DENSITY OF DOMINANT SHRUB SPECIES

MAJOR PLANT SPECIES	ARLO/AGSP				ARLO/FEID				ARTRV/FEID-AGSP			
	1	2	3	MEAN	1	2	3	MEAN	1	2	3	MEAN
FREQUENCY (PERCENT)												
AGSP*	P**	P	P	P	0	0	10	3.3	80	30	50	53.3
FEID	-	-	-	-	10	30	50	30.0	50	90	50	66.7
POSA	100	100	100	100	100	90	100	96.7	60	90	50	66.7
SIHY	40	50	50	46.6	30	10	60	33.3	30	P	20	16.7
STTH	50	30	20	33.3	30	30	P	20.0	P	P	20	6.7
DENSITY (SHRUBS/HECTARE)												
ARLO	7263	7532	6187	6994	12104	12911	11297	12104	-	-	-	-
ARTRV	-	-	-	-	-	-	-	-	4303	7262	4034	5200
CHVI	P	5111	P	1704	-	-	-	-	-	-	-	-
CHNA	-	-	-	-	-	-	-	-	538	1614	1076	1076

MAJOR PLANT SPECIES	HABITAT TYPE (PHASE) ARTRW/AGSP(FEID) 1	2	3	MEAN	ARTRW/AGSP 1	2	3	MEAN	ARAR/FEID 1	2	3	MEAN
	FREQUENCY (PERCENT)											
AGSP	50	30	50	43.3	50	40	40	43.3	20	10	20	16.7
FEID	20	30	10	20.0	-	-	-	-	20	50	P	23.3
POSA	90	100	100	96.7	80	100	80	86.7	100	100	100	100
SIHY	10	90	30	43.3	10	20	30	20.0	40	20	P	20.0
STTH	P	20	20	13.3	20	50	P	23.3	10	P	10	6.7
	DENSITY (SHRUBS/HECTARE)											
ARAR	-	-	-	-	-	-	-	-	10221	19098	17753	15691
ARTRW	3497	7800	5380	5559	4304	5649	6187	5380	-	-	-	-

* AGSP = *Agropyron spicatum*
FEID = *Festuca idahoensis*
POSA = *Poa sandbergii*
SIHY = *Sitanion hystrix*
STTH = *Stipa thurberiana*

ARAR = *Artemisia arbuscula*
ARLO = *Artemisia longiloba*
ARTRW = *Artemisia tridentata* ssp. *vaseyana*
CHVI = *Chrysothamnus visidiflorus* ssp. *visidiflorus*
CHNA = *Chrysothamnus nauseosis* ssp. *albicaulus*

** P indicates that the species was present but was not encountered within the sample plot.

APPENDIX B

Site and vegetation data for sample plots defining each recurring plant grouping. The legend defines variables recorded for each sample. Tables list parameter values for each sample plot included in each recurring plant group. Recurring plant group means are listed for each parameter.

LEGEND

ID# = Identification Number
S# = Sample Number

Environmental Parameters

1) Surface rock fragments (% cover)

2) Class of rock fragments:
   - 1 = Stones
   - 2 = Cobbles
   - 3 = Pebbles
   - 4 = Stones and cobbles
   - 5 = Stones, cobbles and pebbles
   - 6 = Cobbles and pebbles
   - 7 = Stones and pebbles

3) Landform slope (%)

4) Landform aspect:
   Codes 0 to 15 represent 16 azmuths at 22.5 degree increments.
   0=north, 1=NNE, 2=NE, 3=ENE, 4=E etc., 15=NNW

5) Landform configuration:
   - 1 = concave
   - 2 = slightly concave
   - 3 = flat
   - 4 = slightly convex
   - 5 = convex

6) Landform subelement:
   - 1 = Rocky crest
   - 2 = Plateau slope
   - 3 = Interfluve, hummock
   - 4 = Drainageway
   - 5 = Low interfluve, terrace, or over-wash area near drainageway

Vegetation parameters (% cover of species)

SHRUBS:
7) Artemisia arbuscula
8) Artemisia tridentata ssp. wyomingensis
9) Chrysothamnus visidiflorus ssp. visidiflorus
10) Eriogonum sphaerocephalum

LOW WOODY PLANTS:
11) Eriogonum ovafolium
12) Unidentified (phlox-like, flowers in cymes)
13) Unidentified (phlox-like, flowers in axials)
14) Phlox longiloba ? (leaves > 3.5 cm)

GRASS SPECIES:
15) Poa sandbergii
16) Agropyron spicatum
17) Festuca idahoensis
18) Poa cusickii
19) Sitanion hystrix
20) Stipa thurberiana

21) Bromus tectorum
22) Koeleria cristata
23) Poa spp. (with hairy tuft seed)

HERBS:
24) Number of herbaceous (non-grass) species present--
Species included: Erigeron linearis
Erigeron filifolios
Arabis spp.
Crepis acuminata
Agoseris glauca
Astragalus filipes
Astragalus obscurus
Lupinus caudatus
Lupinus wyethii
plus 3-4 others not idenified

25) Total herb cover (%)

26) Size of A. arbuscula (see classes below)

27) Size of A. tridentata ssp. wyomingensis (see classes below)

Class	1	2	3	4	5	6	7	8
Height (cm)	0-15	15-30	30-45	45-60	60-75	75-90	90-105	>105

RPG ONE

ID#	S#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	111	20	5	3	9	2	1	9	0	0	1	0	2	2	0	11	2	2	1	1	0	0	0	0	3	2	3	0
37	321	12	5	6	5	4	2	18	0	0	1	0	1	2	0	10	5	1	0	1	0	0	0	0	10	5	3	0
47	343	10	4	5	3	2	4	11	1	0	2	0	1	1	0	7	3	2	0	0	1	0	0	0	3	2	3	4
48	344	13	5	5	3	2	2	8	0	0	5	0	1	1	0	6	2	3	0	1	1	0	0	0	2	1	3	0
49	421	18	5	7	5	4	2	12	0	0	1	1	0	1	0	11	2	1	1	1	1	1	0	0	4	2	3	0
50	422	16	5	7	5	4	2	11	0	0	0	0	1	1	0	10	2	1	0	1	1	0	0	0	6	5	3	0
51	423	10	6	6	5	4	2	13	0	0	0	1	1	1	0	12	1	1	1	0	1	0	0	0	6	5	2	0
52	424	13	5	6	4	2	14	0	0	1	1	0	1	2	0	6	2	1	0	1	1	0	0	0	8	5	3	0
55	413	25	5	9	5	2	2	12	0	0	0	0	0	1	0	9	4	1	1	1	1	1	1	0	3	2	3	0
56	414	15	6	8	5	2	2	14	0	0	0	0	0	1	0	4	11	1	1	1	1	1	0	0	7	4	3	0
59	433	20	5	10	4	4	2	12	0	0	1	0	1	2	0	7	3	2	0	1	0	1	1	0	7	6	2	0
60	434	20	5	10	4	4	2	15	0	0	0	0	1	1	1	6	3	2	0	1	0	0	0	0	5	4	2	0
62	442	10	5	8	6	4	2	17	0	1	0	0	1	2	0	7	2	2	1	1	1	0	0	0	7	8	2	0
63	443	20	5	6	5	4	2	15	0	0	1	1	1	2	0	6	3	1	0	1	0	0	0	0	8	5	2	0
64	444	27	6	6	6	4	2	14	0	0	0	0	1	1	0	10	1	1	0	1	1	0	0	0	8	5	3	0
MEANS		16.6	5.1	6.8	4.9	3.2	2.9	12.1	0.1	0.1	0.9	0.2	0.9	1.4	0.1	8.1	3.1	1.5	0.4	0.9	0.7	0.3	0.1	0.0	5.8	4.1	2.7	0.3

RPG TWO

ID#	S#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
3	113	20	4	2	6	2	2	19	7	0	5	0	0	2	0	10	2	0	1	1	0	0	0	0	2	2	3	4
8	124	20	5	5	6	2	4	21	1	0	2	0	0	1	0	11	3	2	0	1	1	2	0	0	5	3	3	0
17	211	16	5	4	6	2	4	19	1	0	5	1	1	3	0	0	0	1	0	1	1	0	0	0	6	4	2	5
18	212	13	4	5	6	2	2	19	2	0	6	0	2	2	0	6	1	1	0	1	0	0	0	0	4	3	3	4
19	213	10	4	4	6	4	2	18	1	0	4	0	1	1	0	7	2	1	1	1	0	0	0	0	4	3	3	4
20	214	12	6	6	5	2	2	18	3	0	4	0	0	2	0	4	2	1	0	1	1	0	0	0	4	3	3	4
29	241	14	6	4	5	1	4	20	1	0	6	0	1	0	0	9	3	2	0	1	1	0	0	1	8	5	3	4
38	322	13	5	6	5	4	2	16	1	0	1	0	1	1	0	8	3	1	1	0	1	1	0	0	7	4	2	4
39	323	15	5	6	4	2	5	20	1	0	1	0	1	1	0	8	0	2	0	1	0	6	0	0	7	5	3	4
44	334	43	5	8	5	4	2	18	1	0	2	0	1	1	0	5	1	1	0	1	0	0	0	0	7	4	3	4
54	412	50	6	9	3	2	2	20	1	0	0	1	0	1	0	10	1	1	0	1	0	0	1	0	7	4	3	4
58	432	28	4	10	5	4	2	14	1	0	0	0	1	2	0	6	8	5	0	1	0	0	1	0	5	4	2	4
MEANS		21.1	4.9	5.8	5.2	2.6	2.8	18.5	1.8	0.0	3.0	0.2	0.8	1.4	0.0	7.0	2.2	1.5	0.3	0.9	0.4	0.8	0.2	0.1	5.5	3.7	2.8	3.8

RPG THREE

ID#	S#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
5	121	15	4	4	6	2	4	19	6	0	3	0	0	3	0	9	1	4	0	1	0	0	0	0	5	5	2	4
6	122	15	5	3	10	2	4	18	4	0	0	0	1	3	0	8	4	8	0	0	0	0	0	0	4	4	2	5
7	123	10	3	3	6	2	5	19	9	1	0	1	0	1	0	12	2	2	0	5	1	0	0	0	3	3	3	5
9	131	15	4	4	5	2	4	14	6	0	2	0	0	1	0	8	4	2	0	0	1	0	0	0	5	5	2	4
10	132	5	2	4	6	3	5	9	8	0	4	0	1	1	0	7	4	2	0	1	1	0	0	0	3	4	3	5
11	133	4	4	4	5	2	4	17	6	0	3	1	1	1	0	9	24	4	0	1	0	0	0	0	3	2	4	5
13	141	25	4	6	6	2	5	11	9	0	2	0	2	0	0	8	2	1	0	1	0	1	0	2	5	3	4	5
15	143	10	3	4	7	2	4	15	5	0	2	1	2	0	0	10	3	1	1	1	1	0	0	0	4	3	4	4
16	144	10	4	4	6	4	5	15	4	0	1	0	1	0	0	5	2	1	1	2	1	10	0	0	3	2	4	6
21	221	9	6	5	6	1	4	14	4	0	1	1	1	1	0	4	4	12	1	1	0	0	0	0	8	4	3	5
23	223	9	4	4	6	1	4	10	4	0	1	0	0	0	0	6	2	8	1	1	2	0	0	0	7	4	2	4
27	233	15	4	4	7	1	4	16	2	0	1	1	1	1	0	6	9	3	0	1	1	0	0	0	3	3	3	4
32	244	1	3	4	6	4	5	16	8	0	2	1	1	0	1	2	3	4	1	2	0	0	0	0	3	2	3	4
40	324	8	5	6	4	2	5	22	5	0	1	1	1	1	0	4	4	2	1	2	1	0	0	0	6	3	3	4
MEANS		10.8	3.9	4.2	6.1	2.1	4.4	15.4	5.7	0.1	1.6	0.5	0.9	0.9	0.1	7.0	4.9	3.9	0.4	1.4	0.6	0.8	0.0	0.1	4.4	3.4	3.0	4.6

RPG FOUR

ID#	S#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
4	114	7	3	2	6	5	3	5	35	0	1	1	0	2	0	5	3	2	3	5	0	0	0	0	1	1	3	6
12	134	5	3	4	6	4	5	8	15	0	2	1	0	1	0	6	4	2	1	1	1	0	0	0	4	3	4	5
14	142	2	3	6	6	5	3	5	22	0	1	1	1	0	0	3	6	2	1	3	1	0	0	1	5	3	4	8
22	222	8	4	4	6	3	5	16	12	0	2	0	0	1	0	6	4	4	1	1	1	0	0	0	4	3	3	5
24	224	9	4	4	6	4	5	12	16	0	1	1	0	1	0	6	2	2	1	1	2	0	0	0	8	4	4	6
25	231	5	7	6	6	4	5	10	20	0	1	1	0	1	0	4	0	3	1	1	6	0	0	0	6	3	3	6
26	232	5	6	6	7	4	5	8	12	0	1	1	1	1	1	4	4	2	2	1	4	0	0	0	5	3	3	6
28	234	1	2	5	6	4	5	14	15	0	1	0	1	1	1	3	2	5	2	0	2	0	0	0	5	3	3	5
30	242	4	3	5	5	4	5	14	10	0	3	1	1	1	1	7	2	2	1	1	2	0	0	0	5	3	3	4
31	243	1	3	5	6	4	3	2	17	1	1	1	0	1	1	3	1	5	3	2	3	1	0	0	1	1	3	7
MEANS		4.7	3.8	4.7	6.0	4.1	4.4	9.4	17.4	0.1	1.4	0.8	0.4	1.0	0.4	4.7	2.8	2.9	1.6	1.6	2.2	0.1	0.0	0.1	4.4	2.7	3.3	5.8

RPG FIVE

ID#	S#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
33	311	1	3	6	3	5	5	18	2	0	1	1	0	1	0	4	3	4	1	1	2	0	1	0	8	4	3	4
34	312	15	5	8	3	2	4	6	1	6	1	1	1	1	0	4	1	2	1	1	1	0	2	0	7	4	2	4
35	313	12	3	5	3	1	4	13	2	2	1	0	1	1	0	3	2	9	1	1	1	0	1	0	7	4	2	4
36	314	1	3	5	4	5	3	24	3	2	1	1	0	1	0	1	2	6	1	5	1	2	1	0	3	2	3	7
45	341	5	1	5	3	2	2	15	1	1	2	0	1	1	1	5	2	3	0	1	1	0	1	0	5	3	3	4
46	342	2	2	5	3	4	2	9	4	1	1	1	0	1	0	0	1	7	2	1	1	0	1	0	3	2	3	4
53	411	1	3	10	6	4	5	7	7	0	0	0	1	1	0	4	1	2	0	2	1	0	1	0	7	4	3	4
61	441	12	4	9	5	5	5	10	4	3	0	1	1	1	1	3	5	4	0	1	2	0	1	0	4	4	3	4
MEANS		6.1	3.0	6.6	3.8	3.5	3.8	12.8	3.0	1.9	0.9	0.6	0.6	1.0	0.3	3.0	2.1	4.6	0.8	1.6	1.3	0.3	1.1	0.0	5.5	3.4	2.8	4.4

RPG SIX

ID#	S#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
2	112	50	2	4	10	2	1	4	0	0	1	0	0	1	0	11	0	0	0	8	0	0	0	0	2	2	3	0
41	331	31	5	5	6	4	1	3	0	0	1	0	1	1	0	4	0	0	0	2	0	0	0	0	3	2	2	0
42	332	40	5	5	6	4	1	6	0	0	1	0	1	0	0	6	0	0	0	5	0	0	0	0	7	4	2	0
43	333	70	5	10	5	4	2	15	0	0	2	0	1	1	0	4	1	1	0	2	0	0	0	0	4	2	3	0
57	431	30	5	6	5	5	1	7	0	0	2	0	1	2	0	8	1	1	0	1	0	0	0	0	4	3	3	0
MEANS		44.2	4.4	6.0	6.4	3.8	1.2	7.0	0.0	0.0	1.4	0.0	0.8	1.0	0.0	6.6	0.4	0.4	0.0	3.6	0.0	0.0	0.0	0.0	4.0	2.6	2.6	0.0

APPENDIX C

Soil properties utilized to differentiate between soil groups supporting different plant communities are listed. Possible effects of these soil properties on factors influencing plant distribution are also described.

SEPARATIONS AT FAMILY LEVEL AND AT HIGHER CLASSES

1) Presence of mollic epipedon (Indication of cooler temperatures and greater moisture supply--mollic epipedon increases the available water supplying capacity (AWC) and nutrient availability (NA) in the soil)
2) Solum thickness (Increased AWC and NA as mollic thickness increases)
3) Texture and volumetric rock content of the family control section (Increased AWC with medium and moderately fine textures, and as rock fragment content increases)

SERIES LEVEL SEPARATIONS

1) Presence of A2, E, BA, BCt subhorizons (Increased AWC and NA--generally)
2) Thickness of mollic epipedon (Increased AWC and NA as thickness of mollic epipedon increases)
3) Volumetric rock content of A and Bt horizons (Decrease in AWC and increase in soil temperature as rock content increases)
4) Thickness and dry consistence of soil in the argillic horizon (Increase in AWC as thickness increases; decrease in AWC and soil aeration as dry consistence becomes very hard)
5) Distinguishing properties not commonly considered as series criteria:
   A) Nutrient content
   B) Depth the angular blocky (ABK) or prismatic strata (Increase in AWC and soil aeration as depth to ABK strata increases)
   C) Structure type of subhorizons (BAt) (Subangular blocky - increases rooting volume, AWC, and soil aeration ABK or prismatic - decreases rooting volume, AWC, and soil aeration)

PHASE LEVEL SEPARATIONS BETWEEN SOILS OF SAME FAMILIES

1) Aspect (Soil temperature cooler on N and E aspects)
2) Slope (As slope increases, effective precipitation decreases)
3) Parent Material (General effect on soil texture, rock content, and nutrients)
4) Surface texture (Increase in AWC as texture becomes coarser)
5) Surface class (Increase in AWC as stone cover increases)
6) Physiography (Increase in AWC with concave configurations, AWC decreases with convex configurations)