CHARACTERISTICS OF SOME VEGETATION-SOIL UNITS IN THE JUNIPER ZONE IN CENTRAL OREGON

by

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IN THE JUNIPER ZONE IN CENTRAL OREGON

INTRODUCTION

The Juniper Zone in central Oregon has long been used by livestock operators, agriculturists, wood cutters, and wild game. In spite of all this use, few scientific investigations have been made to provide knowledge on how to manage its native vegetation to provide a sustained yield of profitable products. One result has been continued destruction of palatable and nutritious livestock and game forage. McArdle, et al., (42), reporting on the Pinyon-Juniper Zone in the western United States, estimated that two-thirds of the area was severely depleted, one-fourth was extremely depleted and the average grazing capacity had been reduced to less than half the virgin range. Similar conditions exist in the central Oregon Juniper Zone.

Jensen (32) developed emperical standards to classify range conditions in the Grassland-Juniper type in central Oregon. He supplied little quantitative data concerning characteristics of the virgin area nor did he attempt to classify particular plant communities. Eckert (20) quantitatively and qualitatively classified vegetation-soil units in some sagebrush (*Artemisia* spp.)[1/] types in northern Harney County, Oregon. Sierra juniper (*Juniperus*

1/ Kelsey and Dayton (35), *Standardized Plant Names*, is the source of common plant names. Abrams (1), *Illustrated Flora of the Pacific States*, was used for plant authorities. A list of common and scientific plant names is in the appendix.

occidentalis) is a component of some of these communities. These are the only accounts of work in the zone that have been published. Numerous other works, generally qualitatively characterizing other parts of the Pinyon-Juniper Zone in western United States, have been published (13, 22, 43, 50, 66, 67, 68). Specific reference to these and other pertinent investigations will be made at appropriate places in the text.

If grazing is to be continued, or if other possible uses are to be considered, it is necessary to learn vegetational potentials and limitations of the zone. This can be done best through recognition of discrete ecological units, or ecosystems (55) classified and characterized according to the poly-climax philosophy of community ecology (3, 15, 55).

The purpose of this study was to define and characterize the ecosystems represented by available relicts in the study area. The investigation was designed to simultaneously measure and interpret vegetation, soil, and topographic characteristics of each ecosystem and determine relationships within and among them. The study was also designed to provide a basis for practical use of the results by land managers.

DESCRIPTION OF THE AREA

Physiography and Geology

The Juniper Zone in central Oregon is one of three physiographic subdivisions of the Northwest representative of the major Pinyon-Juniper Zone in the western United States. No pinyon pines (*Pinus* spp.) occur, but general features are similar to the parent zone. Soils are generally shallow and stony and the climate is characterized by high summer temperatures, cool winter temperatures, high wind movements, low relative humidity and low annual precipitation.

The major zone in Oregon is located mostly in the north-central portion of the eastern section of the state. Small isolated islands occur on ridgetops and buttes throughout southeastern Oregon. It grades to the Ponderosa Pine (*Pinus ponderosa*) Zone where moisture is more effective and to the Sagebrush or Grassland Zones of less effective moisture.

Previous reference was made to three physiographic subdivisions of the major zone. These are based on soil parent materials and include: (1) aeolian sands, the study area; (2) residual igneous material; and (3) old sediments (Figure 1). The first subdivision is found in west-central Oregon primarily in Deschutes, Crook, and Jefferson counties. Soil parent materials generally consist of wind-laid and mixed acid igneous and pumice sands. In some places where these materials do not comprise the actual parent material,

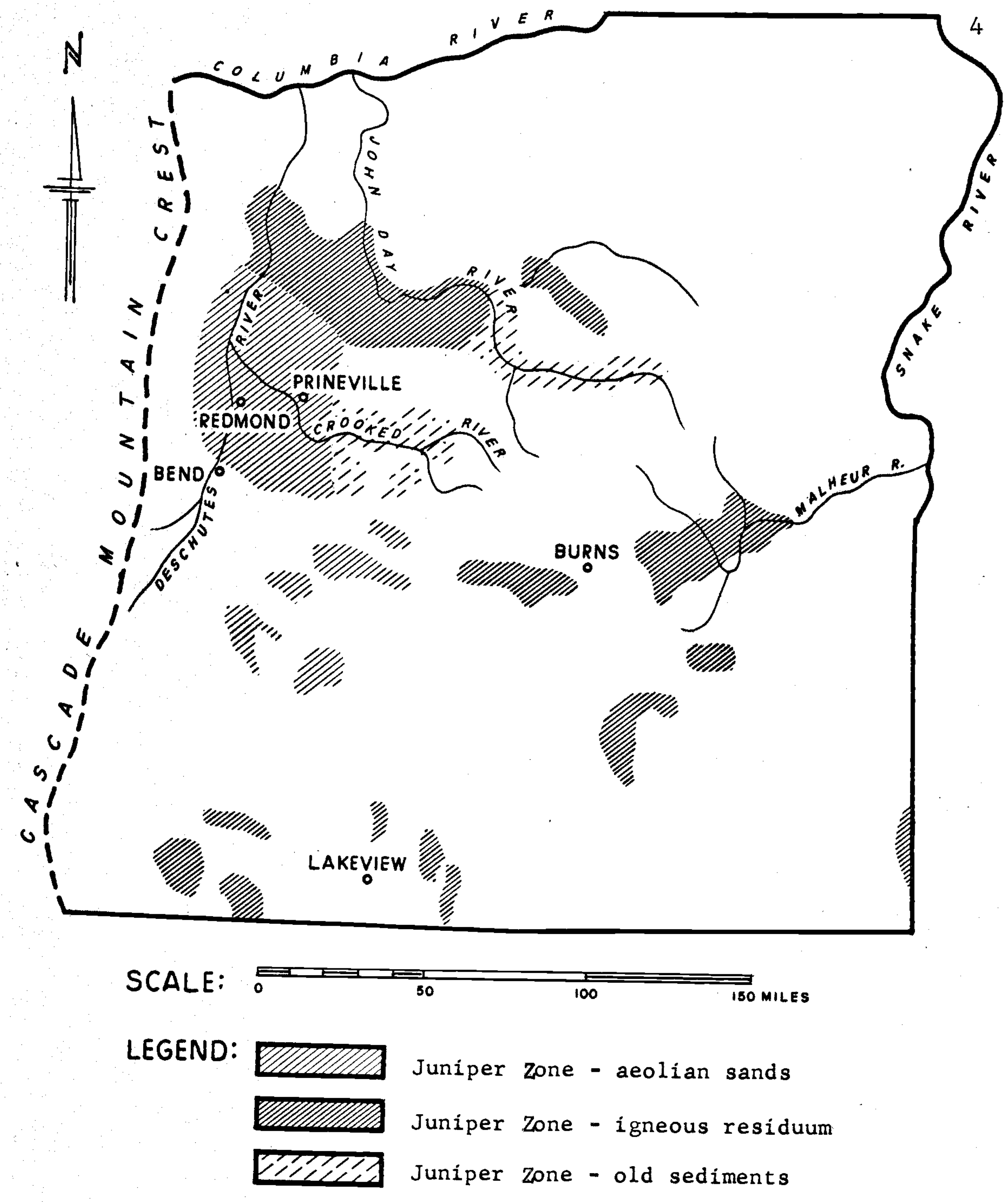

Figure 1.--Distribution of the major subdivisions of the Juniper Zone in eastern Oregon.

pumice is scattered throughout the soil profile, although more abundant in the A horizon. The pumice probably originated from Mt. Mazama, 100 miles southwest of Bend, when it exploded approximately 8,000 years ago (65). Some may have been wind-carried and deposited from more recent eruptions of Mt. Newberry, 25 miles southeast of Bend. The igneous sands were transported from dry lake beds by southwesterly winds.

The second subdivision is located in the northern and southeastern portions of the zone. The igneous soil parent material is varied, comprised of rhyolitic, andesitic or basaltic lava flows which occurred over long periods of geologic time. Some of the oldest flows originated during the Miocene Epoch (30). Others occurred intermittently up to recent centuries.

The third subdivision is located principally in the upper regions of the John Day and Crooked Rivers. The sedimentary materials, primarily the Clarno and John Day Series, were water deposited during the Eocene and Oligocene Epochs (34).

Geologically, the study area is young as compared to the remaining Juniper Zone in Oregon. Consequently, time has not influenced plant community structure or soil development as intensely as it has in other areas. This is seen in the wide spacing of individual plants and the relative paucity of species.

Climate

The climate of the study area is continental and semi-arid characterized by low annual precipitation, dry summers with warm days and cool nights and cool to cold winters relatively snow-free. No month is entirely frost-free although killing frosts generally do not occur during June, July, and August. The average growing season at Bend, Oregon, is 88 days (58, p. 1077), the probable average of the area.

Annual precipitation varies greatly from locality to locality and year to year. At Bend, located in the transition between the Juniper and Ponderosa Pine Zones, the average annual precipitation, based on 56 years of record, is 12.25 inches (60). The highest recorded was 25.95 inches in 1907 and the lowest recorded was 5.75 in 1959. At Redmond, 20 miles north of Bend and located in the center of the area, the average annual precipitation, based on 29 years of record, is 8.54 inches with a high of 14.19 inches in 1948 and a low of 4.39 inches in 1949. Approximately 85 percent of the annual precipitation occurs as rain and snow fairly evenly distributed from October through June. The summer months are characteristically droughty, frequently completely dry. Precipitation that does occur during the summer, most often less than 0.25 inch per storm, is ineffective for perennial plant growth.

Temperature extremes are wide. The highest, 112^{o} F., and the lowest, -45^{o} F., recorded in the area was at Madras (60), 50 miles north of Bend. Even with the high, summer-day temperatures, nights are cool with low humidity.

During the time field observations were made, 1959 and 1960, the area suffered one of the severest droughts on record. Table 1 summarizes precipitation data for these two years, computed on an October-June forage-year basis to show means and departures, at Bend and Redmond. This untimely climatic sequence undoubtedly influenced plant growth, particularly herbaceous species, resulting in a climatic bias of the vegetation data.

Topography

The topography of the study area is quite varied. Elevations range from approximately 2200 feet above sea level at Madras to approximately 5000 feet on top of some of the buttes northeast of Bend. The western part of the area is characterized by a nearly level to rolling upland plain dissected by deep V-shaped gorges of the Deschutes and Crooked Rivers. The eastern part of the area is characterized by numerous buttes rising from 500 to 1500 feet above the floor of the plain.

The plain area is highly variable. From Bend north to the Crooked River, it is interlaced by ropey, basaltic lava flows of Recent times. Deep sands of mixed pumice, andesite, rhyolite, and basalt occur between the lava flows. North of the Crooked River, occasional diastrophitic buttes composed of John Day and Clarno sediments have been uplifted 500 to 1500 feet above the plain floor.

Table 1. Forage-year precipitation, 1958-59 and 1959-60, showing long-term means, departures, and totals; Bend, Redmond [1/]

Station and Year	Month									Forage Year Total
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	
Bend										
1958-59	-0.61	-0.75	-1.18	-0.59	0.41	-0.03	-0.61	-0.39	-0.95	-4.70
1959-60	-0.49	-1.19	-1.15	-0.58	0.40	1.52	0.22	-0.54	-1.24	-3.89
Mean	0.93	1.45	1.83	1.85	1.03	0.76	0.68	1.12	1.25	10.90
Redmond										
1958-59	-0.67	0.56	0.13	-0.02	0.30	-0.56	-0.58	-0.47	-0.43	-1.74
1959-60	-0.11	-0.60	-0.92	0.89	0.45	1.38	-0.11	-0.24	-1.08	-0.34
Mean	0.69	0.90	1.11	1.04	0.70	0.56	0.58	0.82	1.08	7.48

1/ No sign or minus (-) sign indicates positive or negative departures from means.

Among these buttes, alluvial material of highly variable composition has been deposited. Relatively large quantities of pumice is mixed with the alluvium. Occasional pumice "pockets" of varying area and depth occur throughout the plain area.

Some of the buttes in the eastern part of the study area have lava flows dating from Recent time, but most buttes appear to have been formed by diastrophism. Occasional "cinder cones", low cone-shaped buttes with extensive volcanic cinder deposits on their slopes, occur in the central part of the area near Redmond. The diastrophitic buttes are heterogeneous. Most of them are capped with rhyolitic and/or andesitic lavas. Extrusions of tuffaceous sediments appear beneath the lava flows. Sand deposits of similar appearance to those found among the lower-laying lava flows occur on the lee side of the buttes and ridges.

Soils

The soils in the area are in the Sierozem, Brown, and Chestnut great soil groups (37, pp. 25-26). The Chestnuts are minor in extent, occurring mostly on north and northeast slopes where temperature and precipitation effectiveness has favored their development. Sierozems are also limited, occurring in the hotter, drier portions of the area. Azonal Regosols are common.

These soils are similar to soils of other semi-arid climates. They have light colored gray to light yellowish brown A horizons and accumulations of soluble salts or siliceous materials on individual soil peds or rocks in the profile. They are low in organic matter and have low C/N ratios.

Most of the soils are sandy loams but textures range from loamy coarse sand to clay loam. Structure in the B horizon ranges from strongly developed prismatic to weak subangular blocky. Many of the soils lack B horizons. In most cases, large volumes of the solum are occupied by stones.

The depth of the solum ranges from 14 to 44 inches but is generally around 30 inches. The underlying materials affecting plant growth include solid or cracked bedrock, hardpans which are often discontinuous, or semi-consolidated mixtures. The cracked bedrock, which contains thin films of soil in the cracks, allows deeper root penetration than might be expected. Some of the "apparent" bedrock becomes loose and friable when wet. Roots were observed extending into these materials.

The soil surface is slightly acid (pH 6.0) to neutral (pH 7.0). Soil reaction increases with depth, becoming slightly alkaline (pH 7.5) to alkaline (pH 8.0) at the bottom of the B horizon. White calcareous or siliceous deposits on individual soil peds or on the bottoms of rocks are common in the subsoil.

Vesicular plates are common on the surface of most of the soils in undisturbed condition. The role of these two-to-three-inch thick plates in plant growth and distribution is not well understood.

A soil survey has been conducted on lands used for farming within the area (38). Ten soil series were classified and correlated, none of which were encountered during this study.

Vegetation

Sierra juniper is the dominant tree species of the area. An occasional ponderosa pine may be found in canyon bottoms or north slopes where soil moisture is greater. Natural wide spacing of individual junipers provides the aspect of a savanna (Figure 2). Big sagebrush (Artemisia tridentata) is most often the dominant shrub in the understory. Occasionally, it is replaced by antelope bitterbrush (Purshia tridentata) wholly or as a codominant. Other shrubs characteristic of the area are rubber rabbitbrush (Chrysothamnus nauseosus), Douglas rabbitbrush (C. vicidiflorus), gray horsebrush (Tetrademia canescens), granite gilia (Leptodactylon pungens), and low sagebrush (Artemisia arbuscula). Two species of currant (Ribes cereum and R. gooddingii) and spiny hopsage (Grayia spinosa) occur infrequently. Suffrutescent species are represented by various eriogonums (Eriogonum spp.)

Bearded bluebunch wheatgrass (Agropyron spicatum) and Idaho fescue (Festuca idahoensis) are the characteristic grasses of relatively undisturbed communities. Sandberg bluegrass (Poa secunda) and Thurber needlegrass (Stipa thurberiana) are common. Other grasses include bottlebrush squirreltail (Sitanion hystrix), needle-and-thread (Stipa comata), cheatgrass brome (Bromus tectorum), sixweeks

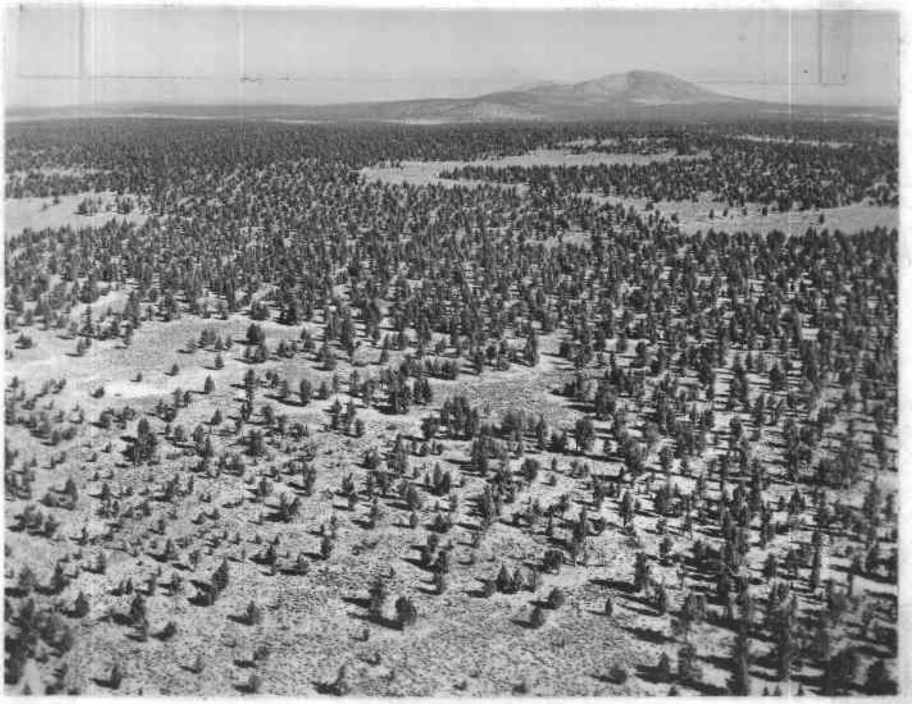

Figure 2. Wide spacing of individual trees provide the characteristic savanna-like aspect of the central Oregon Juniper Zone.

fescue (*Festuca octoflora*), and prairie junegrass (*Koeleria cristata*).

Forbs commonly do not constitute major components of relatively undisturbed communities. Some of the more common perennial forbs are agoseris (*Agoseris* sp.), common yarrow (*Achillea millefolium*), wooly eriophyllum (*Eriophyllum lanatum*), milkvetch (*Astragalus* spp.), lineleaf fleabane (*Erigeron linearis*) and lupine (*Lupinus* spp.).

DEFINITION OF TERMS

Several concepts of vegetation classification and numerous terms have gained following among groups of ecologists as the science of ecology has evolved. Apparent discord has developed concerning community interpretation and terminology. In the interest of more complete understanding, the following definitions of terms and concepts are used.

A plant community is an aggregation of plants. It may be concrete, the one being examined, or abstract, the one synthesized from several or many concrete communities (46, p. 21). A climax community is one which has achieved relative stability through time and space adjustments to a particular effective environment, appears to be self-regenerating and contains no concrete evidence that it is followed by a different community. An effective environment refers to the net effect of all direct and compensatory factors influencing a plant community in a certain habitat. A habitat is a multi-dimensional place in space containing sufficient energy and matter derived from biotic and abiotic sources to support and maintain a plant community. As a result of intensive and intimate study, the complexities of a community and its habitat resolve themselves into components of an ecosystem, an ecological unit containing organic and inorganic components in relatively stable dynamic equilibrium (55). Occasionally, a unit of the landscape very closely related to an ecosystem has at least one differentiating characteristic deviating strongly from those characterizing the ecosystem. It is convenient to refer to such a unit as an <u>ecosystem variant</u> until additional evidence warrants separation into an individual entity or grouping with the original ecosystem.

METHODS

Criteria for Classification and Sample Unit Selection

The ultimate goal of studies attempting to classify plant communities or explain plant growth and distribution would require multifactor analysis of all possible characteristics, measured quantitatively, of the entities in which they occur. Unfortunately, such a method is currently impractical, if not impossible, considering instrumentation and manpower. However, classification can be accomplished if it is based on impartial and critical analyses of quantitative measurements of selected characteristics. This method was used to classify the ecosystems subsequently discussed.

Vegetational measurements included: (1) foliage cover of individual species, (2) total foliage cover and basal area of perennial herbs, (3) total foliage cover of established shrubby and suffrutescent species, (4) average maximum heights of mature shrubby and suffrutescent species, and (5) density counts of shrubby and suffrutescent species. In addition, constancy of all species was computed.

Measured or computed soil characteristics included: (1) percent bare soil surface, (2) percent stones on the soil surface, in the A horizon, and in the horizon immediately beneath the A horizon, (3) percent organic matter and percent total nitrogen in the A horizon, (4) total available soil moisture storage capacity, in inches of water, in the 2- to 14-inch soil zone, and (5) texture of the

A horizon and the horizon immediately beneath the A horizon.

The only topographic feature used for classification purposes was slope aspect. Elevations, slope positions, and slope steepness were noted but they appeared to have little influence on species or community distribution in the study area.

Before any data were collected or analyzed however, reconnaissance was carried out for several seasons to permit tentative classification of the ecosystems. Vegetational criteria used included floristic composition, relative dominance, and vigor. Soil characteristics considered were amount of bare soil surface, stoniness on and in the soil, depth of the solum, and nature of the underlying material. Subjectivity is inferred but it is tolerable. Greig-Smith (27) emphasizes that areas subjectively selected as being distinctive and not transitional on the basis of pre-defined criteria is evidence they represent specific entities.

Vegetation Measurements

The basic sampling procedure, including replication, has been developed and discussed by Daubenmire (16), Driscoll (17), Dyrness (19), Eckert (20), Poulton (48), and Poulton and Tisdale (49). For each ecosystem recognized on the basis of reconnaissance, at least five representative areas were selected for analysis. The areas selected were as widely distributed over the main study area as possible. A 50- x 100-foot plot was randomly located in each representative area. Within each plot, four 50-foot combination line-belt transects were located in restricted random fashion. Along each transect, ten 1- x 2-foot observation plots were systematically located. Final analyses were based on large plot means.

Percent foliage cover of herbs by species and basal area of all perennial herbs was estimated on the 1- x 2-foot observation plots. Foliage cover was determined by visually projecting the leafage of the species to the ground and estimating plot area occupied by this projection. This characteristic was used as the primary herbaceous measurement. Although basal area minimizes climatic bias and foliage removal, foliage cover provides a better estimate of the energy relationships within and among communities. Basal area, total area within the periphery of the root crown of a species, but excluding dead centers, was estimated as a percent of the plot area occupied by all perennial herbs. Data were also taken on percent ground area occupied by mosses, litter, stones and gravel and percent bare soil surface in the 1- x 2-foot plots.

Percent foliage cover of each shrubby and suffrutescent species was measured by line-intercept (9) on the 50-foot transects. Density of each species was obtained by counting all individuals rooted in a 4-foot belt transect bisected by each line transect. Average maximum heights of mature plants was determined by measuring all mature plants of each species within the belt transects. Percent foliage cover of trees was estimated from aerial photographs (44).

Constancy of all species was computed on the basis of presence and absence of species within the bounds of the large plots. All vegetation data were collected during July and August, 1960. Recognizing that some vernal species were not observed or could not be identified, observations at this time probably included those species exerting primary influence within the ecosystems.

Soil Measurements

A soil pit was dug as deep as possible immediately adjacent to each 50- x 100-foot vegetation plot. A complete soil profile description was made following procedures outlined in The Soil Survey Manual (59). More attention was given to stoniness, however. Rather than using classes, the volume of the various horizons occupied by stones was estimated to provide an index of effective soil. Also, stones included rock pieces larger than 1-inch in diameter rather than using the 10-inch diameter minimum set forth in The Soil Survey Manual (59, p. 216). In addition, bedrock characteristics including the presence or absence of cracks and wet consistency were noted. Profile descriptions were made when vegetation data were obtained.

Samples of the A horizon and the finest textured part of the B horizon, or the AC horizon of the Regosols, were collected for physical and chemical laboratory analyses. Physical analyses included mechanical analysis for textural classes and determinations of moisture equivalent (approximate field capacity), 15 atmospheres tension (approximate wilting point), and bulk density. The last three determinations and soil stoniness were used to compute the total available water storage capacity of the 2- to 14-inch soil zone by the following formula (7, p. 13):

$$\text{Available water storage capacity, inches of water} = \text{bulk density} \times \text{soil depth in inches} \times \frac{\text{moisture equivalent} - \text{15 A. tension}}{100} \times \text{percent effective soil.}$$

This zone was selected since it represents the area of greatest root concentration. Chemical analyses included soil reaction (pH) tests of all samples and percentages organic matter and total nitrogen of the A horizon. All analyses were made by the Soil Testing Laboratory of the Oregon Agricultural Experiment Station at Corvallis.

Topography

Slope aspect was determined with a compass and recorded as one of the eight points, i.e., northeast, south, southwest, etc. Elevations at the plot locations were measured with an aneroid barometer. Slope steepness was measured in percent with an abney hand level. Slope position refers to the place on slopes where plots were located and was estimated as to the upper, middle, or lower one-third.

RESULTS

Introduction

Classification is necessary if reasonable understanding and unified communication are to exist among workers in biology. Initially, a taxonomic scheme based on properties useful for remembering and understanding characteristics and relationships among the objects classified needs to be developed. This investigation has resulted in such a scheme in which nine ecosystems and variants of two are named and characterized on the premise that they exist as demonstrable entities with both independent and intergrading characteristics. In some cases, constancy data were used to support measured characteristics segregating ecosystems. In all cases, primary vegetational and soil features selected for classification and characterization purposes are those which have become adapted to and express most fully the time and space relationships of the whole environment of the particular ecosystem.

The magnitude of change of some differentiating characteristics varies gradually or sharply among ecosystems depending on total environmental variation. However, composite comparisons among vegetational and soil characteristics verifies the segregation of each entity.

Classification and Description of the Ecosystems

Table 2 lists the ecosystems and their variants in descending order of effective moisture, shows the number of sample units used

Table 2. Number of sample units and general characteristics of ecosystems in the central Oregon Juniper Zone

Ecosystem	No. of sample units	Aspect	Associated Great Soil group	Elevational range (feet)
(1) Juniperus/Artemisia/ Festuca	5	NW to NE	Chestnut	4250-4500
(2) Juniperus/Artemisia/ Festuca-Lupinus	4	N to NE	Regosol in Brown Zone	4400-4550
(3) Juniperus/Festuca	5	NW	Brown	4100-4300
(Purshia Variant)	(2)	(SE to E)		
(4) Juniperus/Artemisia/ Agropyron-Chaenactis	5	NW to NE	Regosol in Brown Zone	3900-4400
(5) Juniperus/Artemisia/ Agropyron	5	Level	Brown	2550-2650
(6) Juniperus/Agropyron	6	E to NE	Brown	4150-4450
(Purshia Variant)	(2)	(SE)		
(7) Juniperus/Artemisia- Purshia	5	N to NE	Regosol in Brown Zone	4100-4400
(8) Juniperus/Agropyron- Festuca	5	E	Regosol in Brown Zone	4250-4750
(9) Juniperus/Artemisia/ Agropyron-Astragalus	6	S to SW	Brown	4000-4400

to characterize each ecosystem, and provides generalized characteristics of each ecosystem.

Generic names of plants quantitatively dominating the tree, shrub, and herbaceous plant layers are used to name the ecosystems. This method of naming provides a brief diagnostic description by conveying some notion of physiognomy. Generally, a form of trinomial nomenclature was found adequate. In some instances, however, these character species are the same but differ in dominance expression among ecosystems. For example, this occurs between the (1) Juniperus/Artemisia/Festuca and (2) Juniperus/Artemisia/Festuca-Lupinus Ecosystems. Therefore, the generic name of a forb showing one-hundred percent constancy in one entity and considerable less constancy in the other is added to differentiate these two in name. Occasionally, one layer contributes little to the physiognomy of an ecosystem community and a binomial is sufficient. This occurs in the (3) Juniperus/Festuca and (6) Juniperus/Agropyron Ecosystems where the shrub layer is insignificant. Sometimes, layers are codominated by species of similar life-form and the generic name of both dominants are used in the ecosystem names. The (7) Juniperus/Artemisia-Purshia and (8) Juniperus/Agropyron-Festuca Ecosystems are examples of this characteristic.

Samples of at least five stands were used to classify and characterize all but one of the ecosystems and the two ecosystem variants. One unit of the (2) Juniperus/Artemisia/Festuca-Lupinus

Ecosystem was sufficiently different in floristic and soil characteristics to suspect it represented some other entity. The shrub layer in this stand is dominated by Artemisia arbuscula. Only two sample units were used to characterize the Purshia Variants of the (3) Juniperus/Festuca and (6) Juniperus/Agropyron Ecosystems. These variants are minor in aerial extent. The main characteristics are the same as their respective ecosystems, and sufficient representative stands could not be located for analysis.

Direction of slope appears limiting in the occurrence of the Purshia Variants and the relative dominance of Festuca and Agropyron. The Purshia Variants are most strongly expressed on southeast- to east-facing slopes. The ecosystems with Festuca as a major dominant favor northerly slopes. Where Agropyron dominates the herbaceous layer, the respective ecosystems have southerly to level aspects. An exception with Agropyron dominance occurs with the (4) Juniperus/Artemisia/Agropyron-Chaenactis and (8) Juniperus/Agropyron-Festuca Ecosystems. These entities occur on northerly to east slopes with Regosolic soils whose characteristics apparently compensate other factors to favor stronger expression of Agropyron.

Relationships between ecosystems and Great Soil Groups are meager. In one case, however, a Great Soil Group difference provided separation of two ecosystems otherwise identical in the dominants of the three plant layers. The (1) Juniperus/Artemisia/Festuca Ecosystem is associated with a Chestnut soil. The (2) Juniperus/Artemisia/Festuca-Lupinus Ecosystem is associated with a Regosol.

Associating each ecosystem with its Great Soil Group differentiates these two entities in name. Elevation appears nondeterminant in ecosystem distribution.

Tables 3, 4, 5, and 6 illustrate characteristics of the ecosystems. Table 3 shows mean foliage cover, standard errors of foliage cover, and constancy of species arranged in relative order of dominance and constancy. Table 4 shows average maximum heights of mature shrubby and suffrutescent species and standard errors of these heights. Table 5 shows density counts and standard errors of these counts of established shrubby and suffrutescent species. Table 6 shows mean values and standard errors of these values of perennial herb basal area on the soil surface and selected soil characteristics.

The diagnostic features of each ecosystem are organized into the following Key to the Ecosystems. This key is based on vegetational, soil, and topographic characteristics easily recognized in the field. It is provided to assist the reader and potential user of the results of this study to remember some basic characteristics of the described ecosystems. Immediately following the key are more detailed descriptions of the ecosystems.

Legend of the Ecosystems

Ecosystem Number	Ecosystem Name
(1)	*Juniperus/Artemisia/Festuca*
(2)	*Juniperus/Artemisia/Festuca-Lupinus*
(3)	*Juniperus/Festuca* (*Purshia* Variant)
(4)	*Juniperus/Artemisia/Agropyron-Chaenactis*
(5)	*Juniperus/Artemisia/Agropyron*
(6)	*Juniperus/Agropyron* (*Purshia* Variant)
(7)	*Juniperus/Artemisia-Purshia*
(8)	*Juniperus/Agropyron-Festuca*
(9)	*Juniperus/Artemisia/Agropyron-Astragalus*

Table 3. Constancy, mean foliage cover, and standard errors of foliage cover of species in ecosystems in the central Oregon Juniper Zone[1/]
(In percent)

Species	Ecosystem[2/] (1)			(2)			(3)			(4)			(5)			(6)			(7)			(8)			(9)		
	Const.	Cover	Std. Error	Const.	Cover	Std. Error	Const.	Cover	Std. Error	Const.	Cover	Std. Error	Const.	Cover	Std. Error	Const.	Cover	Std. Error	Const.	Cover	Std. Error	Const.	Cover	Std. Error	Const.	Cover	Std. Error
Juniperus occidentalis	100	12.0	0.3	100	12.3	1.7	100	76.7	2.4	100	46.0	4.6	100	10.0	2.0	100	43.0	1.7	100	6.6	1.5	100	32.0	2.8	100	27.7	2.5
Artemisia tridentata	100	7.4	0.9	100	5.1	1.1	100	0.9		100	4.1	1.1	100	8.5	2.4	100	0.9		100	8.2	2.1	100	3.0	0.7	100	6.7	0.8
																(100)											
Festuca idahoensis	100	10.8	0.4	100	10.4	2.5	100	10.8	0.5	100	1.9	0.4	60	0.4		100	1.7	0.3	100	2.5	0.3	100	2.3	0.4			
							(100)	(5.3)	(0.5)																		
Agropyron spicatum	100	5.3	0.5	100	1.5	0.5	100	1.6	0.2	100	3.7	0.5	100	9.2	0.5	100	5.0	0.8	100	0.9	0.1	100	3.2	0.3	100	7.0	0.3
Poa secunda	100	1.6	0.3	100	1.0	0.1	100	0.9		100	0.7		100	1.3	0.3	100	0.7		60	0.2		100	1.4	0.2	100	0.9	
Koeleria cristata	100	0.2		100	0.8		100	0.3		100	0.7					100	0.3		100	0.1		100	0.5		100	0.5	
Astragalus sp.	100	1.4	0.2				60	0.1					100	0.3		50											
Agoseris sp.	100	0.4		25			40	0.1					60	0.1								20			17		
Achillea millefolium	100	0.3					60	0.1		100	0.1		100	0.1		100	0.2		100	0.2		100	0.1		100	0.1	
Lomatium triternatum	100	0.1		100	0.1		100						100	0.6		34			20								
Collinsia parviflora*	100	0.6		100	0.1		100	0.2		100	0.6		100	0.1		100	0.1		100	0.2		100			84		
Gayophytum lasiospermum*	100	0.3		25			80			80	0.5					84			100	1.0		20			50		
Lupinus sp.	40			100	2.3	0.1	60	0.1								17						60	0.2				
Phlox douglasii	40	0.3		100	0.3		100	0.2					20	0.1		100	0.2		20			80	0.3		100	0.4	
Erigeron filifolius				100	0.3																	80	0.1				
Eriogonum microthecum				100	0.3																	20	0.1				
Eriophyllum lanatum	60			75	0.1		100	0.2		60	0.1					68	0.1		40			80	0.5		34		
Bromus tectorum*	60						100	0.2		100	1.7		100	1.7		100	0.4		100	2.7		80	0.1		100	0.5	
Stipa thurberiana				75	0.1		80	0.4		100	0.7		80	2.0		100	0.2		60	0.3		100	0.5		50		
Chaenactis douglasii							20			100	0.3											20					
Astragalus sp.				25			80			100	0.2					100	0.3		60			80	0.3		100	0.2	
Cryptantha ambigua*	20			50			80	0.1		100	0.3		20			100	0.1		100	0.6		100			100	0.1	
Chrysothamnus nauseosus	40			100	0.2		20			60	0.2		100	1.1		34			40	0.2		60	0.3				
Festuca octoflora*													100	0.6		34									34	0.1	
Sitanion hystrix	20									40	0.1		40	0.1					100	0.2		40			17		
Erigeron linearis	60						80	0.1		80	0.2		20			100	0.1		100	0.1					100	0.1	
Purshia tridentata							100	0.6		60	0.1					100	0.1		100	5.5	0.1				34	0.3	
							(100)	(3.5)	(0.6)							(100)	(6.7)	(0.7)									
Chrysothamnus vicidiflorus	80	0.3		100	0.2		100	0.1		60	0.4					84	0.4		100	1.5		60	0.4		50	0.6	
Collomia grandiflora*							80									68			100	0.1		20			17		
Mentzelia albicaulis*										80	0.1								100	0.5		20					
Montia perfoliata*	60	0.3					20												100	0.1							
Eriogonum ochrocephalum				75			20			60												100	0.1				
Astragalus lectulus							60									17									100	0.1	
Stipa comata																			80			20					
Eriogonum sphaerocephalum							20									34						100	0.8				
Linanthus harknesii*				25						80	0.2		20						20			80					
Eriogonum baileyi*				25			60									68	0.1		20						84	0.1	
Eriogonum umbellatum							80						20			34	0.1		20						17		
Penstemon cinereus							80	0.1								17						20	0.1				
Other perennial herbs[3/]		0.1			0.1			0.1			1.4			0.1			0.2			0.1			0.3			0.3	
Other perennial shrubs[4/]		0.3			1.7															0.8						0.2	
Total perennial herbs		20.5			17.0			15.1 (9.6)			10.1			14.3			9.1			4.6			9.8			9.6	
Total shrubs and suffrutescents		8.0			7.5			1.6 (4.5)			4.8			9.6			1.4 (8.0)			16.2			4.6			7.8	

1/ Cover recorded for species having at least 0.1 percent cover in a single ecosystem.
Constancy recorded for species attaining 80 percent constancy or more in at least one ecosystem.
Standard errors recorded for perennial species attaining relatively high cover values and 100 percent constancy in a single ecosystem.
Species characteristics in parentheses indicate ecosystem variants.
Species with constancy but not cover shows presence in insufficient quantity to provide cover estimates.

2/ Ecosystem number in this table and succeeding tables correspond to those appearing in Table 2.

3/ Mostly Carex filifolia in ecosystem (4); variable in others.

4/ Mostly Tetradymia canescens in ecosystems (1), (2), and (9); Tetradymia canescens and Leptodactylon pungens in ecosystem (7).

* Annuals.

Table 4. Mean maximum heights in feet and standard errors of mature shrubby and suffrutescent species in ecosystems in the central Oregon Juniper Zone 1/

Ecosystem	Artemisia tridentata Ht.	Artemisia tridentata Std. error	Purshia tridentata Ht.	Purshia tridentata Std. error	Eriogonum microthecum Ht.	Chrysothamnus nauseosus Ht.	Chrysothamnus vicidiflorus Ht.	Eriogonum sphaerocephalum Ht.
Juniperus/Artemisia Festuca	1.29	0.03				1.09	1.24	
Juniperus/Artemisia Festuca-Lupinus	1.17	0.04			0.69	1.73	0.78	
Juniperus/Festuca (Purshia Variant)	1.17	0.06	3.26 (3.78)	0.16 (0.17)		2.10	0.44	0.45
Juniperus/Artemisia/ Agropyron-Chaenactis	1.32	0.06	0.90			0.99	0.86	
Juniperus/Artemisia Agropyron	1.95	0.11				2.03		
Juniperus/Agropyron (Purshia Variant)	1.32 (1.82)		1.93 (2.69)	(0.07)		1.75	0.66	0.60
Juniperus/Artemisia-Purshia	1.79	0.16	2.49	0.16		1.74	1.40	
Juniperus/Agropyron-Festuca	1.52	0.12			0.72	1.73	0.71	0.69
Juniperus/Artemisia/ Agropyron-Astragalus	1.26	0.05	2.90				0.89	

1/ Standard errors computed for those species attaining 100 percent constancy and contributing a major portion of the cover. Heights and standard errors in parentheses in species columns indicate ecosystem variants.

Table 5. Mean density counts (number per 800 square feet) and standard errors of shrubby and suffrutescent species in ecosystems in the central Oregon Juniper Zone 1/

Ecosystem	*Artemisia tridentata*		*Purshia tridentata*		*Eriogonum microthecum*	*Chrysothamnus nauseosus*	*Chrysothamnus vicidiflorus*	*Eriogonum sphaerocephalum*
	No.	Std. error	No.	Std. error	No.	No.	No.	No.
Juniperus/*Artemisia* *Festuca*	104	20.8				2	55	
Juniperus/*Artemisia* *Festuca*-*Lupinus*	44	8.1			4	3	7	
Juniperus/*Festuca* (*Purshia* Variant)	29 (5)	6.5 (1.2)	4 (6)	0.5 (0.6)		1	10	2
Juniperus/*Artemisia*/ *Agropyron*-*Chaenactis*	26	3.6	1			4	10	
Juniperus/*Artemisia* *Agropyron*	26	3.2				4		
Juniperus/*Agropyron* (*Purshia* Variant)	4 (3)		2 (7)	(1.0)		1	8	1
Juniperus/*Artemisia*-*Purshia*	34	5.4	13	1.7		3	17	
Juniperus/*Agropyron*-*Festuca*	17	1.8			4	2	6	17
Juniperus/*Artemisia*/ *Agropyron*-*Astragalus*	26	3.9	1				9	

1/ Standard errors computed for those species attaining 100 percent constancy and contributing a major portion of the cover. Numbers and standard errors in parentheses in species columns indicate ecosystem variants.

Table 6. Mean values and standard errors of perennial herb basal area on the soil surface and selected soil characteristics in ecosystems in the central Oregon Juniper Zone [1/]

Ecosystem	Basal area perennial herbs		Bare soil surface		Available SMS capacity - 2-14" Zone [2/]		Organic matter - A horizon		Total nitrogen - A horizon		Horizon texture [3/]	
	Pct.	Std. error	Pct.	Std. error	Inches water	Std. error	Pct.	Std. error	Pct.	Std. error	A	B or AC
Juniperus/Artemisia Festuca	7.4	0.3	22.1	5.4	1.41	0.08	4.78	0.52	0.21	0.02	l	c
Juniperus/Artemisia Festuca-Lupinus	6.5	0.8	30.9	1.5	1.98	0.08	1.74	0.09	0.10	0.01	sl	sl
Juniperus/Festuca (Purshia Variant)	4.4	0.6	33.3 (46.8)	0.8 (4.0)	1.81 (2.14)	0.10 (0.12)	3.91 (2.33)	0.35 (0.16)	0.17 (0.10)	0.01 (0.01)	l (l)	sil, c (c)
Juniperus/Artemisia/ Agropyron-Chaenactis	5.2	0.4	52.3	2.0	0.87	0.03	1.59	0.25	0.08	0.09	sl	sl
Juniperus/Artemisia Agropyron	6.6	0.7	41.3	3.9	2.31	0.05	1.50	0.11	0.08	0.01	l	c, cl
Juniperus/Agropyron (Purshia Variant)	3.2	0.3	51.1	3.0	1.34	0.05	2.12	0.04	0.10	0.00	scl (l)	c, cl
Juniperus/Artemisia-Purshia	3.1	0.4	55.0	3.4	1.54	0.08	1.05	0.11	0.06	0.01	sl	sl
Juniperus/Agropyron-Festuca	4.1	0.5	54.7	4.4	0.97	0.07	1.32	0.09	0.07	0.01	sl	sl
Juniperus/Artemisia/ Agropyron-Astragalus	3.5	0.4	45.7	3.0	1.21	0.05	1.63	0.03	0.08	0.00	l	c

1/ Standard errors computed for quantitative measurements. Figures in parentheses under box-head columns indicate values for ecosystem variants.

2/ SMS = soil moisture storage.

3/ The AC horizon is immediately below the A horizon in Regosols. B horizon textures were taken for the finest part of that horizon. Textural classes: cl = clay loam; l = loam; scl = sandy clay loam; sil = silt loam; c = clay; sl = sandy loam.

Key to the Ecosystems.

1. Ecosystems associated with Zonal Soils

    2. Ecosystems associated with northerly slopes and Chestnut soils of rhyolitic/andesitic colluvial origin; Juniperus occidentalis, Artemisia tridentata, and Festuca idahoensis comprising respectively approximately 12, 7, and 11 percent cover --

    Ecosystem (1): Juniperus/Artemisia/Festuca

    2. Ecosystems occurring on varied slopes with Brown soils of varied origin.

        3. Festuca idahoensis dominant (approximately 11 percent cover); Juniperus occidentalis comprising approximately 77 percent cover; ecosystem normally positioned on the lower portion of north slopes on soils derived from volcanic tuff indurated when dry but friable and porous when wet---------------

        Ecosystem (3): Juniperus/Festuca

        Purshia Variant: Occurs on east to southeast slopes; Purshia tridentata comprises approximately 4 percent cover; Festuca idahoensis comprises approximately 5 percent cover.

3. _Festuca idahoensis_ not dominant and may be absent; _Agropyron spicatum_ dominant in the herbaceous stratum.

    4. _Artemisia tridentata_ in very small quantities (approximately 0.9 percent cover); _Juniperus occidentalis_ and _Agropyron spicatum_ comprising respectively approximately 43 and 5 percent cover; ecosystem normally positioned on east to northeast slopes with soils of rhyolitic/andesitic colluvial origin------- Ecosystem (6): _Juniperus/Agropyron_.

        Purshia Variant: Occurs on southeast slopes; _Purshia tridentata_ comprises approximately 7 percent cover.

    4. Artemisia tridentata in large quantities (greater than approximately 7 percent cover).

        5. _Festuca idahoensis_ absent in measured stands (present only under trees); _Juniperus occidentalis_, _Artemisia tridentata_ and _Agropyron spicatum_ comprising respectively approximately 28, 7, and 7 percent cover; _Astragalus lectulus_ present

in all stands; ecosystem positioned on south- and southwest-facing slopes with soils of rhyolitic/andesitic colluvial origin---------- Ecosystem (9): Juniperus/Artemisia/Agropyron-Astragalus.

5. Festuca idahoensis present in very small quantities (approximately 0.4 percent cover); Juniperus occidentalis, Artemisia tridentata, and Agropyron spicatum comprising respectively approximately 10, 8, and 9 percent cover; Astragalus lectulus absent in all stands; ecosystem positioned on gently undulating uplands with strongly developed, almost rock-free soils of water-and/or wind-laid sediments-- Ecosystem (5): Juniperus/Artemisia/Agropyron.

1. Ecosystems associated with Azonal Regosolic soils of mixed aeolian acid igneous and pumice sands and positioned on the upper half of north to northeast slopes.

6. Ecosystems associated with soils developed from deep (approximately 45 inches) sands; Artemisia tridentata

and Purshia tridentata sharing dominance (approximately 8 and 6 percent cover respectively) in the shrub stratum-- Ecosystem (7): Juniperus/Artemisia-Purshia.

6. Ecosystems associated with soils developed from shallow (approximately 16 inches) to moderately deep (approximately 25 inches) sands, indurated hardpans present or absent.

   7. Ecosystems associated with soils developed from shallow (approximately 16 inches) sands; indurated hardpans present; Agropyron spicatum and Festuca idahoensis sharing dominance (approximately 3 and 2 percent cover respectively) in the herbaceous stratum; Juniperus occidentalis comprising approximately 32 percent cover-------------------- Ecosystem (8): Juniperus/Agropyron-Festuca.

   7. Ecosystems associated with soils developed from moderately deep (approximately 25 inches) sands; Agropyron spicatum or Festuca idahoensis dominating the herbaceous stratum; indurated hardpans absent.

      8. Agropyron spicatum dominant (approximately 4 percent cover) in the herbaceous stratum; Juniperus occidentalis and Artemisia tridentata comprising approximately 46 and 4 percent cover respectively; Chaenactis

douglasii present in all stands; Lupinus sp. absent in all stands------------------ Ecosystem (4): Juniperus/Artemisia/ Agropyron-Chaenactis.

8. Festuca idahoensis dominant (approximately 10 percent cover) in the herbaceous stratum; Juniperus occidentalis and Artemisia tridentata comprising respectively 12 and 5 percent cover. Chaenactis douglasii absent in all stands; Lupinus sp. present in all stands------------------------------ Ecosystem (2): Juniperus/Artemisia/ Festuca-Lupinus.

(1) Juniperus/Artemisia/Festuca Ecosystem. This ecosystem occurs in the most mesic locations of the study area. It is characteristic of northwest- to northeast-facing slopes with loamy Chestnut soils supporting a relatively rich and dense flora (Figure 3). Perennial herbaceous cover is approximately 20.5 percent, the greatest amount occurring in any of the entities (Table 3). Soil surface occupied by perennial herbs, organic matter in the A horizon, and total nitrogen in the A horizon, approximately 7.4, 4.78, and 0.21 percent respectively, are also greater in this unit (Table 6). Bare soil surface, approximately 22.1 percent, is less than in the other ecosystems. Although available soil moisture storage capacity

Figure 3. Stand representative of the (1) *Juniperus*/*Artemisia*/*Festuca* Ecosystem illustrating relatively rich and dense vegetation.

in the 2- to 14-inch soil zone, approximately 1.41 inches, is less than in some of the other ecosystems (Table 6), its effectiveness is increased by loamy and clayey surface and subsoils, rockiness of the solum, and reduced insolation on the northerly aspect.

Juniperus occidentalis, Artemisia tridentata, and Festuca idahoensis are the most characteristic species of the plant community. Respectively, they provide approximately 12.0, 7.4, and 10.8 percent cover. Agropyron spicatum, the next most dominant plant, has a cover value of approximately 5.3 percent. It appears to be in high vigor and provides a characteristic bunchgrass aspect (Figure 4). The combined cover value of this species and Festuca idahoensis is at least 20 percent greater than in any of the other entities. Cover of Poa secunda, approximately 1.6 percent, is greatest in this ecosystem.

In addition to its 7.4 percent cover, mature plants of Artemisia tridentata attain an approximate average maximum height of 1.29 feet. Average density of the species is approximately 104 plants per 800 square feet, more than double its density in other ecosystems (Table 5). Density of Chrysothamnus vicidiflorus, more than 30 percent higher than in other units, is the only other diagnostic characteristic of the shrub stratum. However, the diagnostic value of this species is limited by its constancy of 80 percent.

Astragalus sp. is the dominant forb with average cover of 1.4 percent. Although the 100 percent constancy of this species is the

Figure 4. Detail of the understory vegetation in the (1) Juniperus/Artemisia/Festuca Ecosystem. The vegetational aspect is one of large, vigorous plants of Agropyron spicatum although Festuca idahoensis is dominant on a cover basis.

same in the (5) Juniperus/Artemisia/Agropyron Ecosystem, its cover value is nearly five times greater. Agoseris sp. has low cover, 0.4 percent, but it is present in all stands, a characteristic exclusive to this ecosystem.

This ecosystem is associated with only one soil, a Chestnut loam developed from rhyolitic/andesitic colluvium (Series I). 2/ Solum depth is approximately 30 inches. The surface horizon is a loam. The relatively high organic matter content in the surface horizon imparts a very dark brown color. The surface horizon of soils in the other ecosystems do not have colors this dark.

The heaviest part of the B horizon is clay and has strong, blocky structure, very hard when dry and firm when moist. Ordinarily, rooting depth would be restricted because of these subsoil characteristics. In this case, however, approximately 50 percent of the solum volume is occupied by large stones which allow roots to penetrate deeper than might be expected (Figure 5).

2/ Tentative soil series and phase descriptions are presented in Appendix 2. Descriptions and series interpretations were reviewed by Dr. Ellis G. Knox, Soils Specialist, Oregon State University, Corvallis, Oregon.

Figure 5. Profile of Series I associated with the (1) Juniperus/Artemisia/Festuca Ecosystem. Stoniness in the heavy, strongly developed subsoil allows deep root penetration. Compare with Figure 18.

(2) Juniperus/Artemisia/Festuca-Lupinus Ecosystem. This ecosystem, occupying the smallest portion of the study area, is associated with north- to norhteast-facing slopes. The associated soil is Azonal and supports less luxuriant vegetation than the previous ecosystem. Perennial herbaceous cover is approximately 17.0 percent as compared to 20.5 percent in the previously described unit. Juniperus occidentalis, Artemisia tridentata, and Festuca idahoensis also characterize the vegetational component of this ecosystem but differ quantitatively from the (1) Juniperus/Artemisia/Festuca entity (Table 3). Cover of these species is 12.3, 5.1, and 10.4 percent respectively. Cover of Artemisia tridentata provides the most striking difference; nearly 30 percent less in this ecosystem. Average maximum heights of mature Artemisia tridentata is 1.17 feet. Density of the species is less than one-half the density occurring in the first described unit.

Juniperus occidentalis is patchy, occurring as clumps of several trees throughout the ecosystem (Figure 6). The comparative paucity of this species may be partly due to old fires. Charred tree trunks on the soil and tree roots in the soil are common wherever the entity occurs.

Agropyron spicatum provides only 1.5 percent cover in contrast to 5.3 percent in the Juniperus/Artemisia/Festuca association found on Chestnut soils. Foliage cover of Poa secunda is also less, 1.0 percent. Koeleria cristata has a cover value of 0.8 percent, 10 percent greater than in any other ecosystem.

Figure 6. Stand representative of the (2) Juniperus/Artemisia/Festuca-Lupinus Ecosystem. The clumpiness and paucity of the Juniperus occidentalis component is associated with past fires.

Lupinus sp. provides the most striking vegetational difference between this ecosystem and its counterpart on Chestnut soils. Here, the species is present in all stands and has a cover value of 2.3 percent but is absent in the previous ecosystem. Phlox douglasii and Erigeron filifolius provide little cover, 0.3 percent each, but they are present in all stands as compared to 40 percent constancy in the (1) Juniperus/Artemisia/Festuca Ecosystem.

Eriogonum microthecum is diagnostic of this ecosystem. Cover and constancy of the species, 0.3 percent and 100 percent respectively, are greater than in any of the other ecological units described (Table 3).

The soil associated with the (2) Juniperus/Artemisia/Festuca-Lupinus Ecosystem is a shallow (16 inches) sandy loam Regosol overlying mixed alluvium and unconsolidated rhyolitic and andesitic stones (Series II-Shallow, Nonstony Phase). Pentagonal configurations are characteristic of the soil surface when it is dry (Figure 7). Specific reasons for the development of this configuration is not known but it is probably associated with interacting effects of the organic matter content of the surface horizon (1.74 percent), relatively high perennial herb cover, slope aspect, and bare soil surface (30.9 percent). These pentagonal blocks frost-heave; some were observed completely tipped over with moss and small ephemeral plants persisting on what was once the top of the block.

Figure 7. Detail of the soil surface and understory vegetation in the (2) Juniperus/Artemisia/Festuca-Lupinus Ecosystem. The pentagonal configurations on the soil surface are characteristic of this ecosystem.

The entire solum is a sandy loam with roots abundantly distributed throughout the profile (Figure 8). The available water storage capacity in the 2- to 14-inch zone is 1.98 inches, at least 20 percent more than in the same soil zone of Azonal soils in other units. Total nitrogen in the A horizon is 0.10 percent. The underlying material is highly variable but is loose allowing relatively deep root penetration. Pumice sands contribute approximately 30 percent to the solum volume.

(3) Juniperus/Festuca Ecosystem. This ecosystem is characteristic to the lower portions of northwest-facing slopes with Brown soils with loam textures. Perennial herbaceous cover is 15.1 percent. Shrub cover is scant (1.6 percent), exceeding only the (6) Juniperus/Agropyron Ecosystem (Table 3).

Juniperus occidentalis and Festuca idahoensis are the dominant species of the ecosystem. Juniperus occidentalis has a foliage cover of 76.7 percent, nearly twice as much as any other ecosystem (Table 3). This high cover value and the close spacing of individual trees gives the area an aspect of a dense forest (Figure 9). Foliage cover of Festuca idahoensis is 10.8 percent, equalling that of the (1) Juniperus/Artemisia/Festuca Ecosystem. However, individual plants are relatively small and do not have the robust, vigorous appearance characteristic of the species (Figure 10).

Agropyron spicatum, Poa secunda, and Koeleria cristata have 100 percent constancies but are less characteristic perennial

Figure 8. Soil profile of Series II-Shallow, Nonstony Phase associated with the (2) Juniperus/Artemisia/Festuca-Lupinus Ecosystem. Plant roots are abundantly distributed throughout the solum. Different phases of this same series are associated with three other Ecosystems, (4) Juniperus/Artemisia/Agropyron-Chaenactis, (7) Juniperus/Artemisia-Purshia, and (8) Juniperus/Agropyron-Festuca.

Figure 9. Stand representative of the (3) Juniperus/Festuca Ecosystem. This ecosystem has the highest Juniperus occidentalis cover in study area.

Figure 10. Detail of the understory vegetation of the (3) Juniperus/Festuca Ecosystem. Individual plants of *Festuca idahoensis* are less robust than is characteristic for the species.

grasses of this association. Cover values of these species are 1.6, 0.9, and 0.3 percent respectively. Perennial forbs are minor parts of the herbaceous component of this ecosystem.

Purshia tridentata is the most diagnostic species in the shrub layer. Although cover and density values are low, 0.6 percent and 4 plants per 800 square feet respectively, mature plants are tall (3.26 feet). This height is exceeded only in the Purshia Variant of the ecosystem being discussed (Table 4). Cover and density of Artemisia tridentata are greater (0.9 percent and 29 plants per 800 square feet respectively) than Purshia tridentata, but the average maximum height of mature plants of Artemisia tridentata is much less (1.17 feet).

The plant community in the (3) Juniperus/Festuca Ecosystem is associated with two soil series (Series III and Series IV). Both series are Brown loams but have developed from different materials. Series III has developed from friable, tuffaceous material. Series IV has developed from aeolian sands and small, loosely packed rhyolitic and andesitic stones of colluvial origin.

Some internal characteristics of both soils are similar. Available water storage capacity in the 2- to 14-inch soil zone is 1.81 inches. Organic matter content and total nitrogen of the A horizon is 3.91 and 0.17 percent respectively. In contrast to the other ecological units, these soil characteristics are exceeded only in the Chestnut soil of the (1) Juniperus/Artemisia/Festuca Ecosystem.

Subsoil textures and solum depths are different, however, between Series III and Series IV. Series III has a clayey subsoil not too strongly developed. The solum of this series is only 18 inches deep but the friable underlying material allows root penetration which compensates, to some extent, the relatively shallow depth (Figure 11). Series IV has loamy subsoils and the solum is 28 inches deep. The deeper solum and coarser subsoil texture of Series IV apparently affect plant growth and distribution in a way similar to the shallow, clayey subsoiled, friable parent materialed Series III.

Purshia Variant: (3) *Juniperus/Festuca* Ecosystem. The *Purshia* Variant of the (3) *Juniperus/Festuca* Ecosystem is associated with southeasterly slopes and the very stony phase of soil Series III. Vegetational characteristics are the same as the ecosystem except for cover, mature plant height, and density of *Purshia tridentata*; cover of *Festuca idahoensis*; and density of *Artemisia tridentata*. These cover changes naturally result in proportionate changes in total shrub and herb cover.

Cover of *Purshia tridentata* increases from 0.6 percent in the (3) *Juniperus/Festuca* Ecosystem to 3.5 percent in its variant. Average maximum height of mature *Purshia tridentata* plants is 3.78 feet, approximately 0.5 of a foot higher than in the ecosystem. Density of the species increases from 4 plants to 6 plants per 800 square feet, but the crowns of the individual plants in the variant

Figure 11. Profile of Series III associated with the (3) Juniperus/Festuca Ecosystem. The tuffaceous, parent material becomes friable when wet allowing root penetration.

are wide (Figure 12).

Cover of *Festuca idahoensis* decreases from 10.8 percent in the ecosystem to 5.3 percent in its variant. Density of *Artemisia tridentata* decreases from 29 to 5 plants per 800 square feet but cover and mature plant height remains the same. As with *Purshia tridentata*, individual plant crowns of *Artemisia tridentata* in the variant are wide as compared to crown width of the species in the ecosystem.

Visible soil morphological characteristics of the very stony phase of Series III associated with the *Purshia* Variant of the (3) *Juniperus/Festuca* Ecosystem are the same as those in Series III except stoniness of the solum (Figure 13). Relatively large rhyolitic and andesitic stones occupy approximately 50 percent of the profile volume in the phase as compared to 5 percent in the series. Other characteristics determined by laboratory analyses are quite different (Table 6). Available water storage capacity in the 2- to 14-inch soil zone of the phase is 2.14 inches, 15 percent more than the same soil zone in the series is capable of storing. Organic matter and total nitrogen in the A horizon is approximately 37 and 41 percent less respectively in the phase as compared to the series. Regardless of these strong soil differences between the ecosystem and its variant, stronger vegetational similarities favor grouping under the same categorical unit until further study may indicate separation.

Figure 12. Stand representative of the Purshia Variant: (3) Juniperus/Festuca Ecosystem. Density of Purshia tridentata is low, but individual plant crowns are wide. The species is in the center of the picture.

Figure 13. Profile of Series III-Very Stony Phase supporting the _Purshia_ Variant: (3) _Juniperus_/_Festuca_ Ecosystem. Rhyolitic and andesitic stones occupy 50 percent of the profile volume.

(4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystem. This ecological unit is associated with northwest- to northeast-facing slopes and has the characteristic savanna-like aspect of the Juniperus Zone (Figure 14). The associated soil is the same series and type of the (2) Juniperus/Artemisia/Festuca-Lupinus Ecosystem but represents the moderately deep, extremely stony phase of the series.

Perennial herbaceous cover is more than 30 percent less than in previous units. Agropyron spicatum assumes dominance in the herbaceous stratum with an average foliage cover of 3.7 percent. These characteristics indicate environmental conditions more xeric than exist in previously described entities. Juniperus occidentalis has an average foliage cover of 46.0 percent, exceeded only in the (3) Juniperus/Festuca Ecosystem. Artemisia tridentata keeps its dominant status in the shrub layer. Cover of the plant is 4.1 percent, maximum mature plant height is 1.32 feet, and plant density is 26 plants per 800 square feet. Chaenactis douglasii has 100 percent constancy, an exclusive characteristic of this ecosystem.

Festuca idahoensis, Poa secunda, Koeleria cristata and Stipa thurberiana have 100 percent constancies. Cover of Festuca idahoensis is only 1.9 percent, a reduction of at least 73 percent from its dominant status in the former entities.

With the exception of Chaenactis douglasii, perennial forbs provide minor diagnostic value to the component vegetation of the (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystem. Achillea

Figure 14. Stand representative of the (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystem. Juniperus occidentalis is fairly evenly spaced providing the characteristic savanna-like aspect of the Juniperus zone.

millefolium and an unidentified species of Astragalus are the only other perennial forbs with 100 percent constancy. These species are also very common in other ecosystems.

Some annual species assume some diagnostic importance in this ecosystem. Collinsia parviflora has 100 percent constancy and 0.6 percent cover, equalled only in the (1) Juniperus/Artemisia/Festuca Ecosystem. Linanthus harknesii has 0.2 percent cover, greater than in any of the other ecosystems and constancy of the species is 80 percent. Bromus tectorum has an average cover of 1.7 percent, exceeded only in the (7) Juniperus/Artemisia-Purshia Ecosystem.

Shrubs other than Artemisia tridentata have little value for characterizing the (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystem on the basis of dominance or constancy if the species are considered individually. Chrysothamnus nauseosus, Purshia tridentata, and Chrysothamnus vicidiflorus have constancy ratings of only 60 percent and cover values of 0.2, 0.1, and 0.4 percent respectively. Chrysothamnus vicidiflorus has the highest density with 10 plants per 800 square feet. Mature plants of Chrysothamnus nauseosus are the tallest, 0.99 feet. However, the characteristic relationships among these species as compared to the same among species relationships in other entities provides diagnostic features specific to this ecological unit. None of the other ecosystems have the same or even similar alliances among these species.

The soil associated with this ecosystem is a moderately deep (26 inches) sandy loam Regosol overlying fractured basalt bedrock or closely packed basalt stones (Series II-Moderately Deep, Extremely Stony Phase). It differs visually from the soil associated with the (2) Juniperus/Artemisia/Festuca-Lupinus Ecosystem in solum depth, solum stoniness, and nature of the underlying material. The solum of the soil component of the (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystem is 10 inches deeper and contains 50 percent more stones. Only 10 percent of the underlying material in this soil is capable of supplying moisture and available nutrients to plants as compared to 50 percent of the same material in the soil of the (2) Juniperus/Artemisia/Agropyron-Lupinus Ecosystem.

The entire solum is a sandy loam. Roots are abundantly distributed throughout the profile (see Figure 8). Available water storage capacity in the 2- to 14-inch zone is 0.87 inches, less than half the capacity of the shallow, nonstony phase of the same series. This is primarily the result of the greater volume of stones in the solum. Organic matter content and total nitrogen of the A horizon is 1.59 and 0.08 percent respectively, slightly less than the shallow nonstony phase. The soil surface is 52.3 percent bare and has 5.2 percent of its area occupied by root crowns of herbaceous perennials (Figure 15).

(5) Juniperus/Artemisia/Agropyron Ecosystem. This ecosystem is characterized by undulating uplands with strongly developed Brown soils and represents the climatic climax of the central Oregon Juniper Zone. The areal extent of this ecological unit with

Figure 15. Detail of the soil surface and understory vegetation in the (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystem. Approximately 52.3 percent of the soil surface is bare.

vegetation undisturbed by the influence of man is small. The amount of the study area potentially capable of developing similar vegetation is speculative because of farming and past heavy grazing.

Juniperus occidentalis, Artemisia tridentata, and Agropyron spicatum characterize the vegetational component of this ecosystem (Figure 16). Cover of Juniperus occidentalis averages 10 percent. However, the trees are unevenly distributed occurring in small clumps throughout the area. This situation is similar to the grouping of the trees in the (2) Juniperus/Artemisia/Festuca-Lupinus Ecosystem where fire has been a major factor controlling tree survival and distribution. Charred stumps and logs are fairly common.

Artemisia tridentata attains maximum stature in this unit. Average maximum height of mature plants is 1.95 feet. The species has a cover of approximately 8.5 percent. Both of these characteristics are at least 10 percent greater than in any of the other ecosystems. Density is average, 26 plants per 800 square feet.

Agropyron spicatum reaches maximum development on this site. Cover of the species is 9.2 percent, nearly 25 percent more than in any other unit. Most of the plants are robust and widely spaced, prominent characteristics of the association (Figure 17).

Stipa thurberiana has diagnostic value to the (5) Juniperus/Artemisia/Agropyron Ecosystem. The species attains maximum development with 2.0 percent cover and 80 percent constancy. Although the constancy of Stipa thurberiana is exceeded in some of the other ecological units, its cover value is at least

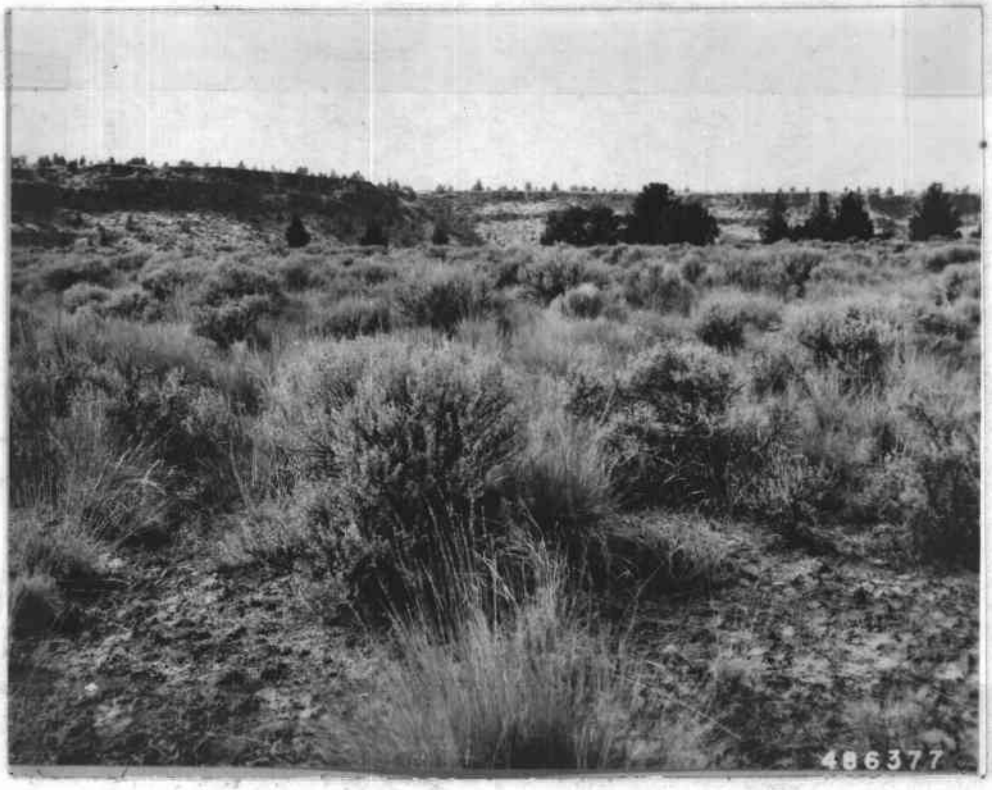

Figure 16. Stand representative of the (5) Juniperus/Artemisia/Agropyron Ecosystem characterized by clumps of Juniperus occidentalis and maximum cover of Artemisia tridentata and Agropyron spicatum.

Figure 17. Detail of the herbaceous and shrubby components of the (5) *Juniperus/Artemisia/Agropyron* Ecosystem. Wide spacing and high cover of *Agropyron spicatum* are diagnostic features of the area.

35 percent greater. The relative scarcity of Festuca idahoensis is also diagnostic. It has a cover of only 0.4 percent occurring mostly in the deep shade of shrubs or trees.

Lomatium triternatum is the only perennial forb in the entity with characterization value. It has 100 percent constancy in three other units, the (1) Juniperus/Artemisia/Festuca, (2) Juniperus/ Artemisia/Festuca-Lupinus, and (3) Juniperus/Festuca Ecosystem, but cover of the species amounts to 0.6 percent, significantly greater than other units (Table 3). In general, a paucity of perennial forbs exists. Including Lomatium triternatum, only seven species were identifiable when the ecosystem was examined.

Chrysothamnus nauseosus is the sole remaining species in the shrub layer. It is characteristic of this ecological unit in that it attains its highest cover value, 1.1 percent (Table 3). However, it is represented by only four plants per 800 square feet.

Two annual grasses had achieved relative diagnostic value when the ecosystem was examined. This was true particularly for cover of Festuca octoflora which was 0.6 percent, more than existed in the (6) Juniperus/Agropyron and (9) Juniperus/Artemisia/Agropyron-Astragalus Ecosystems where it also occurred (Table 3). Bromus tectorum had a cover of 1.7 percent. Other annuals were present but not as characteristic as these species. Extreme caution must be used when considering annuals as possible diagnostic components of any area since they reflect primarily current environmental conditions.

Total cover of perennial herbs (14.3 percent) is 30 percent and 33 percent greater respectively than in the previously described (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystem or the Purshia Variant of the (3) Juniperus/Festuca Ecosystem. This is directly associated with the significant increase in cover of Agropyron spicatum. Total shrub cover (9.6 percent) is greater here than in any of the previously described ecosystems (Table 3). This is due to the increase in cover of Artemisia tridentata.

Two soil series are associated with the (5) Juniperus/Artemisia/Agropyron Ecosystem (Series V and Series VI). Both are strongly developed Brown loams but have originated from different parent materials. Series V developed from river and lake-laid sediments containing small basalt fragments. The parent material of Series VI is loess, very fine sand, and small basalt fragments. The primary internal characteristics visibly different between these series are position, thickness, and texture of the heaviest portion of the B horizon and solum depth. In Series V, this soil layer begins approximately 15 inches below the soil surface, is 8 inches thick, and has clay texture. The same horizon of Series VI starts at an average of 8 inches below the soil surface, is 2 inches thick, and has clay loam texture. Depth to the parent material is 26 inches in Series V and 13 inches in Series VI. Discontinuous caliches occur in the lower B horizons of both soils.

The solum of both soils is relatively stone free, only 5 percent of the solum volume is occupied by small stones.

The heaviest subsoil horizon in these soils is very similar to the same horizon in Series I of the (1) Juniperus/Artemisia/Festuca Ecosystem. In all these soils, this horizon is strong structured, very hard and firm. However, the paucity of stones in the soils of the (5) Juniperus/Artemisia/Agropyron Ecosystem associated with the textural, structural, and consistancy characteristics restricts root penetration (Figure 18). In Series V no roots were found below the heaviest subsoil horizon. The thinness and slightly coarser texture of this horizon in Series VI allows some roots to penetrate to deeper soil material. In Series I, roots are common to abundant throughout the solum.

Other internal characteristics of Series V and Series VI are the same. Available water storage capacity in the 2- to 14-inch zone is 2.31 inches. This quantity is greater than in any of the other units but is less effective because of the topographic position of this unit and subsoil characteristics. Organic matter and total nitrogen of the A horizon is 1.50 and 0.08 percent respectively. These quantities are less than occur in any of the other Zonal soils which are associated with the (1) Juniperus/Artemisia/Festuca, (3) Juniperus/Festuca, (6) Juniperus/Agropyron, and (9) Juniperus/Artemisia/Agropyron-Astragalus Ecosystems.

(6) Juniperus/Agropyron Ecosystem. This ecosystem is associated with east- to northeast-facing slopes with Brown sandy clay loam soils. Shrub paucity provides a distinctive aspect

Figure 18. Profile of Series V supporting the (5) Juniperus/Artemisia/Agropyron Ecosystem. The strong structured, very hard and firm subsoil restricts root penetration. Compare with Figure 5.

(Figure 19) and is characteristic of this ecological unit. Density of Artemisia tridentata is only 4 plants per 800 square feet, the least number counted in any of the units (Table 5). The 0.9 percent cover of the species provides approximately 64 percent of the total 1.4 percent shrub cover. This total shrub cover value is exceeded in all other ecosystems.

An unusual relationship occurs between Agropyron spicatum and Festuca idahoensis. Normally, Agropyron spicatum assumes dominance on sites which appear more xeric than those where Festuca idahoensis dominate. For example, north- and east-facing slopes, generally assumed to be more mesic than south- or west-facing slopes, would be expected to favor dominance of Festuca idahoensis. This condition is illustrated in the (1) Juniperus/Artemisia/Festuca, (2) Juniperus/Artemisia/Festuca-Lupinus, and (3) Juniperus/Festuca Ecosystems. However, Agropyron spicatum with 5.0 percent cover dominates the herbaceous layer while Festuca idahoensis has only one-third as much cover and is a relatively minor vegetational component (Figure 20). A somewhat similar relationship between these two species exists in the (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystem. In this unit, however, Festuca idahoensis has a cover value only slightly less than one-half the cover value of Agropyron spicatum. The abundance of stones in and on the soil as they affect soil moisture, temperature, and plant supporting area of the (6) Juniperus/Agropyron Ecosystem contribute to this relationship.

Figure 19. Stand representative of the (6) Juniperus/Agropyron Ecosystem. Shrub paucity is characteristic of the ecosystem.

Figure 20. Detail of the soil surface and herbaceous vegetation in the (6) Juniperus/Agropyron Ecosystem. Agropyron spicatum dominates this north-slope area. The many large stones on the soil surface is specific to this ecosystem.

Juniperus occidentalis has a cover of 43.0 percent. The trees are fairly evenly distributed providing an aspect similar to the (4) *Juniperus/Artemisia/Agropyron-Chaenactis* Ecosystem.

The dearth of other perennial herbs has diagnostic value. *Poa secunda*, *Koeleria cristata*, *Achillea millefolium*, *Phlox douglasii*, *Stipa thurberiana*, *Astragalus* sp., and *Erigeron linearis* each attain 100 percent constancy ratings. However, the combined cover of all these species is only 2.0 percent which consists mostly of *Poa secunda* with 0.7 percent cover.

Two soil series and a phase of one of these series are associated with the (6) *Juniperus/Agropyron* Ecosystem (Series VII, Series VIII, and Series VII-Shallow Phase). Series VII and its shallow phase are specific to the ecosystem. Series VIII occurs with the *Purshia* Variant subsequently discussed.

Series VII is a sandy clay loam developed from a relatively thin layer of rhyolitic/andesitic colluvium overlying indurated tuffaceous material (Figure 21). The underlying stratum is unrelated to the soil but affects plant growth by restricting root penetration.

With the exception of solum depth, which changes horizon thickness, other characteristics of the series and its stony phase are the same. Solum depth of the series is 40 inches and of the phase is 20 inches. The heaviest part of the subsoil is a clay loam with moderate to strong prismatic and blocky structure, very hard when dry becoming friable when moist. The moist friability of this part of the soil correlated with high stone content (40 percent) permits

Figure 21. Profile of Series VII associated with the (6) Juniperus/Agropyron Ecosystem. The indurated material underlying the soil stops root growth and penetration.

good root penetration. This is in contrast to the subsoil conditions in Series V of the (5) Juniperus/Artemisia/Agropyron Ecosystem. In this soil, the moist consistency of the heaviest part of the subsoil is firm which mechanically restricts root penetration.

The soil surface in the (6) Juniperus/Agropyron Ecosystem is 51.1 percent bare, the highest percentage of any of the Zonal soils. Root crowns of perennial herbs occupy 3.2 percent of the soil surface, less than any of the other Zonal soils. Available water storage capacity in the 2- to 14-inch soil zone is 1.34 inches. Organic matter content and total nitrogen of the A horizon are 2.12 and 0.10 percent respectively.

Purshia Variant: (6) Juniperus/Agropyron Ecosystem. The Purshia Variant of the (6) Juniperus/Agropyron Ecosystem is associated with southeasterly slopes and a Brown loam soil (Series VIII). Vegetational characteristics of the plant association in the variant are the same as the ecosystem except for the strong development of Purshia tridentata (Figure 22). Here, the species attains maximum cover, 6.7 percent (Table 3), almost twice the cover value of the species in the Purshia Variant of the (3) Juniperus/Festuca Ecosystem. Density of Purshia tridentata in the variant being discussed is 7 plants per 800 square feet. Average maximum height of mature plants is 2.69 feet, approximately one foot shorter than in the Purshia Variant of the (3) Juniperus/Festuca Ecosystem.

Figure 22. Stand representative of the Purshia Variant: (6) Juniperus/Agropyron Ecosystem. Purshia tridentata attains its maximum cover on this site.

Soil factors, with slope aspect, appear to be primarily responsible for the development of Purshia tridentata in the Purshia Variant of the (6) Juniperus/Agropyron Ecosystem. The soil is a relatively shallow (20 inches) loam developed from rhyolitic/andesitic colluvium. The stony parent material is loose and has sandy clay material between the large stones. The densest portion of the subsoil is a strong structured, hard and firm clay. Forty percent of the solum consists of relatively large stones, however, which modify the strongly developed clayey subsoil and allow deeper root penetration than exists in Series VII associated with the (6) Juniperus/Agropyron Ecosystem (Figure 23).

Even though the ecosystem and its variant are associated with different soil classes and slopes, similar vegetational characteristics, other than Purshia tridentata, and similarity of some soil charateristics favor grouping under the same categorical unit.

(7) Juniperus/Artemisia-Purshia Ecosystem. The vegetational component of this ecosystem is characterized principally by a conspicuous shrub stratum (Figure 24). Total shrub cover in this unit (16.2 percent) is almost twice as much as the amount of shrub cover in other units. Artemisia tridentata and Purshia tridentata share dominance with crown covers of 8.2 and 5.5 percent respectively. Mature plant height of Artemisia tridentata averages 1.79 feet. The cover and mature plant height values of this species are exceeded only in the (5) Juniperus/Artemisia/Agropyron Ecosystem where it

Figure 23. Profile of Series VIII supporting the Purshia Variant: (6) Juniperus/Agropyron Ecosystem. The stony solum and loose parent material allow deep penetration of Purshia tridentata roots.

Figure 24. Stand representative of the (7) Juniperus/Artemisia-Purshia Ecosystem. Artemisia tridentata and Purshia tridentata share dominance in this entity.

attains its maximum stature. Density of Purshia tridentata, 13 plants per 800 square feet, is nearly twice as great as its density in the Purshia Variants of the (3) Juniperus/Festuca and (6) Juniperus/Agropyron Ecosystems. Average maximum height of mature plants is 2.49 feet.

Herbaceous annuals become quite diagnostic of this ecosystem although they seem inconspicuous in the general aspect. Collinsia parviflora, Gayophytum lasiospermum, Bromus tectorum, Cryptantha ambigua, Collomia grandiflora, Mentzelia albicaulis, and Montia perfoliata all have a constancy of 100 percent. Total cover of these annual species is 11 percent greater than total cover of perennial herbs. Bromus tectorum attained its maximum cover, 2.7 percent, in this association (Table 3). Cover values of Gayophytum lasiospermum (1.0 percent), Cryptantha ambigua (0.6 percent), Mentzelia albicaulis (0.5 percent) and Collomia grandiflora (0.1 percent), are also greater here than in any of the other units.

Doubt may occur concerning the ecological status of the ecosystem because of the abundance of these annual plants. Aspect of the entity, north to northeast, and very rapid internal soil drainage tends to favor comparative dominant expression of these species.

Sitanion hystrix attains maximum development in this ecosystem as compared to the others (Table 3). This species has a constancy of 100 percent and a cover of 0.2 percent. It occurs in five other units but has a maximum constancy of only 40 percent and a cover of only 0.1 percent. Stipa comata is also diagnostic with a constancy of 80 percent. This species occurs in one other area, the (8) Juniperus/Agropyron-Festuca Ecosystem, but has a constancy of only 20 percent. Festuca idahoensis has a cover of 2.5 percent and has little diagnostic value except when considered with the associated species previously discussed.

Generally, herbaceous perennials are widely spaced and impart minor characterization value if considered individually. They occur mostly grouped under the protective shade of shrubs (Figure 25). However, total cover of perennial herbs, 4.6 percent, is characteristic of this ecosystem. This is less than half the total perennial herb cover of any of the other entities (Table 3).

The 6.6 percent cover of Juniperus occidentalis is another diagnostic feature of the plant community in this ecological unit. This cover value of the species is the least amount occurring in any of ecosystems.

The soil associated with the (7) Juniperus/Artemisia-Purshia Ecosystem is a deep, nonstony, sandy loam Regosol overlying a buried, stony, loamy B2 horizon (Series II-Deep, Nonstony Phase). It differs principally from the previously described Regosols in the (2) Juniperus/Artemisia/Festuca-Lupinus and the (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystems in depth to the underlying material (45 inches), nature of the underlying material, and nonstoniness.

The entire solum is a structureless sandy loam (see Figure 8). Internal drainage is very rapid indicated by the mildly alkaline

Figure 25. Ground detail of the (7) Juniperus/ Artemisia-Purshia Ecosystem. Perennial herbs are characteristically grouped under the protective shade of shrubs.

reaction (pH 7.5) of the deepest sandy material. Calcareous deposits, very common in soils of low precipitation regions, are not found in this soil except in the buried horizon and at approximately 50 inches deep. These factors indicate a droughty soil environment even though available water storage capacity in the 2- to 14-inch soil zone is 1.54 inches, a greater amount than some of the other soils (Table 6). This supports the thesis concerning the relative abundance of annual species. Most plant roots are concentrated in the upper 16 inches of the soil. Some roots, particularly large ones of the shrubs and trees, extend into the buried soil.

The amount of bare soil surface (55 percent) is more and the surface area occupied by root crowns of herbaceous perennials (3.1 percent) is less than occurs with any of the other Azonal soils. The surface soil is extremely loose requiring a minimum of traffic to create excessive disturbance (see Figure 25). The comparative low quantities of organic matter and total nitrogen in the A horizon, 1.05 and 0.06 percent respectively, also characterize the soil component of this ecological unit. These amounts of organic matter and total nitrogen were the least measured in any of the ecosystems.

(8) Juniperus/Agropyron-Festuca Ecosystem. The vegetational component of this ecosystem, which is limited to east slopes, is characterized by large, mature Juniperus occidentalis, codominant status of Agropyron spicatum and Festuca idahoensis, and specificity of Eriogonum ochrocephalum and Eriogonum sphaerocephalum (Figure 26).

Figure 26. Stand representative of the (8) Juniperus/Agropyron-Festuca Ecosystem. Large, mature Juniperus occidentalis and the codominant status of Agropyron spicatum and Festuca idahoensis characterize this entity.

Juniperus occidentalis has a cover of 32 percent, the second largest amount of the four ecosystems on Azonal soils. Cover of Agropyron spicatum and Festuca idahoensis is 3.2 and 2.3 percent respectively. Both plants have typical bunchgrass appearances and are spatially separated by considerable bare soil surface (Figure 27). The two species of Eriogonum have constancies of 100 percent, much greater than in the other ecosystems where they occur (Table 3). Cover of Eriogonum sphaerocephalum is 0.8 percent. Density of this suffrutescent species is 17 plants per 800 square feet. The average maximum height of the mature plants is 0.69 feet. This species also occurs in the (3) Juniperus/Festuca and (6) Juniperus/Agropyron Ecosystems but in very minute quantities. Cover of Eriogonum ochrocephalum is low, 0.1 percent. This species is present in three other units, the (2) Juniperus/Artemisia/Festuca-Lupinus, the (3) Juniperus/Festuca, and the (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystems, but not in quantities to provide good cover measurements.

With the exception of Eriogonum sphaerocephalum, the shrub stratum is relatively nondiagnostic of this entity. Most of the 4.6 percent shrub cover is composed of Artemisia tridentata (3.0 percent). This cover value of Artemisia tridentata, however, represents the least amount in any of the ecosystems associated with Azonal soils.

Figure 27. Ground detail of the (8) Juniperus/ Agropyron-Festuca Ecosystem. Agropyron spicatum and Festuca idahoensis share dominance in the herbaceous stratum. The conspicuous seedheads are Koeleria cristata. Several species occupy the same space on the soil surface.

In the herbaceous stratum of the (8) Juniperus/Agropyron-Festuca Ecosystem, seedheads of Koeleria cristata provided a characteristic aspect when the ecosystem was studied (see Figure 27). This feature was inconspicuous in other associations even though cover of the species is often equalled or exceeded. Poa secunda has a relatively large cover value (1.4 percent). Cover of the species is exceeded only in the (1) Juniperus/Artemisia/Festuca Ecosystem.

The soil supporting the vegetation of this entity is a moderately deep (23 inches) very stony, sandy loam Regosol overlying closely packed, cemented, rhyolitic/andesitic colluvium (Series II-Moderately Deep, Very Stony Phase). The primary difference between this soil and others of the same series as it influences plant growth is the cementation of the underlying stratum. This stratum in the Azonal soils associated with the (2) Juniperus/Artemisia/Festuca-Lupinus, the (4) Juniperus/Artemisia/Agropyron-Chaenactis, and the (7) Juniperus/Artemisia-Purshia Ecosystems is penetrable to plant roots.

The entire solum of the soil in the unit being discussed is a structureless sandy loam (see Figure 8) and filled with approximately 35 percent large stones. As a result, available water storage capacity in the 2- to 14-inch soil zone is 0.97 inches. Plant roots are mostly in the top 16 inches of the solum although a few larger ones trail on top of the cemented material, occasionally penetrating a soft spot. Organic matter and total nitrogen in the

A horizon is 1.32 and 0.7 percent respectively, exceeding only the soil associated with the (7) Juniperus/Artemisia-Purshia Ecosystem.

The soil surface has some characteristics diagnostic to this ecosystem. Approximately 54.7 percent of its area is bare. Root crowns of perennial herbs occupy approximately 4.1 percent of the soil surface area. These values are only slightly greater than occur with the soil surface of the (7) Juniperus/Artemisia-Purshia Ecosystem. Characteristically, a single place on the soil surface supporting herbaceous perennials is occupied concomitantly by several species (see Figure 27). In addition, pentagonal configurations occur on the soil but they are more weakly developed than those characteristic to the soil of the (2) Juniperus/Artemisia/Festuca-Lupinus Ecosystem. These peculiar shapes often impart a microaspect of accelerated erosion. Frost heaving, however, appears to be the primary cause of this feature.

(9) Juniperus/Artemisia/Agropyron-Astragalus Ecosystem. This ecosystem occupies locations representing the most zeric conditions of the study area (Figure 28). It is characteristic to south- and southwest-facing slopes and is associated with Brown soils with loam textures. Although total cover of perennial herbs (9.6 percent and shrubs (7.8 percent) is greater than in some ecosystems (Table 3), other plant factor and soil combinations support the thesis of xerism.

Figure 28. Stand representative of the (9) Juniperus/Artemisia/Agropyron-Astragalus Ecosystem. This site represents the most xeric conditions of the ecosystems described.

A fundamental characteristic of this ecological unit is the complete absence of Festuca idahoensis in measured stands. The species is present, but occurs only in dense, protective shade of Juniperus occidentalis. Annual species are present but they are generally less ubiquitous and have less cover than in other ecosystems. One species, Eriogonum baileyi, attains its maximum constancy rating (84 percent) in this unit. These factors indicate more intense competition for limiting environmental factors, particularly effective soil moisture created by increased insolation common to the kind of slopes associated with this ecosystem.

The vegetational component of this entity is characterized by the comparative amounts of Juniperus occidentalis, Artemisia tridentata, and Agropyron spicatum. Cover of Juniperus occidentalis averages 27.7 percent. Mature trees are not as large or well developed as they are in other ecosystems. Agropyron spicatum has a cover of 7.0 percent, exceeded only in the (5) Juniperus/Artemisia/Agropyron Ecosystem. Cover of Artemisia tridentata is 6.7 percent. Stand density of this species is 26 plants per 800 square feet and mature plant height averages 1.26 feet.

A single perennial forb, Astragalus lectulus, has diagnostic value for this ecosystem considering abundance of the species. It has a constancy rating of 100 percent with a cover value of 0.1 percent. The species occurs in two other units, the (3) Juniperus/Festuca and (6) Juniperus/Agropyron Ecosystems, but has constancy ratings of only 60 percent and 17 percent respectively.

The (9) Juniperus/Artemisia/Agropyron-Astragalus Ecosystem is comparatively deficient of perennial herbaceous species. Only 13 different species occur in sufficient quantities and abundance to provide some basis for characterization. Eight of these, Agropyron spicatum, Poa secunda, Koeleria cristata, Achillea millefolium, Phlox douglasii, Astragalus sp., Erigeron linearis, and Astragalus lectulus, attain 100 percent constancy. The remaining five, Agoseris sp., Eriophyllum lanatum, Stipa thurberiana, Sitanion hystrix, and Eriogonum umbellatum have constancy ratings 50 percent or less.

The soil associated with the (9) Juniperus/Artemisia/Agropyron-Astragalus Ecosystem is a Brown loam developed from rhyolitic/andesitic colluvium (Series IX). Solum depth is 21 inches. Fifty percent of the profile volume is occupied by large stones. Below 21 inches, 90 percent of the soil volume is large stones. A discontinuous caliche often occurs at approximately 21 inches below the surface. Very few roots extend below this area.

The heaviest part of the subsoil is a clay. Structure of this horizon is strong and blocky with hard, dry consistance which becomes friable when moist. Friability of the subsoil, in addition to solum stoniness allows deeper root penetration than might be expected (Figure 29). Available water storage capacity in the 2- to 14-inch soil zone is 1.21 inches, the lowest capacity of any of the Zonal soils (Table 6). Organic matter and total nitrogen of the A horizon is 1.63 and 0.08 percent respectively.

Figure 29. Profile of Series IX associated with the (9) *Juniperus/Artemisia/Agropyron-Astragalus* Ecosystem. Friability and stoniness of the clayey subsoil allows good root penetration. Compare with Figure 18.

The soil surface is characteristic of the ecosystem. Small stones, which are very abundant, provide an aspect of an erosion pavement (Figure 30). This pavement is a natural phenomenon and should not be misinterpreted as a pavement created by accelerated erosion.

Figure 30. Detail of the soil surface and understory vegetation of the (9) Juniperus/Artemisia/Agropyron Ecosystem. The abundance of small stones on the soil surface is characteristic of this entity.

DISCUSSION

Climax and Community Concepts in Relation to Vegetation Classification

Although vegetation classification has long been a matter of basic importance in both theoretical and applied botany, the methods used in classification still exhibit wide variation among workers. The results of the present study provide a material contribution toward a critical evaluation of the different methods that are in use.

Climax is a concept familiar to all workers dealing with classification of natural vegetation. The term is defined in the dictionary as, "The relatively stable community achieved by a population of plants or animals culminating from successful adjustment to a particular environment" (23, p. 154). Culminating infers time lapse but is nonspecific.

Various definitions are found in current textbooks of ecology: Climax is the development of vegetation and the formation of soil toward a definite end point determined and limited by climate (6, p. 322); climax is synonymous with a vegetational formation; it is the ultimate terminating community, determined by climate (62, pp. 79-80); climax is the terminal community of succession which is controlled by climate; it is capable of reproducing itself and may not be replaced by other individuals as long as the climate remains the same (46, p. 224); climax is the final or stable community in a successional series; it is self-perpetuating and in equilibrium with the physical habitat (45, p. 196).

All these definitions connote a terminating and dynamically stable plant community determined and maintained by climate. It remains for the student to interpolate time-lapses involved, space relationships, whether the inferred climate is regional or local, physical or bio, or combinations of these, and the degree of heterogeneity characteristic to the equilibrium community. Whittaker (64) maintains that no completely rigorous definition of climax exists and that perhaps none need be developed. However, if that phase of ecology dealing with vegetation classification is to remain a science, some form of unification must be developed to signify the climax situation. Selander's (52) concept of climax and its associated community--a community representing a time phase of great stability in which successional causes cannot be observed and the future cannot be predicted--provides a workable and organized regulative principle. Essentially, this definition concurs with that on page 14 of this manuscript and avoids terms which denote finality in succession.

Most everyone agrees that plant communities exist. One exception appears in the work of Curtis and McIntosh (14) who demonstrated gradients of species toward or away from modal situations. Also, the proponents of the plant community concept agree that the communities are products of the complete environment. Nearly all ecologists concur that succession takes place and that a trend toward mesophytism in succession is evident. The quandary of vegetation classification begins when attempting to define the terminal point of the successional trend. "Terminated" trend is not a proven fact.

The development, perpetuation, and manifestations of a plant community can be likened to the mathematical formula Jenny (31, p. 16) proposed to explain soil formation:

$$\underline{S} = f\,(\underline{cl}, \underline{o}, \underline{r}, \underline{p}, \underline{t}) \qquad \text{(Equation 1)}$$

where S represents a dependent soil expressed quantitatively and cl, o, r, p, and t are assumed to be independent quantitative variables representing respectively climate, organisms, relief, parent material, and time. Plant community development is also affected by these factors. Therefore, V, representing the plant community, can be set to a similar equation:

$$\underline{V} = f\,(\underline{cl}, \underline{o}, \underline{r}, \underline{p}, \underline{t}) \qquad \text{(Equation 2)}$$

The similarity between Equations (1) and (2) strongly indicate concomitant vegetation and soil development and that the long-time successional patterns of the entities cannot be separated.

It is recognized that exact mathematical solution of complete environmental complex-plant community problems is extremely difficult, if not impossible. Also, the mathematical approach tends to destroy the accepted dynamism of plant communities. However, the method can demonstrate and perhaps realistically define the "terminal" point of successional trend and thus isolate climax.

Major (41) attempted to solve the environment-vegetation problem using Equation (2), realizing that in nature the independent variables are only approximately so. By totally differentiating the equation, he shows how it is possible to set up quantitative functions of a single variable holding all others constant. The lithofunction for time, probably the most nebulous of all environmental factors, would be:

$$\underline{V} = f\ (\underline{t})_{\underline{cl},\ \underline{o},\ \underline{r},\ \underline{p}}$$

Supplying quantitative data to this formula would evaluate the time influence on the development of the particular plant community <u>at this time</u>. If an ecologist had lived in the central Oregon Juniper Zone during the Miocene Epoch, approximately 20 million years ago, he would have described a plant community in which *Sequoia sempervirens* was a major component <u>at that time</u> (65). Even more recently, during the Pleistocene Epoch one million years ago, he would have encountered an abundance of *Pinus monticola* in the nearby mountains at that time (29). This tree is practically nonexistent <u>now</u>; being succeeded by *Pinus ponderosa*. Who knows what species this ecologist would encounter one-million or even one-thousand years in the <u>future</u>.

It seems logical then, from the standpoint of providing usable facts to land managers, to accept the natural plant community <u>now</u> as being climax and representing the terminal point of a successional trend provided it meets the requirements--"successional causes cannot be observed and the future cannot be predicted". This concept of climax is the primary basis of the polyclimax theory which contends that many climaxes exist <u>now</u>, each one controlled by one or a few environmental factors. Selleck (53, p. 543) claims that the poly-climax theory is limited because, among other things it does not recognize the geological time scale. Restricting the theory to the previous definition of climax, referring particularly to "......... successional causes cannot be observed....", does include geologic time since the plants in a community now have evolved through geological time to achieve their current status. Even if successional causes can be observed, if there is no evidence of replacement or no possibility to predict future succession, the concept still holds and is the basis of practical vegetation classification.

Ecological Status of the Central Oregon Juniper Zone

Some workers have doubted even the existence of Pinyon-Juniper Zone in other parts of the western United States. Emerson (22) studied the tension zone between the *Bouteloua* and *Pinus-Juniperus* Zones near Las Vegas, New Mexico. From limited soil investigations and species lists of plants, he concluded that the occurrence of the Pinyon-Juniper Zone was associated to areas not occupied by "closed" stands of herbaceous vegetation and thus was not a true vegetational entity. Also, he stated that soil characteristics were incidental influences in the way they controlled growth of grasses. These conclusions paralleled closely those of Cottle (13) in which he stated that xeric grasses dominated and that woody plants occurred only in places where rocks or other factors prevented full expression of the grasslands. Emerson (22) did show that available soil moisture was greater in areas occupied by trees.

It appears that both Emerson (22) and Cottle (13) contradicted themselves in their works. They showed that pinyon and juniper, in their study areas, occupy places where it is virtually impossible for other vegetation to grow. Also, they stated that available soil moisture was greater in the pinyon-juniper areas than in associated desert grasslands. These facts strongly indicate the presence of an environment possessing factor interactions favorable for the natural development of a vegetational unit qualified for taxonomic classification.

Woodbury (67) substantiated the thesis that there is a natural place in space for the Pinyon-Juniper Zone after studying the distribution of "pigmy" conifers (*Juniperus utahensis*, *J. monospermum*, *J. scopulorum*, *Pinus edulis*, and *P. monophylla*) in Utah and northeastern Arizona. He showed that these species were best adapted to ridges, canyons, or rough slopes with coarse, rocky, or shallow soils. He also showed that the upper and lower limits of these species were set by soil moisture deficiencies or excesses. These deficiencies or excesses, however, are not controlled by climatic factors alone; these climatic factors interact with the absorptive, storage, and water-supplying powers of the soil to influence effective soil moisture.

Eckert (20) after characterizing some *Artemisia* types in central Oregon, showed a lower limit of effective soil moisture below which *Juniperus occidentalis* did not exist although other environmental factors remained the same. He concluded that the species made its maximum growth on rocky outcrops, steep slopes, or in intermittent drainage ways where the water-supplying power of the soil was slightly greater than the maximum requirement of climax *Artemisia tridentata* or *A. arbuscula* communities.

The conclusions of these investigations by Woodbury (67) and Eckert (20), as well as the results of others (43, 50, 66, 68), support the thesis that natural landscape units exist where environmental factor combinations are suitable for the development and perpetuation of plant communities characterized partly by juniper and/or pinyon pine. The present study strengthens this hypothesis by showing that *Juniperus occidentalis* is a dominant and characteristic species of ecosystems unaffected by influences other than those naturally occurring.

The polyclimax approach fits well to areas relatively young geologically. These areas usually have fast-changing topographic features or other dominating influences creating significant and easily recognized changes in vegetational, soil, or other components of an ecosystem over short distances. Such conditions exist in the central Oregon Juniper Zone and have allowed segregation and description of entities more alike within than among themselves. As a result, a realistic base for management is provided whereby current vegetational potentials of specific ecosystems are defined. Also, if characteristic vegetational components are missing, the ecosystems can still be identified for management purposes on the basis of soil and topographic characteristics.

For example, a range manager may have a grazing unit composed mostly of the (1) Juniperus/Artemisia/Festuca Ecosystem and past grazing has deteriorated the desirable cattle forage. Since he knows that the vegetational potential of the major portion of the unit is approximately 11 and 5 percent cover of Festuca idahoensis and Agropyron spicatum respectively, his management will be adjusted accordingly; he will not be satisfied with only 2 and 3 percent cover of these species as demonstrated in the (8) Juniperus/Agropyron-Festuca Ecosystem.

Following polyclimax terminology, the vegetational component of the (5) Juniperus/Artemisia/Agropyron Ecosystem is considered the climatic climax of the zone. The association of this entity occurs on undulating topography and loamy soils that are moderately drained. Some ecologists will question the validity of such a designation because of the paucity of Juniperus occidentalis and the dominance of Agropyron spicatum and Artemisia tridentata (Table 3). The energy relationships within and among species were not determined in this work. Consequently, the point at which the influence of a species ceases or becomes insignificant on the internal relationships of any of the associations cannot be isolated. This author does not doubt, however, that Juniperus occidentalis has a controlling influence on the energy relationships within the (5) Juniperus/Artemisia/Agropyron Ecosystem. The species provides shade to modify the microclimate of the entity and removes water and nutrients from the soil that would otherwise be available to other species.

The vegetational components of remaining ecosystems characterized in this investigation are considered topoedaphic climaxes. Factors related to the topography and soils of these units appear to be major controlling influences on the associated plant communities. These factors and their relationships within and among the ecosystems are discussed in the subsequent section, "Vegetation-Soil Relationships".

The vegetation of the study area could have been classified using the continuum concept (14, 63) if single species were considered independently. A family of distribution curves, based on cover, would show that each species has its own distribution center away from which it declines gradually or rapidly as it approaches the margin of its ecological amplitude. This family of curves would also show overlapping ranges among species. For example, Festuca idahoensis varies from 0.4 percent cover in the (5) Juniperus/Artemisia/Agropyron Ecosystem to approximately 11 percent cover in the (1) Juniperus/Artemisia/Festuca and the (3) Juniperus/Festuca Ecosystems. Agropyron spicatum varies from 0.9 percent cover in the (7) Juniperus/Artemisia-Purshia Ecosystem to approximately 9 percent cover in the (5) Juniperus/Artemisia/Agropyron Ecosystem. The entire range of cover values of Agropyron spicatum among the ecosystem associations is contained within the cover range of Festuca idahoensis. This fact implicates no species groupings in the same environment and that no environment is devoid of adapted species.

If each species was considered independently in this manner, the result would be a pattern of complex curves illustrating the diversity of the vegetation but having no practical value from the land management point of view. By considering the total vegetational component of each ecosystem as an independent unit on the basis that each has had a distinctive developmental history (Equation 2, p. 94), there is no evidence of a continuum.

The plant communities could also have been classified following the monoclimax philosophy proposed by Clements (11). He postulated that the climax developed through a certain successional pattern to the "highest type" which is synonymous with a "formation", a unit of vegetation determined and controlled by regional climate. Areas within the formation which did not conform to the climax "type" were designated "disclimax", "preclimax", or "postclimax" with reference to vegetation on disturbed sites, dry sites, or moist sites.

By following this system of classification, the vegetational components of the (1) Juniperus/Artemisia/Festuca, the (2) Juniperus/Artemisia/Festuca-Lupinus, the (3) Juniperus/Festuca, and the (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystems would have been considered "postclimaxes" and that of the (6) Juniperus/Agropyron, the (7) Juniperus/Artemisia-Purshia, the (8) Juniperus/Agropyron-Festuca, and the (9) Juniperus/Artemisia/Agropyron-Astragalus Ecosystems "preclimaxes" of the (5) Juniperus/Artemisia/Agropyron Ecosystem, the climatic climax of the zone. The end result would have been a confusing array of climax types which would provide the land manager little basis for management. The terminology infers either something better ("postclimax") or something worse ("preclimax") with meager knowledge of what to manage for. Cain (8) aptly expressed this view when he concluded that true climax develops only on medium sites and that linking all stable communities to the climax is highly hypothetical and serves no useful purpose.

In summary, the present study confirms the points of view of Tansley (55), Billings (3), Daubenmire (15), Selander (52), and Selleck (53) that we should look upon vegetation as a complex of ecosystems, the only natural units of the landscape. Each ecosystem contains a vegetational component capable of synthesis and classification as an entity easily recognized and adapted to land management.

Vegetation-Soil Relationships

Since plant communities and soils are functional products of the same influences (Equations 1 and 2, p. 94), direct relationships between interpretive categories of the two entities should be expected. If this occurs, it would be relatively simple to characterize ecosystems by relating general vegetation and soil characteristics obtained by field surveys.

Some early workers indicated this to be true although categorical units of soil or vegetation were not identified. Griffiths (28) claimed that when *Agropyron spicatum* was associated with *Artemisia* spp. in the northern Great Basin, soils were almost invariably stony and fertile. Kearney *et al.* (33) suggested the possibility of correlating vegetational distribution with soil chemical and physical properties. Graham (26) recognized that altitudinal zonation of vegetation was due primarily to climatic factors but the zones were often divisible on the basis of edaphic or physiographic factors.

It has not been until approximately the past two decades that categorical units of plant communities and soils have been correlated. One problem was immediately confronted however; this being the criteria for classification within the two systems. For example, soil series of some early surveys have been split into several series after more thorough study had shown strong enough differences between soils within the initial series to warrant separation (59, p. 283).

Spilsbury and Tisdale (54) found that Agropyron spicatum was dominant on practically every soil type they encountered. However, they noted marked differences in density, height, and yield of the species depending on soil depth. Later, Tisdale (56) described three vegetation zones (Agropyron-Artemisia, Agropyron-Poa, and Agropyron-Festuca) and found them to be correlated with three great soil groups (Brown, Chestnut, and Chernozem). Within each zone, however, he recognized edaphic and biotic communities characterized by changes in species presence and dominance.

Gardner and Retzer (24) emphasized that the need for classifying wildland soils is increasing as the need for more intensive management increases. They inferred that soil series level interpretations were adequate for most purposes. Later, Retzer (51) pointed out more definitely that the soil series was the most useful unit for classifying wildlands on the basis of vegetation-soil correlations.

However, Poulton (48), using polyclimax interpretation to classify climax communities in the Columbia Basin of northeastern Oregon, showed that each type of climax is associated with a particular group of soil series. Anderson (2), working in eastern Oregon, showed that certain range sites were related to definite groups of soil series when dealing with Zonal soils. [3/] Eckert (20), after classifying some climax *Artemisia* types in southeastern Oregon, also found that a climax type was associated with numerous soil series. Dyrness (19) classified climax communities associated with Azonal soils in the Ponderosa Pine Zone in southern Oregon. He showed that direct vegetation-soil correlation occurred at the phase of soil type level of interpretation if characteristics other than those used for profile descriptions were considered.

These investigations show conflicting opinions concerning the categorical level of soil associated directly with climax plant communities. The results indicate that compensatory environmental factor interactions strongly influence these relationships. This is summarized well by Poulton and Tisdale (49) who hypothesized that factor compensation may result in apparently identical plant communities occurring on two or more taxonomic soil units or that different plant communities may occur on the same taxonomic soil unit.

3/ A range site is a specific soil and climatic complex associated with a particular climax vegetation (18).

The relationships between the interpretive categories of the vegetational and soil components of the ecosystems delimited in this study are varied. Table 7 illustrates the association between tentatively classified taxonomic soil units and the ecosystems in which they are found.

Two fundamental points are indicated. When dealing with Azonal soils, soils with immature profile characteristics, the phase of soil series type level of interpretation provides direct correlation with a specific climax plant community. In this case, four ecosystems are associated with specific phases of the same soil series--Ecosystems (2) *Juniperus/Artemisia/Festuca-Lupinus*, (4) *Juniperus/Artemisia/Agropyron-Chaenactis*, (7) *Juniperus/Artemisia-Purshia*, and (8) *Juniperus/Agropyron-Festuca*. Contrariwise, Zonal soils, soils with relatively mature profile characteristics, show little direct affinity for a specific climax plant community regardless of level of interpretation. For example, the (3) *Juniperus/Festuca* Ecosystem is associated with two soil series and a phase of one of these series while the (1) *Juniperus/Artemisia/Festuca* Ecosystem is associated with one soil series.

Azonal Soils: The Azonal soils encountered in this study are developing on parent materials of relatively recent origin. They have not reached equilibrium with their current environment and they generally possess uniform profile characteristics. Therefore, factors genetically unrelated to the soils, including subsoil characteristics, are creating the differences in vegetation.

Table 7. Association between tentatively classified soils and described ecosystems in the central Oregon Juniper Zone.

Series and phase number	Generalized type or phase of type description	Ecosystem
Series I	Chestnut loam from rhyolitic/andesitic colluvium on northerly slopes.	(1) Juniperus/Artemisia/ Festuca
Series II-Shallow, Nonstony Phase	Shallow, nonstony sandy loam Regosol over gravelly loam alluvium and rhyolitic/ andesitic colluvium on northerly slopes.	(2) Juniperus/Artemisia/ Festuca-Lupinus
Series III	Brown loam from friable tuffaceous material on northwesterly slopes.	(3) Juniperus/Festuca
Series III-Very Stony Phase	Very stony Brown loam from friable tuffaceous material on south-easterly slopes.	(3) Juniperus/Festuca: Purshia Variant
Series IV	Weakly developed Brown loam from mixed rhyolitic/andesitic colluvium and aeolian sands on northerly slopes.	(3) Juniperus/Festuca
Series II-Moderately Deep, Extremely Stony Phase	Moderately deep, extremely stony, sandy loam Regosol over cracked or closely packed basalt on northerly slopes.	(4) Juniperus/Artemisia/ Agropyron-Chaenactis

Table 7 (continued)

Series and phase number	Generalized type or phase of type description	Ecosystem
Series V	Strongly developed Brown loam from coarse river and lake-laid sediments containing basalt fragments on undulating uplands.	(5) *Juniperus/Artemisia/Agropyron*
Series VI	Strongly developed Brown loam from loess, very fine river sands, and small basalt fragments on undulating uplands.	(5) *Juniperus/Artemisia/Agropyron*
Series VII	Brown sandy clay loam from a thin layer of rhyolitic/andesitic colluvium over indurated tuffaceous material on northeasterly slopes.	(6) *Juniperus/Agropyron*
Series VII-Shallow Phase	Shallow Brown sandy clay loam from a thin layer of rhyolitic/andesitic colluvium over indurated tuffaceous material on northerly slopes.	(6) *Juniperus/Agropyron*
Series VIII	Brown loam from rhyolitic/andesitic colluvium on southeasterly slopes.	(6) *Juniperus/Agropyron*: *Purshia* Variant
Series II-Deep, Nonstony Phase	Deep, nonstony, sandy loam Regosol over a buried, loamy, stony B2 horizon on northeasterly slopes.	(7) *Juniperus/Artemisia-Purshia*

Table 7 (continued)

Series and phase number	Generalized type or phase of type description	Ecosystem
Series II-Moderately Deep, Very Stony	Moderately deep, very stony, sandy loam Regosol over closely packed and cemented rhyolitic/andesitic colluvium on easterly slopes.	(8) Juniperus/Agropyron-Festuca
Series IX	Brown loam developed from rhyolitic/andesitic colluvium on southwesterly slopes.	(9) Juniperus/Artemisia/Agropyron-Astragalus

Phase of the soil series type interpretations were based on depth, stoniness, and nature of the underlying material. The deep, nonstony phase of Series II, associated with the (7) Juniperus/Artemisia-Purshia Ecosystem, was separated primarily on depth (45 inches) and nonstoniness. Rooting depth is not mechanically restricted but the sandy nature of the soil allows for rapid water infiltration and drainage, deep water penetration, and comparatively excessive evaporation from near the surface. Consequently, more precipitation is needed to maintain effective available water than in finer textured shallower soil (39). Lateral soil moisture drainage from positions above the location of this soil may supply additional water to the subsoil. As a result, this soil favors shrubby species such as Artemisia tridentata and Purshia tridentata which characteristically root deeply in addition to maintaining roots in the surface horizons to utilize soil potentials there. Available soil moisture in the surface horizons is not maintained for a sufficient length of time to allow dominant expression of herbaceous species.

In contrast to the preceding soil, the shallow, nonstony phase of Series II supporting the more luxuriant community of the (2) Juniperus/Artemisia/Festuca-Lupinus Ecosystem is shallower (16 inches), overlying a gravelly, loamy material. The internal water relations between the two soils, measured by available soil moisture storage capacity in the 2- to 14-inch soil zone, are nearly the same. However, the proximity of the underlying strata to the surface of this soil provides a better environment. This is accomplished by increased storage of available water at a place where it is more effective. Roots are common in the underlying material of this soil but very few occur in the same strata of the deeper soil. In addition, the nature of the plant community itself modifies the environment to make it more effective. The comparatively high cover of perennial herbs reduces water evaporation from the soil surface which results in increased effectiveness of total precipitation.

More subtle changes in soil characteristics as related to their associated vegetations exists between the (4) Juniperus/ Artemisia/Agropyron-Chaenactis and (8) Juniperus/Agropyron-Festuca Ecosystems. The soils are nearly identical except for the nature of the underlying material and stoniness of the solum. The soil associated with the (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystem has 50 percent of its volume occupied by large stones and it overlies cracked or closely packed bedrock which allows some root penetration. The soil associated with the (8) Juniperus/ Agropyron-Festuca Ecosystem has slightly less volume occupied by large stones (35 percent), but it overlies large stones which have been cemented with carbonate precipitates. The cementation prevents root penetration (61). Depth to the underlying material is the same in both soils. Available moisture storage in the 2- to 14-inch soil zone is only slightly different, 0.87 inches in the (4) Juniperus/

Artemisia/Agropyron-Chaenactis Ecosystem and 0.97 inches in the (8) Juniperus/Agropyron-Festuca Ecosystem. Therefore, the penetrability of the underlying material to roots is the primary reason associated with the vegetational differences. Juniperus occidentalis and Artemisia tridentata are more strongly expressed in the (4) Juniperus/Artemisia/Agropyron-Chaenactis Ecosystem where they can root deeper and not be subjected to competitive stresses as intense as indicated by the presence of the cemented stratum in the (8) Juniperus/Agropyron-Festuca Ecosystem.

In summary, direct vegetation-soil correlation with Azonal soils can be shown at the phase of soil type level of interpretation if phase separation considers the nature of the underlying material as well as solum characteristics. If solum characteristics only are considered, direct correlation becomes nonexistent and differences in climax communities are harder to explain.

Zonal Soils: The nonspecific vegetation-soil correlation of those ecosystems associated with Zonal soils indicates that environmental factor interactions and compensations are strongly influencing the occurrence and dispersion of the associated climax communities. Relationships among the following factors as they affect the soil moisture regime and root growth appear to be the most important:

1. Texture, structure, and thickness of the densest part of the B horizon.
2. Stones on and in the soil.
3. Solum depth.
4. Nature of the underlying material.
5. Intensity and duration of insolation as indicated by slope aspect.

This hypothesis is illustrated in Table 6 (p. 30) which shows a discrepancy between available soil moisture storage capacity in the 2- to 14-inch soil zone and the relative mesism of the ecosystems. The soil of the most mesic ecosystem does not have the most moisture storage capacity as indexed in this manner; the soil of the most xeric ecosystem does not have the least. However, if quantitative expressions of "effective" moisture storage were available, a sequential arrangement would probably occur.

The comparative mesism of the (1) _Juniperus_/_Artemisia_/_Festuca_ Ecosystem associated with Series I is enhanced primarily by solum stoniness and depth and the topographic position of the entity. The fact that roots are well distributed into the parent material is evidence of the effectiveness of the soil. The densest portion of the B horizon has a clay texture and strong, blocky structure. The presence of clayskins on individual soil peds in this horizon is indicative of colloids leaching from surface horizons. These characteristics indicate that a claypan could have formed but the high stone content (50 percent) has prevented this from occurring. At the same time, the stones have provided for more "porous" soil conditions (40) which allow for good water percolation and reduces mechanical impedence to root growth. The clayey texture of all the subsoil allows for maximum water storage. The northerly aspect provides for minimum insolation with a consequent reduction of evaporation. As a result, the precipitation falling on this soil is more effective in adding to and supplying effective available soil moisture.

The climax community associated with the (3) Juniperus/Festuca Ecosystem is supported by strikingly different soils representing two series. The efficiency of the two soils is equalized by compensating effects of texture and structure of the subsoil, solum depth, and the nature of the underlying material. The shallow, clayey textured, relatively strong structured subsoil of Series III reduces the effective available soil moisture and impedes root growth as compared to the deeper, loamy, less well-developed subsoil of Series IV. However, the same amount of precipitation is effective longer in the subsoil of Series III because of its texture and structure characteristics and some moisture is probably drawn from the underlying friable-and-porous-when-wet tuffaceous material. These factors compensate the shallowness of the soil with the resultant effect of supplying the same amount of effective available soil moisture as Series IV. Comparing these soils with Series I associated with the (1) Juniperus/Artemisia/Festuca Ecosystem, it is more droughty because of the shallow, nonstony characteristics of Series III and the coarser texture of Series IV.

The increase in cover of Purshia tridentata and reduction in cover of Festuca idahoensis in the Purshia Variant of the (3) Juniperus/Festuca Ecosystem is associated with stoniness of the stony phase of Series III and slope aspect. The stones (50 percent by volume) modify the clayey texture and strong structure of the subsoil (5) to provide less resistance to root penetration of Purshia tridentata. Also, the easterly aspect favors the development of this species. However, the increased insolation with a corresponding rise in soil surface temperature is apparently approaching lethal conditions for Festuca idahoensis. Nevertheless, the stones on and in the soil provide slower soil heating and less heat loss (40) which compensates partially for the increased insolation as well as the normal position of the ecosystem on northerly slopes. The resultant effect is the maintenance of dominance of Festuca idahoensis, although in a reduced state, and no significant change in cover of other species except Purshia tridentata.

Series V and VI associated with the (5) Juniperus/Artemisia/Agropyron Ecosystem are quite similar morphologically to Series I associated with the (1) Juniperus/Artemisia/Festuca Ecosystem. However, the solums of these soils are rock free and a claypan has developed near the soil surface. As a result, the biological effectiveness of these soils is reduced (4, 10, 36) even though available soil moisture storage capacity exceeds that of all other soils. Root growth is restricted by the claypan (61) and consequently the effectiveness of the available soil moisture is reduced. In addition, the nonstoniness of the soils and the level aspect reduces moisture effectiveness through water vaporization in the soil and evaporation from the soil created by longer, more intense insolation.

The claypan in Series VI is closer to the surface than in Series V, but the thinness of this stratum and the underlying loose material compensates for the comparative shallowness of the restrictive layer. Also, these factors compensate the comparative thickness of the claypan in Series V. Some roots go through the thin claypan, develop into more normal root systems, and take advantage of the growth potential of the underlying strata. No roots grow through the thick claypan of Series V. As a result, the plant communities on both soils are associated with the same ecosystem.

The dominance of comparatively xeric species, particularly *Agropyron spicatum*, in the (6) *Juniperus*/*Agropyron* Ecosystem is peculiar since the easterly aspect would normally indicate fairly good moisture conditions. However, solum and soil surface stoniness (35 and 18 percent respectively) and texture and the nature of the underlying material of Series VII compensate the topographic position of the entity.

The stones reduce the rate of heating as well as heat loss which favors mesism. However, the surface area and solum occupied by stones reduces the effective volume of the soil. In addition, the soil separates of the sandy clay loam and clayey surface and subsoils are apparently of such size and distribution to allow close packing. This results in a reduction of porosity and a corresponding reduction of available moisture storage capacity. With the exception of the Zonal soil associated with the (9) Juniperus/Artemisia/Agropyron-Astragalus Ecosystem, moisture storage is less in this soil than in any of the other Zonal soils. Also, the indurated tuffaceous material which restricts root growth adds to the droughty condition of the entity. The direct and indirect effects of all these characteristics overcome the slope aspect effects and result in a xeric community in an area which could be mistakenly classified comparatively mesic.

The loam surface horizon and clay loam subsoils of Series VIII, penetrability of the substratum, and the more southerly aspect account mainly for the increase of Purshia tridentata in the Purshia Variant of the (6) Juniperus/Agropyron Ecosystem. The penetrable substratum allows for deep rooting of Purshia tridentata, a site requirement necessary for the species. Also, the more southerly aspect favors its development as a result of factor interactions similar to those in the Purshia Variant of the (3) Juniperus/Festuca Ecosystem. The finer texture of this soil as compared to Series VII associated with the ecosystem makes available soil moisture more effective which compensates for any increase in intensity and duration of insolation from a change in slope aspect. Consequently, the vegetational component of the ecosystem, except *Purshia tridentata*, is not significantly changed.

The comparative xeric condition of the (9) *Juniperus/Artemisia/Agropyron-Astragalus* Ecosystem is primarily the result of the southerly aspect. This topographic position allows for maximum intensity and duration of insolation (25) with consequent maximum microclimatic temperatures during the growing season. However, the stone content of the solum (50 percent) and the rubbly characteristic of the soil surface modify the insolation effects by reducing the rate of heating as well as the possible maximum temperature of the effective soil. The stones also provide better conditions for water penetration and root growth into the clayey, strongly structured subsoils and reduce evaporation. As a result, the available soil moisture is more effective than it would be if stones were absent. In spite of these conditions, however, the insolation effects are strong enough to create the relative xerism of this ecosystem expressed in the plant community. This is shown particularly in the paucity of perennial species and the extremely low cover when the dominants are excluded.

In summary, direct vegetation-soil correlation of ecosystem vegetational components associated with Zonal soils cannot be made at a single categorical level of soil interpretation based on current soil classification procedures. Zonal soils, because of their relative maturity, invoke subtle changes in effective environmental conditions which may or may not create significant vegetational changes. Therefore, factors not readily identified in the field or whose compensatory or interacting influences cannot be quantitatively measured must be considered when characterizing an ecosystem or rationalizing differences among ecosystems.

Relationships between texture, structure, and thickness of the densest part of the B horizon; stones on and in the soil; solum depth; nature of the underlying material; and insolation provide some striking correlations and differences within and among the ecosystems and their climax communities on Zonal soils in the central Oregon Juniper Zone. Undoubtedly, other environmental factors, including animals, furnish additional characterization attributes.

PRACTICAL APPLICATIONS

The best current use of the central Oregon Juniper Zone is forage production for grazing animals. The etiological inquiry of this investigation has demonstrated that discrete landscape units, ecosystems, exist in the area and that each has its own biological potential. Consequently, each unit also has specific management requirements. Recognition of these facts by the land manager is essential to assure optimum and sustained forage production for the grazing animals.

Classification and Inventory

A preliminary phase of any range management program involves mapping to show, among other things, the location and distribution of all forage types. The mapping units, essentially forage types, defined by the Inter-Agency Range Survey Committee (57) are used in most mapping jobs. These map units are based on general characteristics of existing vegetation without regard to their ecological status or the recognition, as inclusions, of ecosystems that have specific management characteristics. Subsequent management is then based on the type as a whole. Management changes result from supposed changes in the floristics and other characteristics of the whole type or selected "key" areas [4/] within the type. When ranges are classified on such a faulty basis, plant communities with different productive potentials and successional patterns are placed in the same category. The resultant effect is almost complete chaos because a land manager does not know with certainty his goals and cannot interpret the impact of management on the resource.

For example, a typical range survey would probably include all of the described ecosystems in one type or map unit. Subsequent cattle range management would be based on averages for all ecosystems, for example the average cover of _Festuca idahoensis_ (4.5 percent) and _Agropyron spciatum_ (4.2 percent) as the preferred cattle forages. With reference to the first species, stocking rates would be reduced in six out of nine cases or maintained or increased in three out of nine cases, depending on the location of the "key" area, to fulfill the objective of sustained optimum production of forage. Considering _Agropyron spicatum_, stocking rates would be reduced in five or maintained or increased in four out of nine cases. In all cases, however, such management decisions are completely unrealistic because of the differential productive potentials among the ecosystems.

It is recognized that very often defined ecosystems are not of sufficient areal extent in any one location to constitute a mapping unit or a management unit. The important factor is to recognize that

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4/ A "key" area represents a range area intermediate in distance from grazing animal concentration places, furnishes the bulk of the forage, and constitutes a gauge for management of the range as a whole.

such entities exist and must be considered in classifying and managing range lands. Others have emphasized this point (12, 21, 47), stressing the need for placing range classification on a sound natural basis.

The apparent difficulty involved in mapping, inventory, and subsequent planning is overcome simply by including each ecosystem as a part of a mapping complex and recognizing the basic characteristics of each as contributing but independent integers of the complex. These procedures are being used by some agencies and private operators managing native vegetation by incorporating results of similar studies (19, 20, 48). The question, "How can management of an area be effective if that area consists of numerous, independent units?" can rightfully be asked. The decision on such a question rests in the hands of the individual manager or user. He must decide if current or predicted economics warrant individual management of each ecosystem or if some units will be sacrificed by basing management on others.

Range Condition and Trend

Another type of practical application concerns evaluation of range condition and trend based on guides or standards developed for each ecosystem. Range condition is range health; the relative successional position of a site with regard to the inherent potential of the site. Range trend is the direction of change in condition and shows whether a range site is holding its own or becoming more or less productive as compared to the site potential.

Range condition classification should strongly consider the kind of animal that is or will be using a particular area. For example, all the ecosystems described are ecologically in excellent condition, producing near their maximum inherent vegetational potentials. However, when the grazing animal is considered, condition classifications among ecosystems will vary. The vegetational component of the (1) *Juniperus/Artemisia/Festuca* Ecosystem would be considered excellent condition for cattle because of the abundance of desirable cattle forages. On the other hand, this same ecosystem would rank low in condition for deer because of the relative paucity of deer forage, normally shrubs and forbs. With reference to the (7) *Juniperus/Artemisia-Purshia* Ecosystem, the condition rating of this area would rank relatively high for deer but low for cattle. The reason for this is the comparative abundance of deer forages and absence of cattle forages.

The *Purshia* Variant of the (6) *Juniperus/Agropyron* Ecosystem would rank high in condition for deer but slightly lower for cattle as compared to the other entities. Stable soil is assumed in all these hypothetical condition ratings. It would behoove a range manager then to rate range condition to the animal as well as to the area rather than only to the area. This would implement range classification and use by defining the best practicable grazing use of specific associations.

Range trend must also consider the kind of animal using an area. For example, continued heavy cattle use in the (7) *Juniperus/*

Artemisia-*Purshia* Ecosystem would reduce and perhaps eventually eliminate the grasses and some forbs. The resultant vacuum in the vegetational component of the ecosystem would probably be filled by an increase in density and cover of shrubs, particularly *Purshia tridentata*, a highly desirable deer forage. Thus, at a given time, upward range trend would be indicated for deer range and downward trend for cow range, assuming soil stability in both cases.

Range Rehabilitation

Future range rehabilitation programs for either game or livestock can be enhanced from the results of this study. If a decision were made to improve game forage conditions by seeding *Purshia tridentata*, those ecosystems located on aspects receiving moderate insolation and having soils which allow deep root penetration with little mechanical impedence would be selected initially to give the best results. With reference to cattle range improvement, drought-tolerant, shallow-rooting species would be selected for sites having soils similar to those in the (5) *Juniperus*/*Artemisia*/*Agropyron* Ecosystem. The claypan close to the surface of these soils is essentially noneffective for supporting plant growth unless they are mechanically altered by cultural practices such as deep plowing. On the other hand, deeper rooting species which can take advantage of deeper soil moisture storage would be used in sites with soils similar to those in the (1) *Juniperus*/*Artemisia*/*Festuca* Ecosystem.

The clayey but stony subsoils and northerly aspect of this entity provides more biologically effective moisture.

Additional Research

Another application of the results of this study are the leads provided for extended research of the more important species of the various ecosystems or species that seem to display particular environmental responses. Although not immediately useful in practical form, such inquiry would circumscribe more adequately the environmental requirements of individual species. This work would also bolster the present knowledge of the biological potentials of the various ecosystems as well as provide information on site peculiarities which might influence management or cultural establishment of vegetation.

Purshia tridentata provides a good example of where such work might begin. The data indicates that the ecological requirements of the species include: (1) deep soils or soils with underlying strata of a nature to provide relatively deep rooting; (2) soils which provide a minimum of mechanical impedence to root growth by being coarse textured or, if fine textured, by containing sufficient stones to modify the effects of fine texture and often concomitant strong blocky or prismatic structure; (3) slope aspects to modify hot and cold temperatures to make available soil moisture more effective and maintain soil surface temperatures conducive to seed germination and seedling establishment; and (4) a maximum of overhead shading beyond which the species cannot survive. The influences of these factors on growth and distribution of the species could be evaluated by field study at locations representing different factor combinations. The results of these studies could be refined by growth-chamber and greenhouse studies.

SUMMARY

1. The Pinyon-Juniper Zone in Oregon, characterized exclusively in the tree overstory by Juniperus occidentalis and referred to as the Juniper Zone, is subdivided into three physiographic units. These are based on soil parent materials and include: (1) aeolian sands in central Oregon, primarily Deschutes, Crook, and Jefferson counties; (2) residual igneous material located in north-central, south-central, and southeastern Oregon; and (3) old sediments located in the upper regions of the John Day and Crooked Rivers.

2. In the central Oregon Juniper Zone, nine relatively undisturbed ecosystems and variants of two are defined and characterized following polyclimax concepts. Simultaneous analysis and interpretation of selected vegetational, soil, and topographic characteristics provided classificatory criteria for each ecosystem. Vegetational characteristics included foliage cover, basal area, heights and density of shrubby and suffrutescent species, and constancy. Soil characteristics used were complete morphological soil descriptions including estimates of bare soil surface, amounts of stone on and in the soil, available soil moisture storage capacity in the 2- to 14-inch soil zone, organic matter and total nitrogen in the A horizon, and textural analyses of the A and the AC horizons in Azonal soils and the A and B horizons in Zonal soils.

The only topographic characteristic useful for characterization purposes was slope aspect. Elevation, slope position, and slope steepness appeared to have little influence on species or community distribution.

3. A taxonomic Key to the Ecosystems was developed using vegetational, soil, and topographic characteristics easily recognized in the field. Ecosystems where vegetation was disturbed by grazing or other causes were easily recognized by use of this key.
4. The ecosystems described are in climax condition. Any successional causes could not be determined and future changes in any of the associations could not be predicted.
5. Direct correlations exist between interpreted phases of Azonal soil types and the vegetational component of four ecosystems. This occurred when soil unit interpretation included the nature of the underlying material and the effects of this material on plant growth.
6. Direct correlations did not always exist between interpreted categories of Zonal soils and the vegetational component of specific ecosystems. In three of the five ecosystems with Zonal soils, more than one interpretive soil unit supported the associated plant community. In the other two ecosystems, a single soil series supported the respective plant communities.

7. In those ecosystems associated with Zonal soils, cause and effect relationships between vegetation and soils were refined by considering interactions and compensations among the following factors: (1) texture, structure and thickness of the densest part of the B horizon; (2) stones on and in the soil; (3) solum depth; (4) nature of the underlying material; and (5) intensity and duration of insolation as indicated by slope aspect.
8. Practical applications of the findings to range and wildlife habitat management and additional research are suggested.

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A P P E N D I C E S

Appendix 1. Scientific names, authorities, and common names of species mentioned in the text.

Scientific Name and Authority	Common Name
Achillea millefolium L.	common yarrow
Agoseris sp. Raf.	agoseris
Agropyron spicatum (Pursh.) Scribn. & Smith.	bearded bluebunch wheatgrass
Artemisia spp. L.	sagebrush
Artemisia arbuscula Nutt.	low sagebrush
Artemisia tridentata Nutt.	big sagebrush
Astragalus spp. (Tourn.) L.	milkvetch
Astragalus lectulus S. Wats.	purple wooly-pod
Bromus tectorum L.	cheatgrass brome
Bouteloua sp. Lag.	grama
Carex filifolia Nutt.	threadleaf sedge
Chaenactis douglasii (Hook.) Hook. & Arn.	Douglas chaenactis
Chrysothamnus nauseosus (Pall.) Bitt.	rubber rabbitbrush
Chrysothamnus vicidiflorus (Hook.) Nutt.	Douglas rabbitbrush
Collinsia parviflora Dougl.	littleflower collinsia
Collomia grandiflora Dougl.	collomia
Crypthantha ambigua (A.Gray) Greene.	crypthantha
Erigeron filifolius Nutt.	threadleaf fleabane
Erigeron linearis (Hook.) Piper.	lineleaf fleabane
Eriogonum spp. Michx.	eriogonum
Eriogonum baileyi S. Wats.	Bailey's eriogonum
Eriogonum microthecum Nutt.	slenderbrush eriogonum
Eriogonum ochrocephalum S. Wats.	wooly eriogonum
Eriogonum sphaerocephalum Dougl.	rock eriogonum
Eriogonum umbellatum Torr.	sulfur eriogonum
Eriophyllum lanatum (Pursh.) Forbes	wooly eriophyllum
Festuca idahoensis Elmer.	Idaho fescue
Festuca octoflora Walt.	sixweeks fescue
Gayophytum lasiospermum Green.	groundsmoke
Grayia spinosa (Hook.) Moq.	spiny hopsage
Juniperus monosperma (Engelm.) Sarg.	oneseed juniper
Juniperus occidentalis Hook.	sierra juniper
Juniperus scopulorum Sarg.	Rocky Mountain juniper
Juniperus utahensis (Engelm.) Lemm.	Utah juniper
Koeleria cristata (L.) Pers.	prairie junegrass
Linanthus harknesii (Currn.) Green.	gilia
Leptodactylon pungens (Torr.) Rydb.	granite gilia
Lomatium triternatum (Pursh.) Coult. & Rose.	nineleaf lomatium
Lupinus spp. L.	lupine

Appendix 1 (continued)

Mentzelia albicaulis Dougl.	whitestem mentzelia
Montia perfoliata (Donn.) Howell.	indianlettuce
Penstemon cinerius Piper.	gray penstemon
Phlox douglasii Hook.	Douglas phlox
Pinus spp. (Tourn.) L.	pine
Pinus edulis Engelm.	Colorado pinyon pine
Pinus monophylla Torr. & Frem.	singleleaf pinyon pine
Pinus monticola Dougl.	western white pine
Pinus ponderosa Dougl.	ponderosa pine
Poa secunda Presl.	Sandberg bluegrass
Purshia tridentata (Pursh.) D.C.	antelope bitterbrush
Ribes cereum Dougl.	wax currant
Ribes gooddingii Peck.	Goodding gooseberry
Sequoia sempervirens (Lamb.) Endl.	redwood
Sitanion hystrix (Nutt.) J.G.Smith	bottlebrush squirreltail
Stipa comata Trin. & Rupr.	needle-and-thread
Stipa thurberiana Piper.	Thurber needlegrass
Tetrademia canescens D.C.	gray horsebrush

Appendix 2. Tentative descriptions of soil series and phases with associated ecosystems.

Series I: Chestnut loam from rhyolitic/andesitic colluvium on northerly slopes.

Associated Ecosystem: (1) Juniperus/Artemisia/Festuca

Horizon	Depth	Description
A11	0- 3"	Very dark brown (10YR 2/2 moist), dark gray (10YR 4/1 dry) loam; moderate, coarse platy breaking to single grain; loose, very friable, very slightly sticky, very slightly plastic; pH 6.0; common roots; boundary abrupt, smooth.
A12	3-10"	Very dark brown (10YR 2/2 moist), dark brown (10YR 3/3 dry) silt loam; weak, medium, subangular blocky; soft, friable, slightly sticky, slightly plastic; pH 6.5; abundant roots; boundary clear, smooth.
B1	10-15"	Dark brown (10YR 3/3 moist), dark yellowish brown (10YR 3/4 dry) silty clay loam; weak, fine, angular blocky; hard, firm, slightly sticky, slightly plastic; pH 7.0; common to abundant roots; boundary clear, wavy.
B21	15-20"	Dark yellowish brown (10YR 3/4 moist), dark brown (10YR 4/3 dry) clay loam; moderate, medium, angular blocky; hard, firm, sticky, plastic; pH 7.0; few to common roots; boundary clear, wavy.
B22	20-30"	Dark yellowish brown (10YR 4/4 moist), dark yellowish brown (10YR 4/4 dry) clay; strong, medium, angular blocky; very hard, firm, sticky, plastic; pH 8.0; few to common roots; boundary abrupt, smooth; common clayskins on the ped surfaces.

Appendix 2 (continued)

Horizon	Depth	Description
C(Dr)	30"+	Dark yellowish brown (10YR 4/4 moist), yellowish brown (10YR 5/4 dry) clay loam; weak, fine, angular blocky; firm, hard, slightly sticky, slightly plastic; pH 8.0, few roots. Soil mainly thin coatings around large rhyolitic and andesitic stones.

Forty-five to 50 percent of the solum volume is large rhyolitic or andesitic stones. Calcareous deposits are common on ped surfaces and stones in the lower B and C horizons. Pumice is distributed throughout the profile. The surface horizon is strongly vesicular.

Series II: Sandy loam Regosol on north and east slopes in the Brown Zone and developed from pumicy sands.

Associated Ecosystems:
(2) *Juniperus/Artemisia/Festuca-Lupinus*
(4) *Juniperus/Artemisia/Agropyron-Chaenactis*
(7) *Juniperus/Artemisia-Purshia*
(8) *Juniperus/Agropyron-Festuca*

Horizon	Depth	Description
A11	0- 3"	Dark brown (10YR 3/3 moist), gray brown (10YR 5/2 dry) sandy loam; medium, thick platy breaking to single grain; loose, nonsticky, nonplastic; pH 6.0; common roots; boundary abrupt, smooth.
A12	3- 7"	Dark brown (10YR 3/3 moist), brown (10YR 5/3 dry) sandy loam; single grain; loose, nonsticky, nonplastic; pH 6.5; abundant roots; boundary clear, smooth.
AC	7-14"	Dark yellowish brown (10YR 3/4 moist), brown (10YR 5/3 dry) sandy loam; single grain; soft, loose, nonsticky, nonplastic; pH 7.0; abundant roots; boundary clear, smooth.

Appendix 2 (continued)

Horizon	Depth	Description
C	14-22"	Dark yellowish brown (10YR 3/4 moist), brown (10YR 4/3 dry) sandy loam; single grain; loose, nonsticky, nonplastic; pH 7.5; common to abundant roots; boundary clear, wavy.

The soil contains approximately 30 percent pumice by volume. The surface horizon is strongly vesicular. The soil overlies unrelated material.

Four phases of this series type are recognized. Phase separation was based on depth to the underlying material, characteristics of the underlying material, and solum stoniness. Each phase supports a separate ecosystem.

Shallow, Nonstony Phase: Shallow (16 inches), nonstony over gravelly, loamy, alluvium and rhyolitic and andesitic stones; 50 percent of the underlying material is large stones; roots are common in the underlying material; occurs on north to northeast slopes.

Associated Ecosystem: (2) _Juniperus_/_Artemisia_/_Festuca_-_Lupinus_

Moderately Deep, Extremely Stony Phase: Moderately deep (26 inches), extremely stony over cracked or closely packed basalt; the solum contains approximately 50 percent large stones; 90 percent of the underlying material is large stones; few roots penetrate the cracks of the underlying material; occurs on northwest to northeast slopes.

Associated Ecosystem: (4) _Juniperus_/_Artemisia_/_Agropyron_-_Chaenactis_

Appendix 2 (continued)

Deep, Nonstony Phase: Deep (45 inches), nonstony over a buried, loamy, B2 horizon; 50 percent of the underlying material is small stones; very few roots extend into the underlying material; occurs on north to northeast slopes.

Associated Ecosystem: (7) Juniperus/Artemisia-Purshia

Moderately Deep, Very Stony Phase: Moderately deep (23 inches), very stony over large, closely packed rhyolitic and andesitic stones cemented probably with carbonates; the solum contains approximately 35 percent large stones; roots do not penetrate the cemented material; occurs on east slopes.

Associated Ecosystem: (8) Juniperus/Agropyron-Festuca

Series III: Brown loam from friable tuffaceous material on northwesterly slopes.

Associated Ecosystem: (3) Juniperus/Festuca

Horizon	Depth	Description
A11	0- 2"	Very dark gray brown (10YR 3/2 moist), gray brown (10YR 5/2 dry) loam; moderate, medium, platy; soft, loose, slightly sticky, slightly plastic; pH 6.0; abundant roots; boundary abrupt, smooth.
A12	2- 6"	Very dark gray brown (10YR 3/2 moist), dark gray brown (10YR 4/2 dry) loam, moderate, medium, crumb; soft, very friable, slightly sticky, slightly plastic; pH 6.5; abundant roots; boundary abrupt and smooth.

Appendix 2 (continued)

Horizon	Depth	Description
B1	6- 9"	Dark yellowish brown (10YR 4/4 moist), dark brown (10YR 4/3 dry) clay loam; moderate, fine, angular blocky; hard, friable, slightly sticky, slightly plastic; pH 6.5; common roots; boundary clear, smooth.
B2	9-13"	Dark brown and dark yellowish brown (10YR 3/4, 4/4 moist), dark brown (10YR 4/3 dry) clay; moderate, medium prismatic breaking to strong, medium, angular blocky; very hard, very firm, sticky, plastic; pH 7.0; roots common; boundary clear, wavy.
B3	13-18"	Brown (10YR 4/3 moist), yellowish brown (10YR 5/4 dry) clay loam; moderate, medium, angular, blocky; hard, friable, slightly sticky, slightly plastic; pH 7.5; few to common roots; boundary clear, wavy.
C(Dr)	18"+	Tuffaceous material very hard when dry becoming friable when moist. Roots are common, apparently penetrating when the material is wet.

The modal type of this series is relatively stonefree, 5 percent of the profile volume occupied by stones. Pumice is distributed throughout the profile. This soil is normally on north- to northwest-facing slopes. The surface horizon is strongly vesicular.

Very Stony Phase: Very stony Brown loam from friable, tuffaceous material; the solum contains approximately 50 percent large rhyolitic and andesitic stones unrelated to the solum; occurs on southeasterly slopes; horizon number, sequence, and characteristics are the same as the series type.

Associated Ecosystem: (3) Juniperus/Festuca-Purshia Variant

Appendix 2 (continued)

Series IV: Weakly developed Brown loam from mixed rhyolitic/ andesitic colluvium and aeolian sands on northerly slopes.

Associated Ecosystem: (3) Juniperus/Festuca

Horizon	Depth	Description
A1	0- 9"	Very dark gray brown (10YR 3/2 moist), dark gray brown (10YR 4/2 dry) loam; moderate, medium, granular; soft, loose, slightly sticky, slightly plastic; pH 6.0; abundant roots, boundary clear, smooth.
B1	9-15"	Dark brown (10YR 3/3 moist), dark brown (10YR 4/3 dry) loam; weak medium, subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; pH 6.0; common roots; boundary clear, wavy,
B2	15-28"	Dark brown (10YR 3/3 moist), yellowish brown (10YR 5/6 dry) silt loam; weak, medium, subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; pH 6.0; common roots; boundary clear, wavy.
C	28"+	Dark brown (10YR 4/3 moist); yellowish brown (10YR 5/4 dry) gravelly loam; massive; soft, loose, slightly sticky, slightly plastic; pH 6.5; few roots; mixed rhyolitic/andesitic colluvium and aeolian sands.

This soil is relatively stonefree to 24 inches depth. Below this point, stones occupy 40 percent of the profile volume. Pumice is distributed throughout the profile.

Appendix 2 (continued)

Series V: Strongly developed Brown loam from river and lake-laid sediments containing small basalt fragments and occurring on undulating uplands.

Associated Ecosystem: (5) *Juniperus*/*Artemisia*/*Agropyron*

Horizon	Depth	Description
A11	0- 2"	Very dark gray brown (10YR 3/2 moist), light gray brown (10YR 6/2 dry) loam; weak, medium, platy breaking to single grain; loose, very friable, nonsticky, nonplastic; pH 6.5; roots few; boundary abrupt, smooth.
A12	2- 6"	Dark brown (10YR 3/3 moist), gray brown (10YR 5/2 dry) silt loam; weak, fine, subangular blocky; soft, friable, slightly sticky, slightly plastic; pH 7.0; abundant roots; boundary abrupt, smooth.
A3	6- 9"	Dark brown (10YR 3/3 moist), brown (10YR 5/3 dry) silty clay loam; moderate, medium, subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; pH 7.0, common roots, boundary abrupt, wavy.
B21	9-15"	Dark brown (10YR 3/3 moist), dark gray brown (10YR 4/2 dry) silty clay; moderate, medium prismatic breaking to moderate, medium, angular blocky; hard, very firm, sticky, plastic; pH 7.5; roots few; boundary abrupt, wavy.
B22	15-23"	Dark brown (10YR 4/3 moist), dark yellowish brown (10YR 3/4 dry) clay; strong, medium prismatic breaking to strong, medium angular blocky; very hard, very firm, sticky, plastic; pH 8.0; few roots; boundary abrupt, wavy; few clayskins.

Appendix 2 (continued)

Horizon	Depth	Description
B3	23-26"	Yellowish brown (10YR 5/4 moist), yellowish brown (10YR 5/4 dry), silty clay loam; weak, medium, angular blocky; slightly hard, firm, slightly sticky, plastic; pH 8.0; few roots, boundary abrupt, smooth.
C(Dr)	26"+	River and/or lake-laid sediments with partially decomposed basalt stones. No roots.

A strongly developed soil relatively stonefree, 5 percent by volume. The B horizon definitely restricts root penetration. Calcareous deposits on soil peds in the B horizon and on the few stones in the B and C horizons. A discontinuous caliche at approximately 28 inches. Pumice distributed throughout the profile. Occasional small pockets of nearly pure pumice in the B horizon. The surface horizon is strongly vesicular.

Series VI: Strongly developed Brown loam from loess, very fine sands and small basalt fragments and occurring on undulating uplands.

Associated Ecosystem: (5) *Juniperus*/*Artemisia*/*Agropyron*

Horizon	Depth	Description
A11	0- 2"	Dark brown (7.5YR 3/2 moist), gray brown (10YR 5/2 dry) loam; moderate, medium, platy; soft, friable, slightly sticky, nonplastic; pH 7.0; few roots; boundary abrupt, smooth.
A12	2- 8"	Very dark gray brown (10YR 3/2 moist), brown (10YR 5/3 dry) silt loam; weak, medium, subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; pH 7.5; abundant roots; boundary abrupt and wavy.

Appendix 2 (continued)

Horizon	Depth	Description
B22	8-10"	Dark brown (10YR 3/3 moist), brown (10YR 5/3 dry) clay loam; moderate, medium prismatic breaking to weak, medium, angular blocky; very hard, friable, sticky, plastic; pH 7.5; common roots; boundary clear, wavy.
B3	10-13"	Dark gray brown (10YR 4/2 moist), pale brown (10YR 6/3 dry) silty clay loam; weak, medium, angular blocky; hard, firm, slightly sticky, slightly plastic; pH 8.0; few roots, boundary gradual, wavy.
C(Dr)	13"+	Loess, very fine river sands, and partially decomposed basalt fragments; pH 8.0; few roots to 24 inches, none below this.

A relatively stonefree soil (5 percent by volume). Root penetration restricted by the B horizon. Pumice scattered throughout the profile. The surface horizon is strongly vesicular. Calcareous deposits in the lower B and in the C horizons.

Series VII: Brown sandy clay loam from rhyolitic/andesitic colluvium over indurated tuffaceous material on northeasterly slopes.

Associated Ecosystem: (6) *Juniperus*/*Agropyron*

Horizon	Depth	Description
A11	0- 3"	Very dark gray brown (10YR 3/2 moist), gray brown (10YR 5/2 dry) sandy clay loam; moderate, medium, platy; soft, very friable, very slightly sticky, very slightly plastic; pH 6.0; few roots; boundary abrupt, smooth.

Appendix 2 (continued)

Horizon	Depth	Description
A12	3- 9"	Very dark gray brown (10YR 3/2 moist), dark gray brown (10YR 4/2 dry) loam; weak, fine, subangular blocky; soft, friable, very slightly sticky, very slightly plastic; pH 6.5; common and abundant roots; boundary abrupt, wavy.
B1	9-18"	Dark brown (10YR 3/3 moist), dark brown (10YR 4/3 dry) silty clay loam; moderate, medium, angular blocky; slightly hard, friable, slightly sticky, slightly plastic; pH 7.0; common and abundant roots; boundary clear, smooth.
B21	18-32"	Dark brown (10YR 4/3 moist), dark yellowish brown (10YR 4/4 dry) silty clay loam; strong, medium, angular blocky; hard, friable, slightly sticky, slightly plastic; pH 7.5; roots common; boundary abrupt, smooth.
B22	32-40"	Dark brown (10YR 4/3 moist), dark yellowish brown (10YR 4/4 dry) clay loam; moderate medium prismatic breaking to strong, medium, angular blocky; very hard, friable, sticky, plastic; pH 8.0; few roots; boundary clear, wavy; few clayskins.
C(Dr)	40-44"	Mixed rhyolitic/andesitic colluvium. Thin clayey material coating the stones. Roots extend into the rock cracks.
D	44"+	Indurated tuffaceous material non-friable when moist.

The solum contains approximately 35 percent large stones. Few peds and rocks in the lower B horizon coated with a calcareous deposit. Pumice distributed through the profile. The surface horizon is strongly vesicular and has many small pebbles adhering to the bottom of the plates.

Appendix 2 (continued)

Shallow Phase: Shallow (20 inches) occurring near the tops of northerly slopes and having a weakly expressed B1 horizon; horizon number, sequence, and characteristics except thickness are the same as the series type.

Associated Ecosystem: (6) Juniperus/Agropyron

Series VIII: Brown loam from rhyolitic/andesitic colluvium on southeasterly slopes.

Associated Ecosystem: (6) Juniperus/Agropyron-Purshia Variant

Horizon	Depth	Description
A11	0- 3"	Very dark gray brown (10YR 3/2 moist), gray brown (10YR 5/2 dry) loam; moderate, coarse, platy; soft, very friable, very slightly sticky, very slightly plastic; pH 6.0; few roots; boundary clear, smooth.
A12	3- 7"	Dark brown (10YR 3/3 moist), brown (10YR 5/3 dry) loam; weak, fine, subangular blocky; soft, very friable, slightly sticky, slightly plastic; pH 6.5; roots abundant; boundary clear, smooth.
A3	7-12"	Dark brown (10YR 3/3 moist), dark brown (10YR 4/3) silt loam; moderate, fine, subangular blocky; slightly hard, very friable, slightly sticky, slightly plastic; pH 7.0; roots abundant, boundary abrupt, wavy.
B1	12-15"	Dark brown (10YR 3/3 moist), dark brown (10YR 4/3 dry) silty clay loam; moderate, fine, angular blocky; slightly hard, very friable, slightly sticky, slightly plastic; pH 7.5; roots common; boundary abrupt, wavy.

Appendix 2 (continued)

Horizon	Depth	Description
B22	15-20"	Dark gray brown (10YR 4/2 moist), dark yellowish brown (10YR 4/4 dry) clay; strong, medium to fine, angular blocky; very hard, firm, sticky, plastic; pH 8.0; few roots; boundary abrupt, wavy.
C(Dr)	20"+	Mixed rhyolitic/andesitic colluvium with thin, sandy clay material coating the stones; pH 8.0; roots penetrate the cracks betwen the stones.

The solum contains approximately 40 percent large stones. Few calcareous deposits on soil peds and stones in the lower B horizon. Siliceous deposits on rocks in the C and lower B horizons. Pumice distributed throughout the profile. The surface horizon is strongly vesicular and has many small pebbles adhering to the bottom of the plates.

Series IX. Brown loam from rhyolitic/andesitic colluvium on south to southwesterly slopes.

Associated Ecosystem: (9) *Juniperus/Artemisia/Agropyron-Astragalus*

Horizon	Depth	Description
A11	0- 4"	Very dark gray brown (10YR 3/2 moist), gray brown (10YR 5/2 dry) loam; weak, medium platy; soft, very friable, slightly sticky, slightly plastic; pH 6.0; common roots; boundary abrupt, smooth.
A12	4- 7"	Dark brown (10YR 3/3 moist), dark gray brown (10YR 4/2 dry) silt loam; weak, medium, subangular blocky; soft, friable, slightly sticky, slightly plastic; pH 6.5; common to abundant roots; boundary clear, wavy.

Appendix 2 (continued)

Horizon	Depth	Description
B21	7-16"	Dark yellowish brown (10YR 3/4 moist), dark brown (10YR 4/3 dry) silty clay loam; moderate, medium, angular blocky; very hard, friable, sticky, plastic; pH 7.5; common roots, boundary clear, wavy.
B22	16-21"	Dark brown (10YR 3/3 moist), dark brown (10YR 4/3 dry) clay; strong, medium angular blocky; very hard, friable, sticky, very plastic; pH 8.0; few roots; boundary clear, irregular; common clay-skins.
C(Dr)	21"+	Large, closely packed rhyolitic/andesitic colluvium with clay loam or silty clay on the stone surfaces.

Stones occupy approximately 50 percent of the profile volume to the C(Dr) horizon. Stones occupy approximately 90 percent of this horizon. Some stones and soil peds in the C(Dr) and lower B horizons have calcareous deposits on their surfaces. Siliceous deposits are common on stones in the C(Dr) horizon. A discontinuous caliche often occurs at approximately 25 inches below the surface. The surface horizon isstrongly vesicular. Pumice distributed throughout the profile.